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GULF COAST
DEEP WATER PORT FACILITIES STUDY

Appendix C
Eastern Gulf Hydrobiological Zones

a report to

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

1 APRIL 1973

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Arthur D. Little, Inc.

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Gulf Coast Deep Water Port Facilities Study

APPENDIX C

EASTERN GULF HYDROBIOLOGICAL ZONES

A report to

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

prepared under

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Arthur D. Little, Inc.

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INTRODUCTION

The Gulf of Mexico is a semi-enclosed basin with a surface area of 1,540.000 square kilometers. On the north and east sides, the continental shelf makes up 22 percent (340,000 square kilometers) of this area and is covered by water shallower than 100 fathoms (180 meters). The continental slope, between 100 and 1,700 fathoms (180-3,060 meters), covers 20 percent (310,000 square kilometers), of the total area. Another 20 percent, below the depth of 1,700 fathoms, covers the Sigsbee and Florida plains. To the southeast are the two connections with other seas – the Straits of Florida with a sill depth of 475 fathoms (860 meters), and the Yucatan Channel, with a 1,120-fathom (2,000-meter) sill depth.

A comprehensive description of the water masses of the Gulf of Mexico, their interaction with the atmosphere, and circulation at the surface and at depths still remains to be compiled. However, the work that has been done to date indicates that a major current – *the Loop Current – exists in the eastern Gulf and is the key to understanding and predicting general circulation patterns.* The Loop Current enters the Gulf through the Yucatan Channel, moves in a clockwise loop and exits through the Florida Straits (Zone XXV), transporting one-third the volume of the Gulf Stream at rates of 1 to 4 knots. *This transported volume is sufficient to fill the Gulf basin in 30 months.* The Loop Current also varies seasonally, can develop large eddies and influences the currents on the continental shelf.

The northeast continental shelf extends from the Mississippi Delta to the Dry Tortugas; it is in contact with major draining systems including the Mississippi discharge, the major rivers of Mississippi, Alabama and Florida and the very broad area of the Everglades. *The water on the shelf is not only modified and changed by the interface of the Loop Current but also by the fluctuations in these draining sources.* This shelf water is further modified by the influence of the tidal fluctuations and meteorological conditions. There are a number of important areas of enrichment by upwelling which further change the characteristics of the water masses.

The natural marine and coastal resources of the eastern Gulf coast are important both economically and ecologically. The commercial and sport fisheries resources of the region are extensive and provide considerable income. Their potential value is great and can be of significance not only to the region but to the nation.

The coastal zone of Florida contains approximately 800 miles of Gulf shoreline and 2560 miles of bay and estuary shoreline. It is characterized by either high energy sand beaches with accompanying developed or developing recreational and related entrepreneurial activities or low wetlands that are extremely valuable in terms of biological productivity.

I. THE EASTERN GULF OF MEXICO

A. REGIONAL CLIMATE

A detailed description of the climate of each individual hydro-biological region in the eastern Gulf of Mexico (Figure C-1) cannot be provided. *The only significant climatic discontinuity in this area occurs at the coastline,* and this feature cannot be studied in any detail because the available marine data have been summarized only for fairly large areas (Figure C-2). Charts of climatic features, such as storm tracks, mean wind circulation, and mean sea surface temperatures, are included in climatological atlases for the Atlantic Ocean but in most instances these provide very little detail in the eastern Gulf. Even if resources were available to undertake the preparation of summaries for the nearshore region (XV-XIX), *the quantity of ship reports in most of these areas would probably prove inadequate for reliable climatological values.* *

In view of the difficulties mentioned above, this discussion will necessarily be limited to a fairly general treatment of the climate of the eastern Gulf of Mexico rather than to the individual hydro-biological regions. Data for the coastal regions, provided by station data, will be presented and compared with data for the summary areas marked on Figure C-2. More intercomparisons of the data from the summary areas will be made but these areas cannot be very closely associated with specific hydro-biological regions. Data from summary area D (Figure C-2) can probably be considered representative of zone XXVI and most of the observations in summary area C were probably taken in the southern half of zone XXIV. However, summary areas A and B include portions of several distinct hydro-biological zones.

1. General Climatic Features

The subtropical high pressure belt extends over or near the Gulf of Mexico throughout the year. As shown by the mean low-level flow charts prepared by Atkinson and Sadler (1970), the eastern Gulf is in the western portion of the Bermuda high pressure cell from *March through September.* During this period *winds tend to be southeasterly in the southern Gulf and southerly or southwesterly in the northern Gulf.* From *October through February,* the mean charts of Atkinson and Sadler show a separate cyclonic cell over or near the northwestern Gulf with *northwesterly winds over the eastern Gulf.* During this period cold air masses arrive from the continent with some regularity, but are modified rapidly as they move over the warm waters. In spring and summer the whole eastern Gulf is dominated by tropical air masses arriving from the south and southeast. (Additional information on the persistence of the patterns indicated above will be provided in a later section.)

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*Note: For review convenience, selected statements have been italicized in this abridged report; statements the editors consider germane to the contractor's needs.

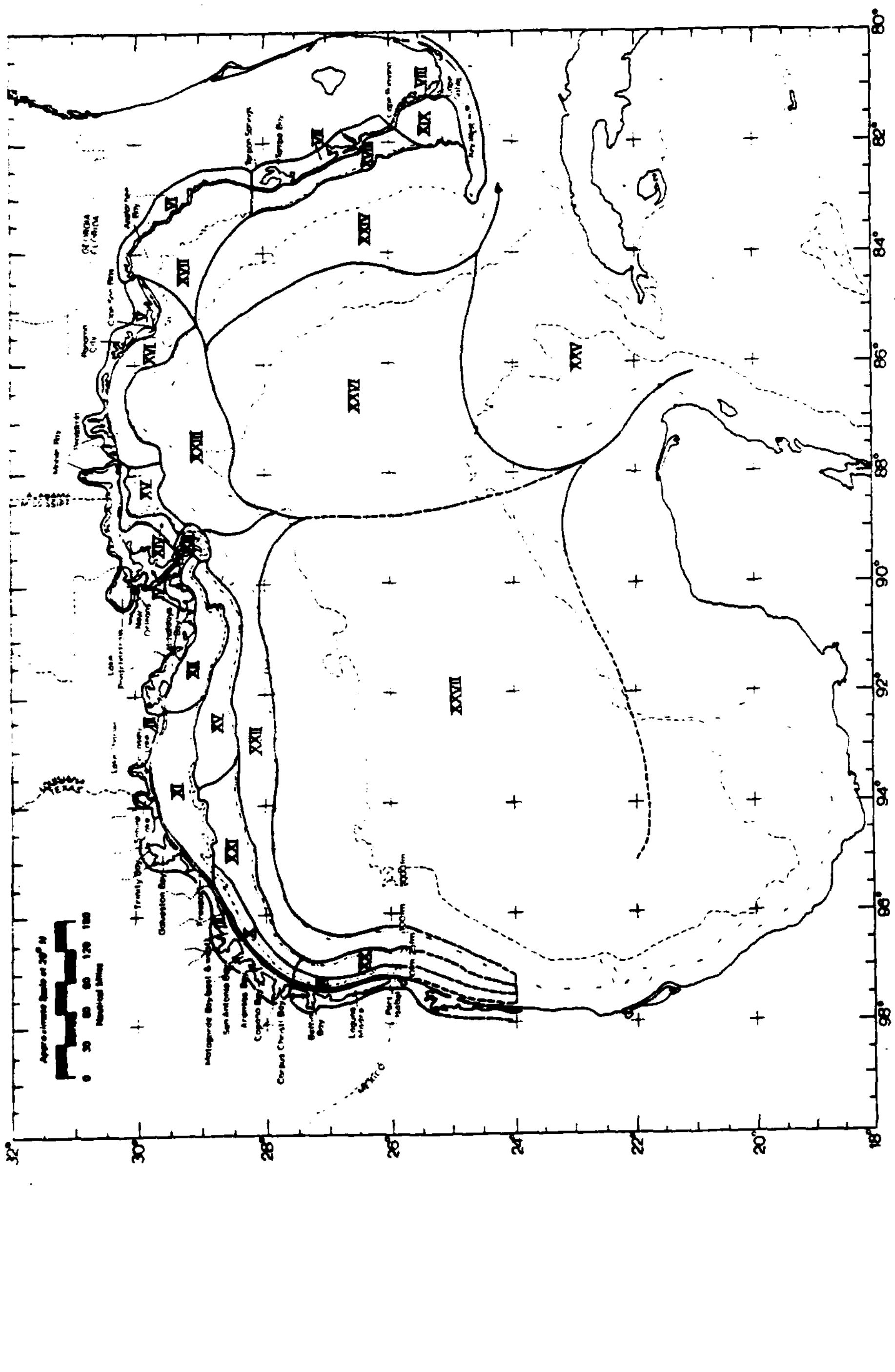

FIGURE C–1 DISSIMILAR HYDROBIOLOGICAL ZONES–GULF OF MEXICO

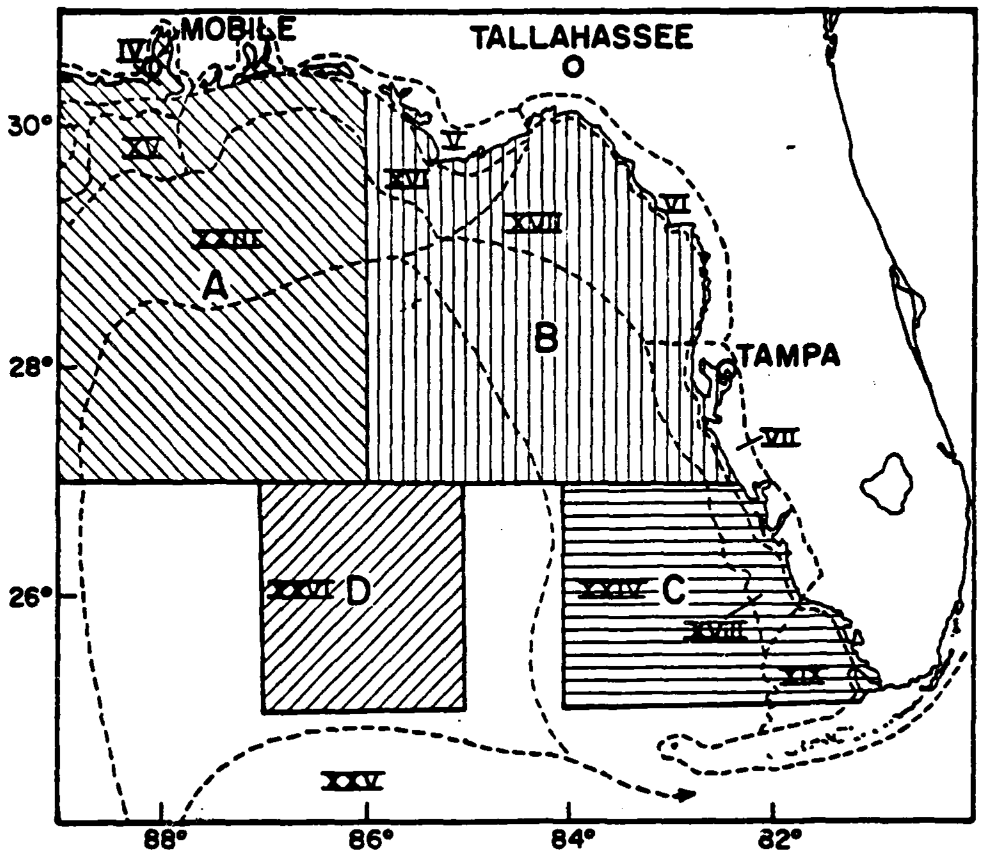

FIGURE C–2 PRIMARY COASTAL STATIONS, MARINE SUMMARY AREAS, AND HYDRO-BIOLOGICAL AREAS

The seasonal patterns of cloudiness and weather along the northern and northeastern Gulf coast are controlled primarily by extratropical cyclones and fronts in winter and by convective showers in summer. The northern Gulf coast stations, which are influenced much more often by extratropical cyclones, show nearly as much rainfall and cloudiness in winter as in summer. Stations along the southeastern Gulf coast are influenced less frequently by extratropical cyclones and frontal passages and show a rather pronounced winter rainfall minimum. Although *hurricanes* do not occur frequently enough to significantly influence the seasonal rainfall patterns, they *represent an important severe weather consideration in the eastern Gulf from June through November.*

Storms in the eastern Gulf of Mexico are relatively rare in comparison with many marine locations. The area is, however, occasionally affected in winter by extratropical cyclones and by tropical cyclones in summer and fall. In addition, there are weak storms, especially in summer, which are difficult to classify. Some of these are of tropical origin, but do not reach tropical storm intensity; others develop in response to upper-level cyclonic circulations.

Statistics for hurricanes (wind speeds greater than 74 mph) and tropical storms (wind speeds between 40 and 74 mph) are often grouped together since it is usually difficult, especially in the older records, to determine the storm intensity while at sea. The probability of a tropical storm or hurricane influencing the eastern Gulf coast during any given year is about 50 percent and the probability of two hurricanes or tropical storms occurring during a given year is about 15 percent (Hope and Neumann, 1971).

Most hurricanes and tropical cyclones influencing the eastern Gulf move into the area from the south or southeast. During the period 1901-1971, only seven hurricanes and seven tropical storms formed in the Gulf north of 25°N and east of 85°W.

Detailed information on hurricane and tropical storm frequencies for 50-mile coastal segments has been presented for an 85-year record (1886-1970) by Simpson and Lawrence (1971). They show that along the Gulf coast from south Florida to Mobile, there is very little difference in the length of the tropical storm season. In 10 of the 13 coastal segments the earliest storm was in June and the latest in October. There is one case of a February tropical storm in extreme southern Florida and three of the segments have recorded storms in November.

The *frequency of tropical storms and hurricanes* for the 50-mile segments of coastline varies from 8 to 18 (over the 85-year period) with *highest values near Pensacola, Cedar Key and extreme southwestern Florida. The sectors with the lowest frequency are near Panama City (9 cases) and Tampa to Fort Myers* (8-10 cases). Of course, these storms are often quite large and influence a much larger area than the 50-mile coastal segment in which they move onshore. The distribution of hurricanes (wind speeds of 74 mph or greater) is similar to the data presented above except for lower frequencies (3-12 cases in the 85-year record). "*Great hurricanes*" (wind speeds of 125 mph or greater) *have influenced the Gulf coast between Mobile and southern Florida on 10 occasions in the 85-year period.* Except for one case near Mobile, all of these storms moved inland south of Tampa.

Much of the damage at coastal locations due to hurricanes results from the marked rise in water level, which is referred to as the hurricane surge or tide. Some of the most pronounced surges in the northern and eastern Gulf area, as taken from Dunn and Miller (1964) and Sugg, Pardue and Carrodus (1971), are given in Table C-1. The maximum surge height at any given location depends on many factors including storm intensity, bottom topography and coastline configuration. There is little doubt, however, that *a hurricane as intense as Camille of 1969, and moving in the most favorable direction and speed, would be capable of producing a very damaging surge at any location along the Gulf coast.*

TABLE C-1

MAJOR HURRICANE SURGES

Location	Surge Height (feet)	Month of Occurrence
Pass Christian	25	August 1969
Ocean Springs	15	August 1969
Mobile	12	July 1916
Pensacola (Fort Barrancas)	11	September 1906
Panama City	6	July 1936
St. Marks	12	October 1877
Cedar Key	10	September 1896
St. Petersburg	8	October 1921
Tampa	15	September 1848
Fort Myers	9	October 1921
Punta Rassa	14	October 1873
Naples	11	October 1944
Marco Island	10	October 1910
Everglades	10	October 1910

Hurricanes and tropical cyclones are capable of producing effects which may persist for days or weeks. The heavy rains associated with these storms may lead to abnormally large river discharges which may affect coastal areas for a period of days or longer. For example, a tropical storm which never reached hurricane intensity in October 1941, resulted in a maximum three-day rainfall of 35 inches some miles inland from Cedar Key (Dunn and Miller, 1964). Intense hurricanes are capable of bringing cold water to the ocean surface with the result that cold pools may persist over the open ocean for periods of weeks. A marked case of this type in the Gulf of Mexico resulted from hurricane Hilda of 1964, in which there was a cooling of the surface water as much as 9°F (Leipper, 1967).

Despite some fairly large differences cited above, geographical variations in hurricane frequency and maximum storm surge height along the Gulf coast will probably prove to be relatively small in very long-term records. The "great" hurricane statistics would, however, suggest that the *very intense storms are much more likely south of Tampa than in the northeastern or northern Gulf.*

Preferred storm tracks over the Gulf of Mexico and nearby land areas are shown by Klein (1957). No tracks are shown over the Gulf from March through October, except those of tropical origin during the months June through September.

In a more recent study (SUSIO, 1972) weather maps for the 1954-1969 period were examined in an effort to obtain some statistics on the seasonal frequency and intensity of extratropical cyclones over the eastern Gulf (Table C-2). The maps used in this study were, for the most part, at 12-hour intervals and a number of significant low-pressure centers may have been missed. On the other hand, some rather weak cases were undoubtedly included.

TABLE C-2

INLAND-MOVING LOW PRESSURE CENTERS

	90°W to Apalachicola	Apalachicola to 28.5°N	28.5°N to Ft. Myers	Ft. Myers to 25°N	All Sectors
Winter	1.6	2.2	0.2	0.4	4.4
Spring	0.7	1.0	0.3	0.2	2.2
Summer	0.7	0.6	0.2	0.1	1.6
Fall	1.6	0.6	0.2	0.1	2.9
Total	4.6	4.8	0.9	0.8	11.1

Mean seasonal frequency (in occurrences per year) in the indicated coastal sectors. Hurricanes and tropical cyclones have been excluded.

The frequency statistics from this study (Table C-2) show that low-pressure centers are much more frequent in the northern Gulf than south of 28.5°N latitude and are, in general, most frequent in winter. However, a fairly large percentage of the cases occur in spring and fall. Intensity statistics for this set of data show that a very small percentage of the extratropical cyclones over the Gulf have central pressure as low as 1000 mb, with the greatest number of intense cases in fall and winter. Most of the summer cases had relatively high central pressures.

Thunderstorms are quite frequent along the northern and eastern Gulf coast. As shown by Table C-3, the annual totals range from 60 to 100 with about two-thirds of the thunderstorm days occurring during the period from June through September. The higher frequency of thunderstorms in winter at Mobile and Pensacola, in comparison to the other stations, is related to the greater frequency of extratropical cyclones and fronts in the area.

TABLE C-3

THUNDERSTORM FREQUENCY AT COASTAL STATIONS

	Mean Annual Number of Days with Thunderstorms	Percent of Thunderstorms During the Period June – Sept.	Percent of Thunderstorms During the Period Nov. – Feb.
Mobile	87	63	14
Pensacola	65	65	12
Apalachicola	73	73	7
Tallahassee	79	70	6
Tampa	91	66	5
Fort Myers	100	75	5
Key West	60	67	7

The high frequency of summer thunderstorms in Florida reflects the greater convective activity over the land. Stations very near the coast show somewhat lower values than those some distance inland and radar observations of precipitation suggest that there may be a minimum area along the coastline with somewhat higher values at some distance off the coast. At least in some coastal areas, this is due to a higher frequency of nighttime thunderstorms over the water in comparison with land areas.

Thunderstorm data for the marine summary areas (Figure C-2) are difficult to compare with those for coastal stations. The marine data combine thunderstorm and lightning occurrences and statistics refer to percentage frequency of occurrence at the standard observing times. On the other hand, the coastal station data are in the form of mean number of days with thunderstorms.

The mean percentage frequency data of thunder and lightning for the marine summary areas A, B and C are shown in Table C-4. Thunderstorms appear with about the same frequency in all three areas in winter and spring but in summer and fall there is a considerable higher frequency in the southern sector.

TABLE C-4

THUNDER AND LIGHTNING OBSERVATIONS

	Winter	Spring	Summer	Fall	Annual
Area A	0.6	1.5	4.3	1.4	2.0
Area B	0.9	1.4	3.9	0.7	1.8
Area C	0.8	1.5	2.8	0.6	1.4

Mean percentage of ship observations in Areas A, B and C (Figure C-1), reporting thunder or lightning (from U.S. Naval Weather Service Command, 1970).

A very high portion of the occurrences of thunder and lightning (70-80 percent) is reported at 0600 GCT (about 0100 local time) and a very low portion of lightning in the data has biased the statistics toward high frequencies. This could arise from the fact that lightning can be seen for great distances at night.

2. Winds and Waves

The discussion of the large-scale circulation patterns over the Gulf of Mexico and their seasonal changes, as presented in an earlier section would suggest that winds with a northerly component would tend to be quite prevalent in the eastern Gulf from October through February and those with a southerly component would dominate the pattern from March through September. Actually, the wind direction varies considerably from day to day in response to synoptic systems traversing the area.

Some indication of the nature of the flow is given by considering the relative frequency of winds with northerly and southerly components. During the period October through February, when the mean charts suggest the flow of polar air from the continent, the wind observations show a northerly component about 50 percent of the time and a southerly component about 30 percent of the time. During the period March through September, when tropical air masses dominate the area, the percentage of winds with southerly components is only slightly greater than that with northerly components. The statistics for the two coastal stations are quite similar to the marine areas A and B except for a higher frequency of northerly components at the land stations during the March through August period.

Mean annual wind speeds at the coastal stations and for the marine areas A, B and C are shown in Table C-5, along with the mean monthly maximum and minimum values. The coastal locations, except for Mobile, show appreciable lower speeds. The strongest speeds occur during the winter or early spring at all locations. The lowest mean wind speeds were observed in July or August at all locations.

TABLE C-5

WIND SPEED DATA

	Mean Annual	Maximum	Minimum
Mobile	10.0	12.1 (2)	7.7 (7-8)
Pensacola	8.1	9.4 (2)	6.6 (7-8)
Apalachicola	8.0	9.1 (3)	6.6 (7)
Tallahassee	7.4	9.1 (3)	5.9 (7-8)
Tampa	8.8	9.8 (2&4)	7.2 (8)
Area A	11.7	14.2 (1-2)	8.2 (7)
Area B	11.0	13.9 (2)	7.9 (7)
Area C	10.8	13.0 (11&1)	7.9 (7)

Mean annual wind speeds and mean monthly maximum and minimum speeds for selected coastal stations and marine areas. Speeds are in knots; month of occurrence of maximum and minimum values are shown by number (1=January, 2=February, etc.).

The marine areas show fairly small month-to-month differences in mean speed except for appreciably lower values during the months May through August. As shown by data presented in Table C-6, during this summer period up to 40 percent of observations show speeds less than 7 knots and only 6-7 percent of the observations show speeds greater than 16 knots. During the remainder of the year the frequency of light winds is considerably less with the order of 20-25 percent of the observations with speeds greater than 16 knots. Differences between areas A, B and C are relatively minor but the data for area D suggests a considerably lower frequency of low wind speed.

TABLE C-6

WIND STATISTICS (for Marine Areas of Figure C-1)

	Area A		Area B	
	Sept. – Apr.	May – Aug.	Sept. – Apr.	May – Aug.
Mean Speed (kn)	13.2	9.0	12.6	8.4
Less than 7 kn	16%	37%	19%	38%
Greater than 16 kn	26%	7%	22%	6%

	Area C		Area D	
	Sept. – Apr.	May – Aug.	Sept. – Apr.	May – Aug.
Mean Speed (kn)	12.0	8.5	–	–
Less than 7 kn	19%	40%	8%	22%
Greater than 16 kn	20%	6%	19%	7%

Wave heights are, of course, closely associated with wind speeds. Wave height frequency data for the same periods used in Table C-6 are shown in Table C-7. These data show that *wave heights in excess of 10 feet occur considerably less than 5 percent of the time throughout the year and are very rare during the summer months.* From over 13,000 observations in Area A, there were only four cases during the winter months when wave heights exceeded 17 feet.

TABLE C-7

WAVE HEIGHT OBSERVATIONS

	Area A		Area B		Area C	
	6 Ft.	10Ft.	6 Ft.	10 Ft.	6 Ft.	10 Ft.
Sept. – Apr.	15	3	17	4	11	2
May – Aug.	3	0	4	0	2	0

Percentage of wave height observations exceeding the specified values. A zero value means less than 0.5 percent.

3. Other Weather Elements

Precipitation in the eastern Gulf appears almost entirely in the form of rain and drizzle. Snow at the northern coastal stations is very rare and none of the same 59,000 observations in Area A reported snow, sleet or hail.

The ship data provide only precipitation frequency data and this refers only to occurrences at the standard observing times. Data of this type (Table C-8) show higher rainfall frequencies in Area A than Area C by about 50 percent, which is considerably greater than the difference in rainfall amount at the coastal stations between southern and northwestern Florida (Table C-9).

TABLE C-8

PRECIPITATION OBSERVATIONS

	Mean Annual	Maximum Monthly	Minimum Monthly
Area A	3.4	4.7 (9)	2.4 (6)
Area B	3.0	6.2 (9)	0.9 (11)
Area C	2.3	4.1 (9)	0.4 (4)

Mean annual percent of ship observations reporting precipitation and the maximum and minimum mean frequencies during individual months.

TABLE C-9

PRECIPITATION STATISTICS

	Mean Annual Precipitation (inches)	Percentage of Precipitation During the Period June thru Sept.	Percentage of Precipitation During the Period Dec. thru March
Mobile	65.5	41.4	34.9
Pensacola	63.4	43.3	30.0
Apalachicola	56.2	52.5	25.8
Tallahassee	56.9	47.5	28.5
Cedar Key	46.6	55.9	23.8
Tampa	51.6	60.2	20.6
Fort Myers	53.3	63.6	14.3
Everglades	54.7	62.5	12.4

The heaviest rainfall at all stations in Table C-9 occurs in July or August except for Apalachicola and Everglades, which show a September maximum. All of the marine areas (Table C-8) show the highest frequency in September. The concentration of the rainfall in summer in northern and western Florida leads to the highest river discharges in late summer and early fall, in marked contrast to the seasonal patterns observed throughout the rest of the United States (Langbein and Wells, 1955). The season of lowest river discharge over this area is in late spring.

Fog at locations along the northern and eastern Gulf coast is fairly common during the winter months and rare during the summer. Statistics for the marine areas (Table C-10) show this same pattern. At coastal stations, the maximum frequency of heavy fog (reducing visibility to one-fourth mile or less) is reported in 10-15 percent of the days during the period November through March (SUSIO, 1972). During the period April through October, heavy fog is reported on one to two percent of the days.

TABLE C-10

FOG OBSERVATIONS

	Mean Annual	Maximum Monthly	Minimum Monthly
Area A	0.6	2.0 (3)	0.1 (6-10)
Area B	0.4	1.7 (3)	0 (7-8;10-11)
Area C	0.2	0.8 (2)	0 (4-5;7-11)

Mean annual percent of ship observations reporting fog and the maximum and minimum frequencies during individual months.

Mean temperature data for the eastern Gulf area (Table C-11) show much larger seasonal ranges at the coastal locations than the marine areas. This pattern results primarily from colder winter temperatures at the coastal locations. The extreme temperatures show the same tendency with a small difference between coastal and marine areas in maximum values and a large difference in minimum values.

TABLE C-11

TEMPERATURE STATISTICS

	Mean Annual	Monthly Maximum	Monthly Minimum	Extremes
Pensacola	68	82 (7)	54 (1)	97-11
Tallahassee	68	81 (7)	54 (1)	104-(-2)
Tampa	72	82 (7)	61 (1)	97-23
Area A	76	84 (7)	65 (1)	100-32
Area B	76	83 (8)	64 (1)	100-40
Area C	78	83 (7)	70 (12-2)	99-50

B. REGIONAL GEOLOGY

The physical divisions of the eastern Gulf of Mexico are best characterized by physiography and bathymetry, Figure C-3. Relief and depth have been determined by fundamental differences in the geological history. Processes and factors that have had greatest influence are the differences in supply of terrigenous, siliceous, clastic sediments and the genesis of carbonate sediment, mostly as skeletal remains of marine organisms. In turn, this has been controlled by: 1) climate and climatic changes, 2) nature of adjoining land masses, i.e., rock type and relief, 3) sea level changes and 4) energy conditions, i.e., waves and currents.

Except for subsidence in the environs of the Mississippi River Delta, *diastrophic movement has not been a significant influence in the recent geological past.* With reference to the geological map, Figure C-4, the only evident structures superimposed upon the continental masses are: 1) Gulf Coast Geosyncline and

2) Ocala-Middle Ground Arch. A less evident structure is the Apalachicola Embayment that extends northeastwards as the East Georgia Trough. The drastic geographic, environmental and biological changes that have occurred in the Gulf during the last 15 to 20 million years are related to changes in world climate, sea level lowering and glacial eustatic fluctuations.

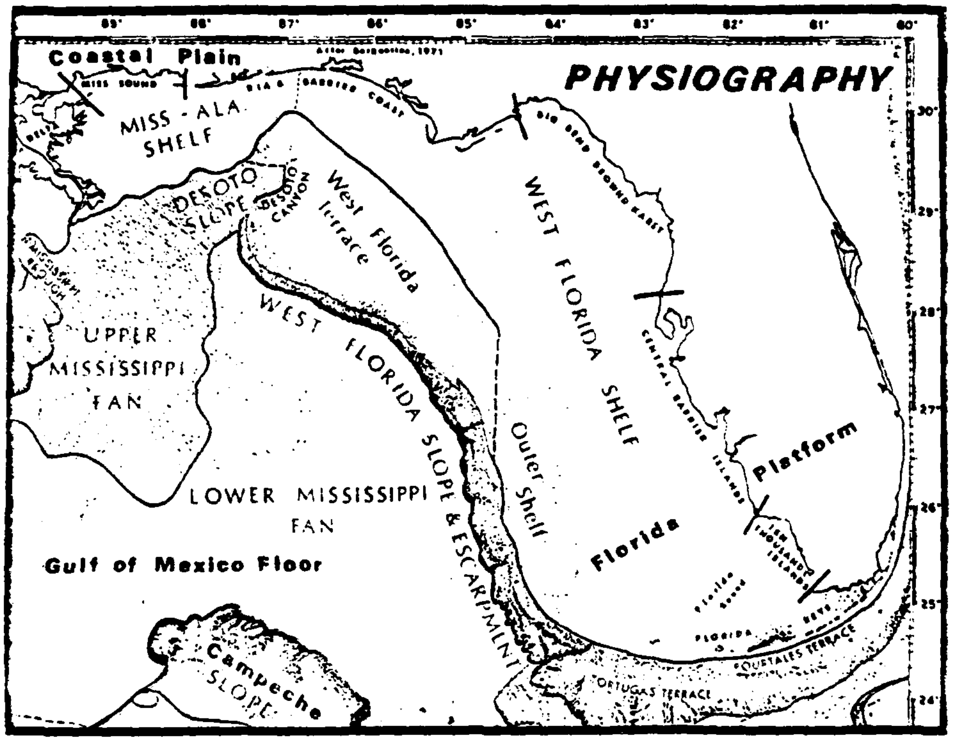

FIGURE C–3 BATHYMETRY

There are four fundamental divisions in the eastern Gulf of Mexico superimposed upon the primary continental-oceanic entities. The (I) Gulf of Mexico Basin is underlain by oceanic crust and depths of 12,000 feet and more occur. The basin is a mediterranean type sea partially enclosed by land masses. It is the adjoining land masses that determine the three additional environmental entities eastward of the Mississippi River Delta and Yucatan: (II) Yucatan Channel and Straits of Florida. (III) carbonate platform of Peninsular Florida and West Florida Shelf, and the (IV) Mississippi-Alabama Shelf and De Soto Slope associated with the clastic province of the Gulf Coastal Plain of continental North America. The transition from the carbonate province to the clastic province to the clastic occurs as a zone extending northeast from De Soto Canyon through the Apalachicola Delta toward Charleston, S.C.

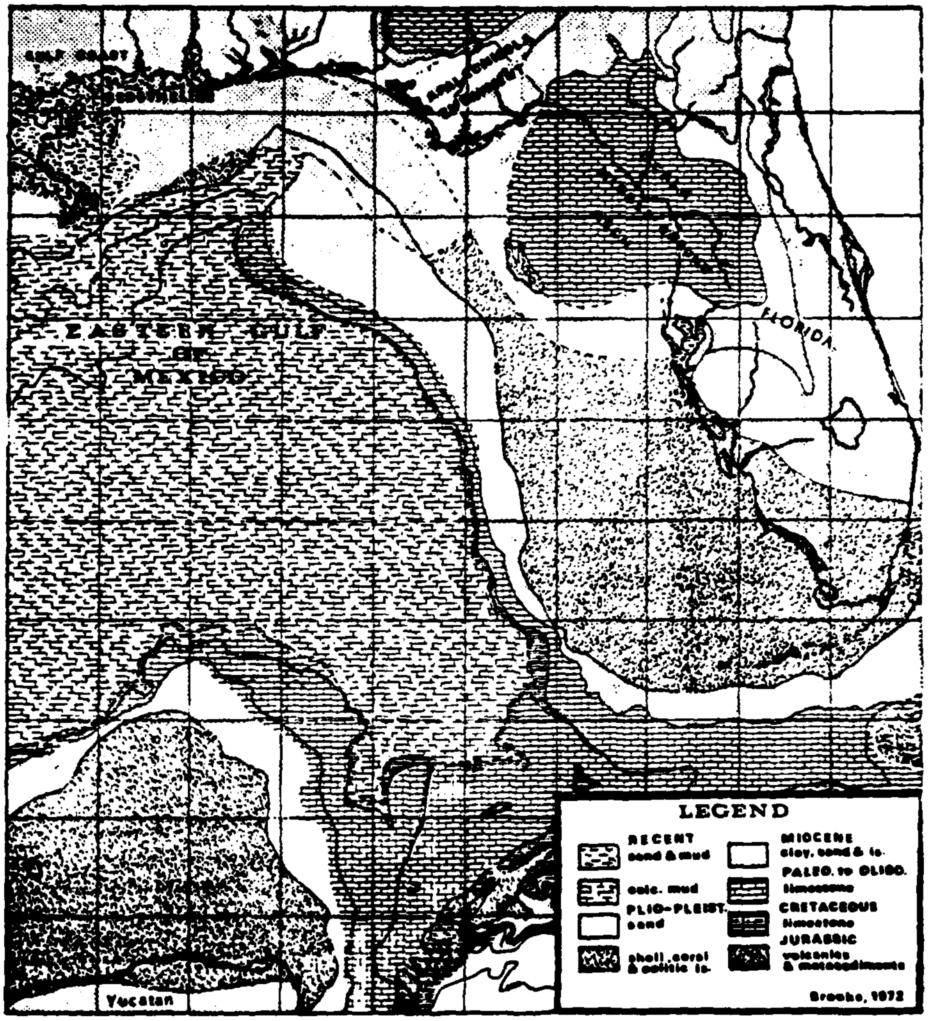

FIGURE C–4 GENERALIZED GEOLOGICAL MAP

The present shore lines and associated estuaries, marshes, swamps, beaches, lagoons, etc., are ephemeral and have existed less than 6,000 years. Sea level has been as much as 300 feet higher and 350 lower within the past 15 million years. *The existing coastal features are always in a state of dynamic change.* The 1) supply of terrigenous sediments, 2) eustatic changes in sea level, 3) *energy conditions of waves and currents influenced by the "ramp" depths directly offshore determine the coastal type.* With reference to Figure C-5, one should note the relationship between the coastal types, the rivers, and the 10 fathom contour. The ramp depth is directly related to the origin and nature of the underlying rock. (See Figure C-4.)

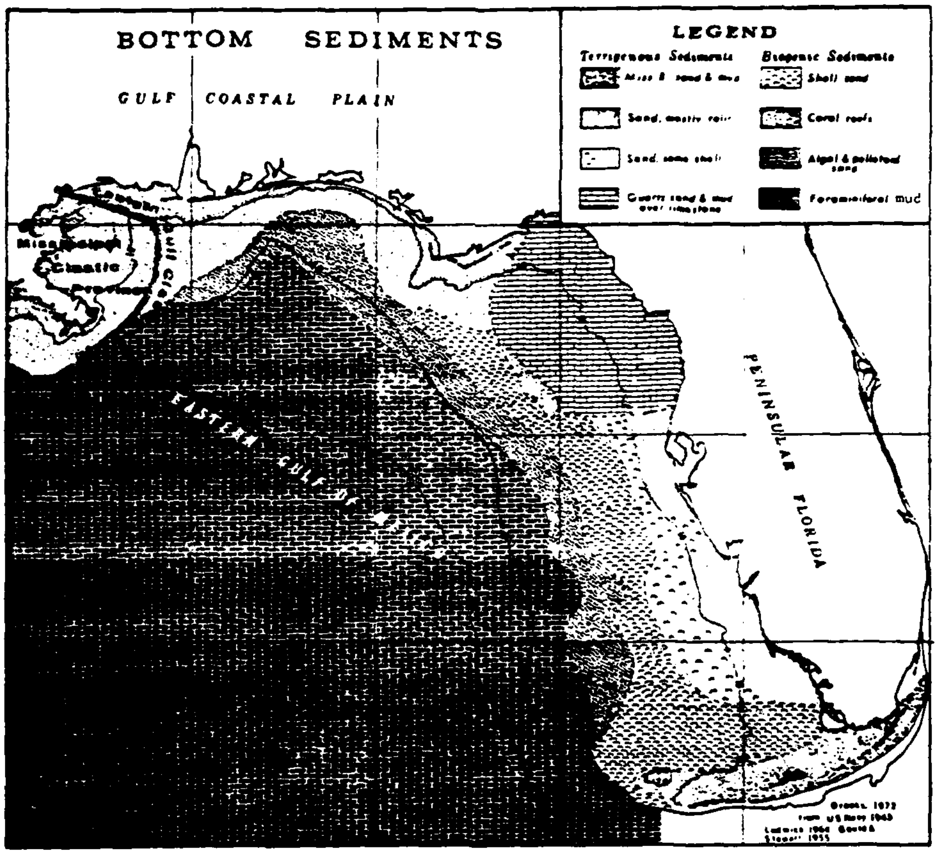

FIGURE C–5 RECENT SEDIMENTS AND BOTTOM CONDITIONS

The logical geological classification of the hydro-biological division delimited by the Deep Water Port Committee would be:

I. Gulf of Mexico Floor and Slopes (XXVI)
II. Yucatan Channel and Straits of Florida (XXV)
III. Florida Carbonate Platform
  A. Coastal and Estuarine Features
    1. Big Bend Drowned Karst (VI)
    2. Central Barrier Coast (VII)
    3. Ten Thousand Islands (VIII)
    4. Florida Bay and Keys
  B. Inner Shelf, Littoral
    1. Drowned Limestone Plain (XVII)
    2. Central Barrier Littoral Zone (XVIII)
    3. Florida Sound (XIX)
  C. West Florida Shelf (XXIV)
IV. Gulf Coast
  A. Coastal and Estuarine Features
    1. St. Bernard Delta, Mississippi Sound & Mobile Bay (IV)
    2. Panhandle Barrier-Ria Coast (V)
  B. Inner Shelf
    1. Mississippi-Alabama Inner Shelf (XIV, XV)
    2. Panhandle Inner Shelf (XVI)
  C. Outer Mississippi-Alabama Shelf and Upper DeSoto Slope (XXIII)

II. ESTUARIES, BAYS, LAGOONS, AND NEARSHORE

A. PHYSICAL CHARACTERISTICS

1. Hydrology

It is appropriate to discuss the similarities within the region before discussing the dissimilarities. *All of the nearshore areas, the bays and estuaries are shallow and well-mixed bodies of water.* They are flushed by a combination of fresh water through flow and tidal action. In the nearshore areas tidal forces and bottom friction forces are much larger than wind forces. From the experience of Ross in field testing in the Tampa Bay vicinity it was found that wind effects penetrate the upper foot and a half of the surface waters in the nearshore areas. *The predominant current patterns even in the presence of prevailing winds were those determined by tidal flow, runoff and bottom topography.*

A map showing the drainage pattern for the coastal zones of the eastern Gulf area is shown in Figure C-6.

2. Chemistry

This section attempts to condense some of the many reports, theses, and research efforts quantifying the chemical character of the estuaries of the eastern Gulf of Mexico.

Nutrients are among the best documented chemical elements in the near shore Gulf. Phosphorus in particular has received considerable attention in part because of its possible role in red tide outbreaks (Ketchum and Keen, 1948) and because of the extensive phosphate deposits in Florida. For other elements, such as mercury, the data is scanty, and we can only provide accounts of occasional determinations.

Nitrogen and phosphorus enter the water from the atmosphere, municipal and industrial wastes, fertilizers, and animal wastes. In Hillsborough Bay and Charlotte Harbor, phosphate mining operations contribute major phosphorus burdens to the receiving waters (Alberts, 1970; U.S. Department of Interior, 1969). The available data indicate the *greatest contribution of phosphorus to water is the direct result of the activity and interference of man (Task Group Report, 1967).*

The distribution and concentration of dissolved orthophosphate in Florida streams was summarized by Kaufman (1969). He indicated that the orthophosphate content of streams in parts of the state can be correlated with phosphatic-rock formations in the drainage area. A secondary cause of elevated phosphorus was pollution, a conclusion that was reported earlier by Odum (1953). The Alafia, Peace, and Fenholloway Rivers carried the greatest orthophosphate burdens in Florida although it should be noted that Kaufman's estimates of phosphate concentrations are greater by a factor of 2 to 3 than similar measurements made on the Alafia and Peace Rivers by the Department of Interior (1969) and Alberts (1970), respectively. The discrepancy may be a result of differences in the analytical methods used.

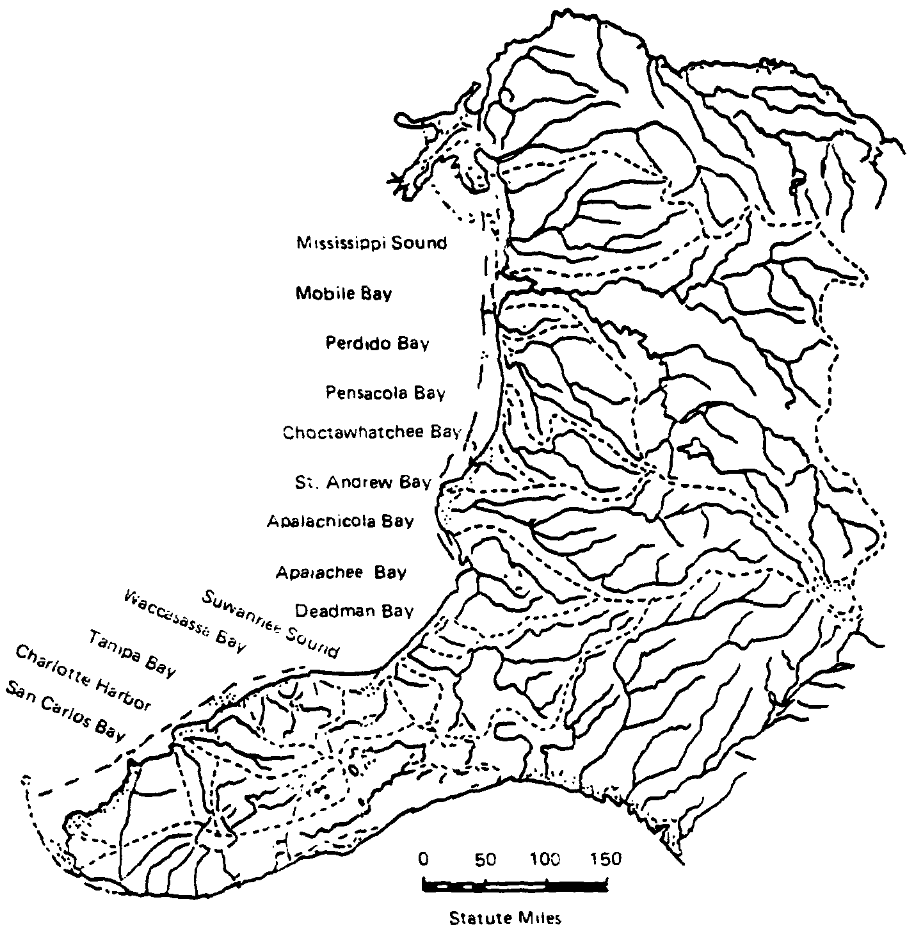

FIGURE C–6 DRAINAGE PATTERN OF THE EASTERN GULF COASTAL AREA

Hopkins *et al.* (1972) compared the degree of euthrophication of several Florida estuaries by preparing a plot of the sum of the nitrate and phosphate concentrations versus the chlorophyll pigments (the numbers derived in such a comparison are termed the euthrophication index). The results of Hopkins and co-workers efforts are shown in Figure C-7. In devising the euthrophication index number, the nitrate concentration was weighted because nitrate may be limiting to phytoplankton particularly in many Florida areas (Saville, 1966). The work of Hopkins *et al.* (1971) indicated that the Alafia and Manatee Rivers are areas with high nutrient and pigment concentrations whereas the Waccasassa and Crystal Rivers

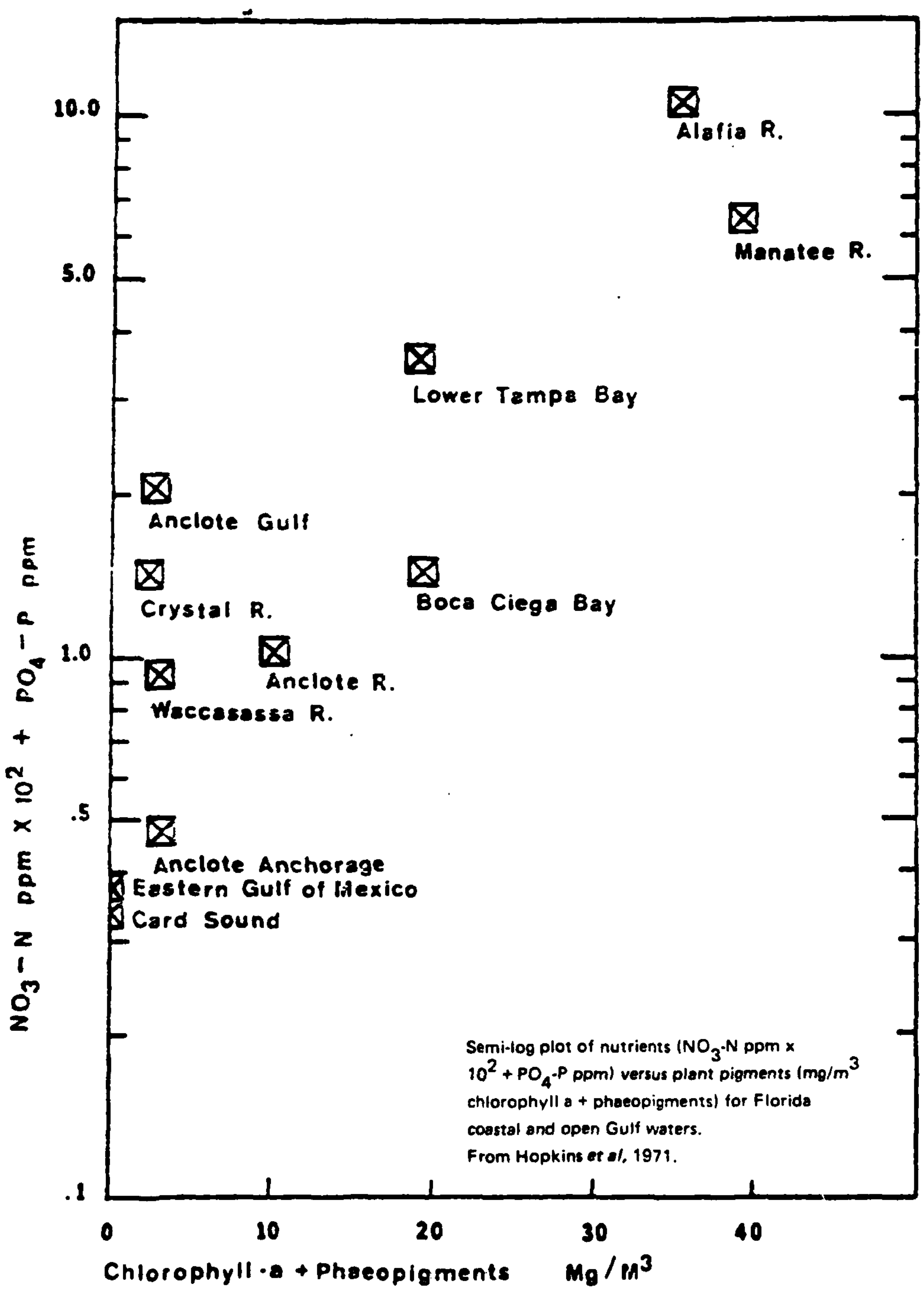

FIGURE C–7 NUTRIENT AND PIGMENT CONCENTRATIONS

have low chlorophyll concentrations, but intermediate nutrient levels. The loop current in the eastern Gulf of Mexico was characterized by low nutrients and pigment levels, as was Card Sound.

Florida's surface waters have distinct regional variation in pH, especially at the lower pH values. Environmental conditions will affect the hydrogen ion concentration, but the pH range encountered in Florida is less than 4.0 to greater than 8.5. The factors affecting the pH are, (1) the geology of the terrain (i.e.: carbonate or non-carbonate rock outcrops); (2) alkaline ground-water inflow; (3) drainage from swamplands and (4) industrial and agricultural effluents (Kaufman, 1970). Generalizing Kaufman's (1970) work, the lowest pH values (between 4 to 6) were found across the northern portion of the state from Pensacola to Jacksonville. Between Gainesville and Lake Okeechobee, and in pockets along the Apalachicola and St. Johns Rivers, the pH ranged between 6 to 7. An exception to this was a large area centering around the Alafia and Manatee Rivers, where the pH was occasionally less than 4.0. South of Lake Okeechobee to the Florida Keys, the pH was greater than 7.0.

Kaufman indicated that most of the waters with a pH below 6.0 are: a) upstream from the influences of significant alkaline ground water inflow; b) drain non-carbonate terraines; or, c) are affected by drainage from swamps especially during periods of high flow. In general, the low pH waters had a low specific conductance, low bicarbonate concentration, are soft, high colored (except in West Florida) and contain appreciable iron. Kaufman indicated that these low pH waters had low buffer capacity, permitting organic acids to have a pronounced effect.

The pH of several north Florida Rivers (St. Mary's, Suwannee, and Sopchoppy Rivers) was found to fluctuate in response to river discharge, and, in general, increased discharge resulted in a lowering of the pH.

Natural waters with a pH from as low as 6.0 to over 8.5 reflect the presence of limestone outcrops or alkaline ground water inflow. These waters have moderate to high conductance, hardness and bicarbonate concentration and are well buffered. Regions with waters having a pH less than 4.0 are affected by industrial or agricultural activity and are centered around the phosphate mining regions and north of Lake Okeechobee.

Differences in color of surface waters in Florida have been summarized by Kaufman (1969). Surface waters with a color of 200 or more color units (Pt-Co scale) around the Gulf coast are found from Apalachee Bay southward to Tampa Bay with the *Caloosahatchee Canal contributing highly colored water below Charlotte Harbor. Surface waters from the Everglades generally have a color less than 100 color units. West of Apalachee Bay the surface waters decrease in color from 200 to less than 100 color units at the Florida-Alabama border.* Streams with large fluctuations in runoff show considerable variation in color, but the greatest color increases occur right after a rainfall as a result of the flush of organic matter and in general coincide with periods of high flow. Seasonal variation in color was observed with a maximum color found between July through October. Brogden (1971) repeated color measurements on selected Gulf coast estuaries and found essentially similar results to Kaufman and also emphasized that runoff was a controlling factor in affecting color.

Another paper of chemical interest in the Gulf of Mexico is one concerning suspended matter. Manheim, *et al*; (1972) analyzed 200 surface water samples for suspended material. They found that suspended matter in excess of 1 mg/L was confined to just a few kilometers off the Louisiana and Texas coasts. Suspenates from areas farther out than 100 kilometers were mainly organic in nature. In general, Florida's coastal waters have *very low turbidity, decreasing from the southwest to the southeast. Dredging has an adverse effect on the turbidity and the marine biota.*

Brogden (1971) found that the humic acids in several Florida streams had a continuous molecular weight distribution over a range of 300-5,000 and that only about 5 to 13% of the humic acids had molecular weights over 5,000. In a number of cases where humic acid containing fresh water mixed with sea water, there was evidence for the loss of a substantial fraction of the high molecular weight fractions. At least part of this loss was due to the formation of a precipitate containing heavy molecular weight material. The majority of the fresh water humic acid material is stable in sea water and only a loss of approximately 10% can be expected.

Water quality data for the Peace, Manatee, Alafia, Hillsborough, Anclote, Suwannee, Apalachicola, Choctawatchee, and Yellow Rivers have been tabulated by the U.S. Geological Survey *Quality of Surface Waters of the United States*, 1967. Detailed data for fluoride, phosphate, temperature, pH turbidity and conductivity as well as information on other water sources may be found in the cited reference.

Of the rivers listed, the *most undesirable water quality is found around the Tampa Bay-Charlotte Harbor areas*. The Peace and, in particular, Alafia Rivers have elevated concentrations of silicate, calcium, magnesium, sulfate, chloride, and fluoride. In the Peace River, however, the concentrations of these materials was seen to vary seasonally with river flow.

Water quality was found to increase, progressing toward the western end of the state; the *Apalachicola, Choctawhatchee and Yellow Rivers generally have high dissolved oxygen contents and good water quality in other respects.*

A number of reports have been compiled which provide an extensive tabulation of chemical data for selected regions along the Gulf coast. These publications indicate seasonal trends, give the range of variation, maxima and minima over a long-term sampling period. For these data the reader is referred to the publications by the Florida Board of Conservation (1966); Gorsline (1963); Federal Water Pollution Control Administration (1971a and 1971b); Marine Science Institute, University of South Florida (1971); National Oceanic and Atmospheric Administration (1972); United States Department of Interior (1971); and Florida Power Corporation (1972).

The most extensive study of trace elements in the Gulf of Mexico water is one just completed on the offshore area off Escambia-Santa Rosa counties in Florida. This co-operative interdisciplinary synoptic study has been called ESCAROSA I.

Six trace metals were measured in this investigation: cadmium, lead, copper, chromium, zinc and manganese. The concentrations of these elements have been calculated in parts per billion (ppb) and have been plotted for each station for both surface and bottom waters. Isopleths for these concentrations have been drawn. Although these data represent only a limited time period, and all the analyses have not been completed, the contours indicate the occurrence of certain events in the Florida Territorial Sea off ESCAROSA, and also establish the level of concentration for each of these elements at the time of sampling.

Except for copper concentrations, the average concentration for the five other measured trace metals is approximately ten times the concentrations typically observed in open-ocean waters. These higher concentrations would seem to indicate an enrichment of these trace metals in the offshore waters through the effluents of Escambia, Perdido and Mobile Bays, and the Mississippi River. *An examination of the distribution of each of these trace metals reveals a large tongue of water moving into the ESCAROSA area from the west, possibly from Mobile Bay or the Mississippi River.* The water movement from Pensacola and Perdido Bays is shown but the evidence is not nearly so pronounced as the westerly tongue of water (specific data and information as regards ESCAROSA can be obtained through SUSIO or the Florida Coastal Coordinating Council).

B. RESIDENT AND TRANSIENT MARINE BIOTA

1. Benthic Plants

Knowledge of the distribution of benthic marine algae in the eastern Gulf of Mexico has accumulated during the past twenty years to an extent that now permits recognition of a number of coastal zones and their boundaries or transition areas.

The most significant and scholarly of all publications on *benthic algae* of the eastern Gulf of Mexico, and the work contributing most to the knowledge of the coastal subregions, is that of *Earle* (1969) *on the brown algae*. She *divided the Gulf coast from the Mississippi Delta to the Florida Keys into six zones* (Figure C-8, modified after Earle, 1969) listed 72 species with distribution data and ecological notes. These *subregions are separated by transition zones rather than distinct boundaries and they vary in distinctiveness with season.* They become relatively less distinctive from coastal waters with depths of less than three meters to open Gulf waters with depths of 10 to 100 meters. The principal environmental factors are water temperature, turbidity and light penetration, depth, slope, substrate, salinity regime, water movement, and tidal regime.

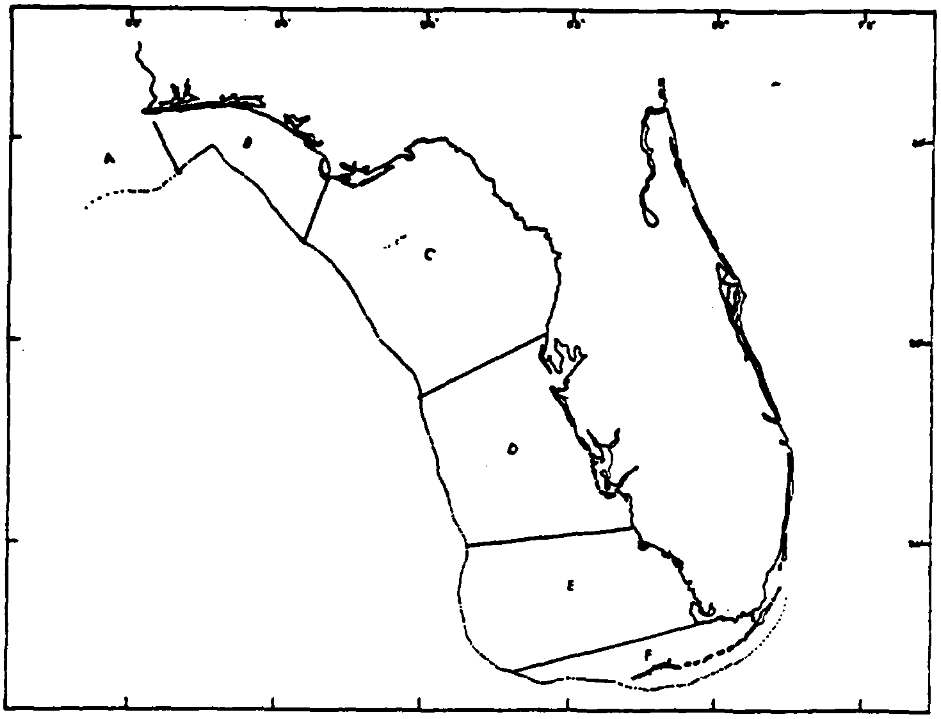

FIGURE C-8 SUBREGIONS INDICATED BY BENTHIC ALGAE

2. Plankton

Plankton in the eastern Gulf, ranging from warm temperature to subtropical, *seems to show distinct seasonality in abundance*. In coastal regions of the southwest Florida shelf the biomass maximum appears in summer whereas in intermediate shelf waters of the central and northeastern Gulf the seasonal maximum occurs in winter. Annually, averages for zooplankton biomass range from 0.08 to 0.80 ml/m^3, 0.02 to 0.10 ml/m^3 and 0.01 to 0.10 ml/m^3 in estuarine, shelf and eastern central Gulf regions, respectively. Locally both on the intermediate shelf and in estuaries biomass can be much higher.

The principal holoplankton species in terms of biomass in estuaries appears to be *Acartia tonsa*. On the basis of St. Andrew Bay data (Hopkins, 1966) and studies in progress on the anclote estuary and Tampa Bay (Hopkins and Weiss, unpublished data) other species of importance in Florida Gulf coast estuaries are the copepods *Oithona brevicornis*, *O. nana*, *Paracalanus crassirostris*, *P. parvis*, the larvacean, *Oilopleura dioica* and a rotifer, *Synchaeta* sp. These, along with *A. tonsa*, constituted over half the biomass and numbers of plankton taken with a number 10 net (150 μ mesh) in St. Andrew Bay.

Clear trends in species diversity have been recognized in Gulf coast estuaries as elsewhere. Numerous investigators have noted that in general *plankton variety decreases with decreasing salinity*. Hopkins (1966) found this to be true in St. Andrew Bay System, with greatest diversity occurring at stations with the highest mean salinity and least diversity at stations with lowest mean salinity. This trend is apparent, too, in the Anclote estuary and in Tampa Bay (Hopkins and Weiss, unpublished data).

The principal regulating factors for seasonal patterns in estuarine zooplankton have not yet been clearly defined. Multiple linear regression analyses suggested that temperature, salinity, and phytoplankton biomass fluctuations accounted for less than 30 percent of the seasonal variability of the zooplankton population in St. Andrew Bay (Hopkins 1966). These factors, however, temperature in particular, may be exerting a controlling influence indirectly by affecting the species composition of the plankton and consequently predator-prey relationships. There is evidence that in both St. Andrew and Tampa Bays levels of microzooplankton are in large measure regulated by ctenophores and jellyfish which graze especially heavily on the smaller zooplankton in winter.

Superimposed on natural determinants is *man's impact on estuarine and nearshore plankton* which comes in the form of industrial and domestic alterations of water quality (F.W.P.C.A., 1969). As with runoff and temperature, this influence varies regionally, with *greatest* impact to be expected *in more heavily populated coastal areas such as Tampa and Escambia Bays.*

It is generally conceded that *phytoplankton* (pelagic vs. *benthic) production in estuarine and inshore areas is exceeded by the primary production of attached seagrasses, algae, epiphytes and benthic photosynthetic microflora* (Pomeroy, 1960 for Boca Ciega Bay; Saville, 1966 for Waccasassa Bay; Taylor and Saloman, 1968 for Boca Ciega Bay; Bader and Roessler, 1971 for Card Sound on Florida's east coast). In addition, *benthic plant communities* (e.g., diatoms, blue-greens, seagrasses) *aid in stabilizing sediments.* Wood (1967) mentioned filamentous blue-green algae extending 2 inches in the sand at Port St. Joe, Florida and inferred that these could additionally be a food source for mollusks and other phytophagous animals. Taylor and Saloman (1968) suggested that total primary production was six times that of pelagic phytoplankton in Boca Ciega Bay.

In most bay and harbor studies (Marshall, 1956 for Alligator Harbor and Tampa Bay systems; Hopkins, 1966 for St. Andrew Bay System; Saunders *et al.* 1967 for Tampa Bay system; Taylor and Saloman, 1968 for Tampa Bay system) *maximum production and/or standing crop is in upper reaches, gradually decreasing towards the mouth.* Contrarily, Saville (1966) reported maximum production toward the mouth of the Waccasassa Bay and Thomas and Simmons (1960) showed an increase in production seaward from the Mississippi River. No doubt, runoff, tidal exchange, flushing rates, basin length and depth. turbulence and time and source of nutrient enrichment or rejuvenation influence these seaward gradients.

The Waccasassa River, Florida has a poor phytoplankton crop (Saville, 1966) while a similar tributary, the Fenholloway River, is non-productive because of extensive pollution. Thomas and Simmons gave values of 0 to 0.057 g C/m^3/day for the Mississippi River. Marshall (1956) listed maximum Chl *a* values for Florida lakes as 112 mg Chl a/m^3, with a mean value of 19.2 mg/m^3, while comparatively only the most productive estuaries (e.g., Long Island Sound) had similar values.

It appears from phytoplankton primary production estimates that the Tampa Bay system is one of the most productive estuaries along the eastern Gulf of Mexico (0.4 g C/m^2/day or 2.5 g C/m^2/day, if benthic plants are included, for Boca Ciega Bay alone). See Table C-12.

Wood (1967) observed that in tropical and subtropical estuaries or enclosures there are co-dominant phytoplankters, e.g., for Biscayne Bay. This phenomenon of co-dominance appears to be typical along the entire Gulf coast. If we look at available estuarine data (Marshall. 1956; Hopkins, 1966; Saville, 1966; Saunders *et al.*, 1967) it can be concluded that different species have seasonal peaks, yet there are resident assemblages that characterize eastern Gulf estuarine conditions that would include the diatoms *Skeletonema costatum, Chaetoceros* spp. *Rhizosolenia stolterfothii, R. setigera, Cylindrotheca closterium, Cyclotella* spp., *Thalassiosira* spp., *Thalassionema nitzschioides, Cerataulina pelagica, Bacillaria paradoxa, Asterionella japonica, Paralia sulcata, Bacteriastrum* spp., *Nitzschia seriata, Leptocylindrus danicus, Bellerochea* sp., and the dinoflagellates *Ceratium hircus, Gymnodinium splendens*, small *Gymnodinium* and *Gyrodinium* spp., *Polykrikos* spp., *Peridinium* spp., e.g., *P. gracile.* It has already been mentioned that estuarine and inshore studies showed unidentified microflagellates (15 μ) numerically dominating the majority of phytoplankton samples.

According to Saunders and Fryxell (in press), the Tampa Bay system is quite distinct in its diatom assemblage. Tampa Bay is also rather unique in that at times it can have coincident dinoflagellate blooms, e.g., *Gymnodinium breve, Gonyaulax monilata* (both toxic species, one of coastal origin), *Cochlodinium citron, Gymnodinium splendens, Gonyaulax spinifera,* and *Peridinium quinquercorne* (Steidinger, unpublished observations for summer, 1971). *Several eastern Gulf estuaries are the scene of heavy nontoxic phytoplankton blooms* (particularly dinoflagellates) *during summer months and these can cause isolated animal mortalities by lowering the available oxygen content in seawater.*

The major portion of the preceding discussion on plankton has been extracted virtually verbatum from the API report, *A Summary of Knowledge of the Eastern Gulf of Mexico, 1972.* The titles and authors of the articles from which the plankton discussion was taken are "E. Zooplankton" by Dr. Thomas L. Hopkins and "F. Phytoplankton" by Karen A. Steidinger. Subsequent discussions in this report on plankton are likewise from the same source.

TABLE C-12

DAILY COMPUTATION OF PRIMARY PRODUCTION IN GRAMS CARBON

Location	Method	M^3 or M^2	Grams C/Day Gross	Net	Inbetween or Unspecified	Reference*
North Carolina estuaries	O_2	m^2	0.15-0.46	0.08-0.25		1
Texas bays	O_2	m^2	0.55	0.01		1
Baltimore Harbor	O_2	m^2	0.9			1
Long Island Sound	O_2	m^2	2.4	0.5		1
Georgia estuary	O_2	m^2	0.7	0.1		1
Corpus Christi, Texas Bay	O_2	m^2	3.3			1
Waccasassa Bay, Fla.	^{14}C	m^2			0.3 (0.026-0.761)	2
Breton Sound	^{14}C	m^3			0.13-1.4	3
Blind Bay	^{14}C	m^3			0.03-2.3	3
Mississippi Delta	^{14}C	m^3			0.005-0.32	3
Old Tampa Bay	O_2	m^2	0.27-0.65			4
Hillsborough Bay	O_2	m^2	0.58-0.95			4
Tampa Bay proper	O_2	m^2	0.32-0.53			4
Tampa Bay entrance	O_2	m^2	0.27-0.49			4
Boca Ciega Bay	O_2	m^2	0.33-0.48			4
Puget Sound	?	m^3			ca 0.3	2
Narragansett Bay	?	m^3			ca 0.25	2
Sargasso Sea	^{14}C	m^3			0.02	2
Gulf Stream	?	m^3			0.03	2
Tropical Pacific	^{14}C	m^3			ca 0.01-0.25	5
NE & S Gulf of Mexico	^{14}C	m^3			ca 0.003-0.01	5
Eastern Gulf	^{14}C	m^2			0.1	5
Inshore Gulf	^{14}C	m^2			ca 0.08	5
Offshore Gulf	^{14}C	m^2			ca 0.06	5
Gulf of Mexico	^{14}C	m^2			0.1	5
Caribbean Sea	^{14}C	m^2			0.1-0.2	5
Fertile Seas	?	m^2			0.5-1.0	6
Upwelling areas	?	m^2			1.5-2.0	6
Large algae beds	?	m^2			20.0	6
Theoretical maximum	?	m^2			25.0	6

*1) Williams, 1966, 2) Saville, 1966, 3) Thomas and Simmons, 1960, 4) Taylor and Saloman, 1968, 5) El-Sayed (in press), 6) Riley and Chester, 1971.

3. Benthic Invertebrates

The horizontal and bathymetric distribution of benthic invertebrates that live in the eastern Gulf of Mexico is imposed by a complex of abiotic factors such as temperature, salinity, substrate availability and wave shock, and by biotic factors such as predators, competitors and the presence of suitable forage. No two species are identical in their ecological requirements or physiological tolerance limits. Thus, species borders range from narrow to very broad; they may be continuous or discontinuous, and they often coincide with the distribution of chemical or geological features of the environment. Only rarely are the borders of different species congruent.

In the *eastern Gulf of Mexico where major faunal boundaries are indistinct, the biogeographical area consists of broadly overlapping Carolinian and West Indian components. Carolinian species predominate in the northern Gulf Coastal Zone V. From Apalachee Bay southward West Indian forms gradually become predominant:* (Zones XVII and VI, XVIII and VII). Faunal components south of Cape Romano are distinctively West Indian; (Zones XIX and VIII). Many species in reef communities of the Florida Keys are restricted to southern latitudes, and are not found in shallow waters of the northern Gulf. Although widely disjunct species have been reported, the range for most so-called disjunct Carolinian species is broken in southeastern Florida and Florida Bay. Offshore, West Indian reef species range into the northern Gulf, particularly below the ten fathom isobath, Zones XXIII and XXIV. Seasonal changes in benthic populations are most evident off the northern coast and in the Big Bend area; regions XVI and XVII.

Important recurrent ecological groups, or communities have been identified and characterized in the eastern Gulf by means of common and usually conspicuous indicator invertebrate species listed in the subsequent sections. Lists of species are presented as Tables C-13 through C-21.

TABLE C-13

LOWER CONTINENTAL SLOPE AND DEEP EASTERN GULF

a. Hard Substrates

Bebryce grandis	soft coral
Chrysogorgia elegans	soft coral
Acanella eburnea	soft coral

b. Soft Substrates

Hymenopenaeus robustus	shrimp
Benthesicymus cereus	shrimp
Bathyplax typhla	crab

TABLE C-14

DEEP CONTINENTAL SHELF AND UPPER SLOPE

a. Hard Substrates

Muricea laxa	soft coral
Thesea grandiflora	soft coral
Scleracia guadalupensis	soft coral

b. Soft Substrates

Scaphella junonia	junonia
Clypeaster subdepressus	sea urchin
Plagiobrissus grandis	sea urchin

TABLE C-15

SHALLOW SHELF FROM CAPE SABLE TO TARPON SPRINGS

a. Unconsolidated Substrates

Phalium granulatum	scotch bonnet
Moira atropos	heart urchin
Hepatus epheliticus	crab
Luidia clathrata	starfish
L. senegalensis	nine-armed starfish
Strombus alatus	conch
Ovalipes guadulpensis	crab
Arenaeus cribrarius	crab
Encope michelini	sea urchin

b. Hard Substrates

Millepora alcicornis	fire coral
Speciospongia vesparia	loggerhead sponge
Hippiospongia lachne	sheepswool sponge
Oculina diffusa	hermatypic coral
Siderastrea siderea	hermatypic coral
Antillogorgia acerosa	soft coral
Ptergorgia anceps	soft coral

c. Marine Grass Beds

Lytechinus varigatus	sea urchin
Echinaster sentus	starfish
Cardita floridana	starfish
Turbo castaneus	snail
Modulus modulus	snail
Cerithium muscarum	fly specked cerith
Pinna carnea	bivalve
Chione cancellata	bivalve
Codakia orbiculata	bivalve

TABLE C-16

COASTAL ZONE FROM CAPE SABLE TO CAPE ROMANO

a Low Salinity Marshes

Procambarus alleni	crayfish
Uca rapax	fiddler crab
Cardisoma guanhumi	land crab

b. Mangrove Dominated Ecosystems

Littorina agulifera	mangrove periwinkle
Aratus pisonii	mangrove crab
Melampus colleus	mangrove coffee snail
Neritina virginea	virgin nerite
Isognomon alatus	flat tree oyster
Ostrea frons	coon oyster

TABLE C-16 (Continued)

c. **High Salinity Bays**

Batillaria minima	false cerith
Luidia senegalensis	starfish
Amygdalum papyria	paper mussel
Petaloconchus nigricans	worm shell

d. **Marine Grass Beds**

Tozeuma carolinensis	shrimp
Fasciolaria tulipa	true tulip
Cardita floridana	broad ribbed cardita
Pagurus annulipes	hermit crab
Penaeus duorarum	pink shrimp
Lytechinus variegatus	sea urchin
Modulus modulus	snail
Bittium varium	snail
Chione canellata	cancellate venus

e. **High Energy Beaches**

Ocypode albicans	ghost crab
Donax variabilis	coquina
Emerita talpoida	sand flea
Oliva sayana	lettered olive

TABLE C-17

COASTAL ZONE FROM CAPE ROMANO TO THE ANCLOTE RIVER

a. **Low Salinity Marches** (Spartina – Juncus)

Littorina irrorata	marsh snail
Neritina virginea	virgin nerite
Rangia cuneata	bivalve
Macoma mitchelli	bivalve
Ophiophragmus filogranus	brittle star
Polymesoda caroliniana	carolina marsh clam

b. **Mangrove Dominated Ecosystems**

Littorina agulifera	mangrove periwinkle
Aratus pisonii	mangrove crab
Melampus colleus	mangrove coffee snail
Neritina virginea	virgin nerite
Isognomon alatus	flat tree oyster
Ostrea frons	coon oyster

c. **High Salinity Bays**

Tellina similis	candy-stick bivalve
T. alternata	bivalve
Murex florifera	snail
Cerithium muscarum	fly specked cerith
Echinaster sentus	starfish
Phoronis architecta	––

d. **Marine Grass Beds**

Tozeuma carolinensis	shrimp
Fasciolaria tulipa	true tulip
Cardita floridana	broad ribbed cardita
Pagurus annulipes	hermit crab
Penaeus duorarum	pink shrimp
Lytechinus variegatus	sea urchin
Modulus modulus	snail
Bittium varium	snail
Chione canellata	cancellate venus

e. **High Energy Beaches**

Ocypode albicans	ghost crab
Donax variabilis	coquina
Emerita talpoida	sand flea
Oliva sayana	lettered olive

f. **Oyster Reef Communities**

Crassostrea virginca	virginia oyster
Petrochirus diogenes	hermit crab
Lima pellucida	bivalve
Crepidula convexa	slipper shell
Menippe mercenaria	stone crab
Ophioderma brevispinum	brittle star

TABLE C-17 (Continued)

g. Man-Made Substrates

Ligyda baudiniana	sea roach
Balanus amphitrite	barnacle
Zoobotryon verticillatum	bryozoan

TABLE C-18

SHALLOW SHELF FROM THE ANCLOTE RIVER TO OCHLOCKONEE BAY

a. Oyster Reefs

Crassostrea virginica	virginia oyster
Balanus amphitrite	barnacle
B. eburneus	barnacle
Stylochus frontalis	flatworm
B. exustus	mussel

b. Marine Grass Beds

Tozeuma carolinensis	shrimp
Fasciolaria tulipa	true tulip
Cardita floridana	broad ribbed cardita
Pagurus annulipes	hermit crab
Penaeus duorarum	pink shrimp
Lytechinus variegatus	sea urchin
Modulus modulus	snail
Bittium varium	snail
Chione canellata	cancellate venus

c. Unconsolidated Substrates

Phalium granulatum	scotch bonnet
Moira atropos	heart urchin
Hepatus epheliticus	crab
Luidia clathrata	starfish
Strombus alatus	conch
Ovalipes guadulpensis	crab
Arenaeus cribrarius	crab
Encope michelini	sea urchin

d. Hard Substrates

Leptogorgia virgulata	soft coral
Ircinia fasciculata	garlic sponge
Murex fulvescense	spiny murex
Siderastraea siderea	hermatypic coral
Muricea pendula	soft coral
Astrangia solitaria	ahermatypic coral
Phyllangia americana	ahermatypic coral
Tubularia crocea	hydroid
Hydractinia echinata	hydroid

TABLE C-19

COASTAL ZONE FROM ANCLOTE RIVER TO OCHLOCHONEE BAY

a. Low Salinity Marshes (*Spartina — Juncus*)

Procambarus blandingi	crayfish
Polymesoda caroliniana	carolina marsh clam
Macrobrachium ohione	freshwater shrimp
Modiolus demissus	mussel
Littorina irrorata	marsh snail
Neritina reclivata	marsh nerite
Rangia cuneata	bivalve
Uca minax	fiddler crab
U. pugnax	fiddler crab
Palaemonetes pugio	shrimp

b. Marine Grass Beds

Tozeuma carolinensis	shrimp
Fasciolaria tulipa	true tulip
Cardita floridana	broad ribbed cardita
Pagurus annulipes	hermit crab
Penaeus duorarum	pink shrimp
Lytechinus variegatus	sea urchin
Modulus modulus	snail
Bittium varium	snail
Chione canellata	cancellate venus

TABLE C-19 (Continued)

c. Unconsolidated Substrates

Melongena corona	crown conch
Tagelus divisus	bivalve
Clibanarius vitatatus	hermit crab
Fasciolaria hunteria	gastropod
Pandora trilineata	bivalve
Macoma constricta	bivalve
Chaetopterus variopedatus	parchment tube worm

d. Oyster Reef Community

Crassostrea virginica	virginia oyster
Balanus amphitrite	barnacle
B. eburneus	barnacle
Stylochus frontalis	flatworm
B. exustus	mussel

TABLE C-20

NORTHEASTERN SHALLOW SHELF FROM MISSISSIPPI SOUND TO ST. GEORGE'S SOUND

a. Jetty Communities

Ligydia exotica	sea roach
Littorina ziczac	snail
Crassostrea virginica	oyster
Bunodosoma cavernata	aneomone
Tubularia crocea	hydroid
Arbacia punctulata	sea urchin
Murex fulvescens	spiny murex
Leptogorgia virgulata	soft coral

b. Hard Substrates

Leptogorgia virgulata	soft coral
Ircinia fasciculata	garlic sponge
Murex fulvescense	spiny murex
Siderastraea siderea	hermatypic coral
Muricea pendula	soft coral
Astrangia solitaria	ahermatypic coral
Phyllangia americana	ahermatypic coral
Tubularia crocea	hydroid
Hydractinia echinata	hydroid

c. High Energy Beach

Ocypode albicans	ghost crab
Donax variabilis	coquina
Emerita talpoida	sand flea
Oliva sayana	lettered olive

d. Sandy Shelf

Phalium granulatum	scotch bonnet
Moira atropos	heart urchin
Hepatus epheliticus	crab
Luidia clathrata	starfish
Strombus alatus	conch
Ovalipes guadulpensis	crab
Arenaeus cribrarius	crab
Encope michelini	sea urchin

TABLE C-21

NORTHERN ESTUARIES, BAYS AND SOUNDS

a. *Spartina — Juncus Marsh*

Procambarus blandingi	crayfish	*Neritina reclivata*	marsh nerite
Polymesoda caroliniana	carolina marsh clam	*Rangia cuneata*	bivalve
Macrobrachium ohione	freshwater shrimp	*Uca minax*	fiddler crab
Modiolus demissus	mussel	*U. Pugnax*	fiddler crab
Littorina irrorata	marsh snail	*Palaemonetes pugio*	shrimp

TABLE C-21 (Continued)

b. Bays and Sounds (Sandy Beaches)

Periploma fragile	bivalve
Abra aequalis	bivalve
Corbicula contracta	bivalve
Diplononta punctata	bivalve
Mulinia laterialis	bivalve
Nuculana acuta	bivalve
Pandora trilineata	bivalve

c. Oyster Reefs

Crassostrea virginica	virginia oyster
Balanus amphitrite	barnacle
B. eburneus	barnacle
Stylochus frontalis	flatworm
B. exustus	mussel

d. Marine Grass Beds

Penaeus setiferus	
P. aztecus	
Tozeuma carolinensis	shrimp
Fasciolaria tulipa	true tulip
Cardita floridana	broad ribbed cardita
Pagurus annulipes	hermit crab
Penaeus duorarum	pink shrimp
Lytechinus variegatus	sea urchin
Modulus modulus	snail
Bittium varium	snail
Chione canellata	cancellate venus

The shrimp fishery of the Gulf of Mexico is the most valuable *commercial fishery in the United States.* In 1970, *over 83% of the nation's total shrimp catch came from Gulf waters.* This harvest amounted to about 145.3 million pounds that had a dockside value of nearly 108.2 million dollars. The volume and value of shrimp harvested in the eastern Gulf was about 31 million pounds and approximately 23 million dollars, which represents between one-quarter and one-fifth of the entire shrimp fishery.

Although nine species of shrimp are taken in the commercial shrimp harvest, the three most important ones are the brown shrimp, *penaeus aztecus;* white shrimp; *p. setiferus;* and pink shrimp, *duorarum.* Together they comprise about 98% of the commercial shrimp landings. The remainder is made up of royal red and sea bob shrimp. Figures depicting the distribution of harvest of the first three species by depth, species, season, and locality were presented by Osborn, Maghan, and Drummond (1969).

Brown, white, and pink shrimp all have similar life cycles and feed on a variety of benthic invertebrates as well as organic detritus. (Williams, 1965; Darnell, 1958.) Females carry between one-half and one million eggs that are spawned offshore. Brown shrimp generally spawn in winter and spring, while pink and white spawn mainly between April and August.

Larval and post larval stages develop rapidly and are carried by currents into estuarine areas where they mature in a few months and might reach a total length of as much as six inches. While in the estuarine areas they are particularly sensitive to contamination. Through late summer, fall, and early winter, mature shrimp move offshore where they spend the remainder of their lives and are taken in commercial shrimp fisheries. The average life span of these shrimp is about 18 months; however, some individuals might live several years and reach a length upward of ten inches and weigh four ounces or more. Shrimp are considered as an annual crop and catch predictions are based on the abundance of young entering coastal waters each spring. (Osborn, Maghan, and Drummond, 1969; Viosca, 1957; Collier, Ingle, Gunter, and Viosca, 1959; Roessler, Jones and Munro, 1969; U.S. Department of Commerce, 1972.)

4. Fish

The *eastern Gulf of Mexico supports a large and diverse ichthyofauna comprising elements of both temperate and tropical affinity*. Within the area under investigation the fishes occupy several fairly discrete biotyopes and may consequently be relegated to a corresponding number of faunal assemblages.

Most fishes of the coastal-estuarine faunal assemblages are restricted to shallow waters throughout their lives, although some may ultimately come to reside well offshore. Most are subject to wide fluctuations of temperature, salinity, turbidity and other variates generated by weather and tidal action. Much of this fauna is associated, at least as juveniles, with grass flats, marshes, and similar habitats within the richly productive estuarine systems. In the northern Gulf, for example, such areas serve as nursery grounds for menhaden, adults of which are responsible for the largest fishery, in terms of pounds landed, in the Gulf of Mexico (Reintjes, 1970). Other commercially important fin-fishes dependent wholly or in part upon this biotope include the drums and sea trouts (Sciaenidae) and the mullets (Mugilidae).

As noted by Reid (1954), ichthyofaunal transition within the coastal estuarine biotope along the eastern Gulf is a gradual one, in which the southern forms begin to appear somewhat irregularly and seasonally while species density of the northern fishes decreases.

In support of Reid's observation, Topp has compared species composition at six coastal and estuarine localities, based on percentages of coincident species of the families Sciaenidae (drums and seatrouts), Cyprinodontidae (killifishes), Gobiidae (gobies), Blenniidae (Blennies), Gerreidae (mojarras) and a few others representative of this biotope. Localities compared are:

Zone VIII:	Florida Bay (Tabb and Manning, 1961)
Zone VII:	Charlotte Harbor-Caloosahatchee Estuary (Wang and Raney, 1971); Tampa Bay (Springer & Woodburn, 1960)
Zone VI:	Cedar Keys (Reid, 1954)
Zone V:	St. Andres Bay (Vick, 1964)
Zone I-II:	Texas coastal waters (Gunter, 1945; Hoese, 1958)

The resulting matrix of values so derived (by Topp) reveals *no pronounced distribution "barriers" for the coastal-estuarine fish fauna of the eastern Gulf*. Insofar as the fishes are concerned, the divisions between Zones IV, V, VI, VII, and VIII should not be regarded as "faunal boundaries," but rather as convenient but artificial breaks in an otherwise gradual transition.

The practice of raising seafood under controlled conditions is another approach toward meeting the demand for edible and industrial species. Many biologists, as well as business organizations are encouraged to believe that we are now in a position to begin a program of commercial marine aquaculture – a program which would improve our often primitive methods of harvesting food from the sea. At present, federal, state and private programs are being directed toward the propagation and rearing of high yield and high price species such as shrimp, oyster, spiny lobster, stone crab, and pompano (Iversen, 1968). The extensive coastal zone of the Gulf has considerable potential for aquaculture. Several experimental and commercial projects have already been started.

The International Oceanographic Corporation has 70 acres leased for oyster farming at Cedar Key (Zone VI). The project has not yet proven to be commercially feasible. Ocean Farms, Inc., has applied for a lease for oyster cultivation in Levy County (also near Cedar Key). The lease has not been approved by the County Commissioners.

Sea Farms, Inc., of Key West (Zone VIII) has been farming baby shrimp for bait on a small scale. They have recently requested additional bottom-land leases, but because of the dredging necessary to set up the nursery beds, these leases have not yet been granted.

Experiments have been made to raise pompano in salt water lagoons in the Keys. Enmont Industries did a $4.2 million gross business in pompano in 1969, but could not make enough net profit to stay in business.

The one commercial aquaculture venture that appears headed for success is involved in shrimp farming. Through November of 1971, Marifarms, Inc., of Panama City, Florida (Zone V) had harvested over 500,000 pounds of shrimp for the year. This company, a pioneer in commercial aquaculture, has invested over $6 million in its initial four years of operation.

It is the largest commercial shrimp farming enterprise in the world. The project involves some 2500 acres and not only plants and cultivates the shrimp, but also processes the harvested shrimp.

Dr. Harold Humm of the University of South Florida has been researching algae farming and has done some projects on oyster farming in the Tampa Bay area (Zone VII).

Regulations on acquaculture in Florida are spelled out in the Aquaculture Law passed by the State Legislature in 1969 (*Florida Statutes*, Chapter 253).

With the large amount of interest shown in aquaculture, and with state governments encouraging this type of activity, *it would seem a distinct possibility that sea farming will expand on the Gulf coast in the next several years.*

5. Marine Mammals

The *marine mammal fauna of the eastern Gulf of Mexico consists almost entirely of the cetaceans* (whales and dolphins – there are no porpoises, in the technical sense, in the eastern Gulf). There are, on the other hand, two other groups represented; namely, the sirenians (manatees or sea cows) and the pinnipeds (seals and sea lions). Data on the majority of these animals in the eastern Gulf are limited or essentially nonexistent.

Nevertheless, there is enough general information on most and specific information on some, to be able to discuss the marine mammals on a regional basis. Those species herein discussed as being "endangered" have been so designated by the U.S. Environmental Protection Agency (see the journal *Science* for May 14, 1971, page 655, for notice of the cetaceans). The same agency has also designated *the manatee as endangered. All marine mammals in U.S. territorial waters are now protected* (under a law enacted in late 1972) and human activities regarding them will be subject not only to rigid controls, but under the law some of these mammals will be subjected to supported research as well, as related to their conservation.

General categories of marine mammals, along with scientific names, and regional locations, are listed in Table C-22. In general, all species are found within their expected ecological districts throughout the eastern Gulf of Mexico and consequently some of the *dissimilar zones as designated for this overall study are not particularly applicable to the marine mammals.* Even so, there are some generally dissimilar ecological regions which do relate to the marine mammals – such as coastal versus pelagic (high seas).

We feel that *none of the marine mammals in the eastern Gulf would potentially receive significant biological harm at the species level from the activities of man as now suggested and proposed* (namely, activities regarding deep water ports including those for oil tankers). However, there are *local populations, particularly in coastal zones, that might be significantly affected by such activities.* None of the species involved are restricted to the eastern Gulf, and hence even curtailment of local populations would not necessarily mean overall biological injury to the species.

Man's activities in this region would probably not be too serious with regard to marine mammals unless through pollution or some similar cause all fishes were destroyed. Bottlenosed dolphin might be expected to move out of any temporary ecological disturbances, but long-term effects of pollution might force them away permanently. As mammals, and therefore air breathers, pollution would have to be

TABLE C-22

EASTERN GULF MARINE MAMMALS

LARGE WHALES	
Black Right Whale (*Balaena glacialis*)*	Near shore to high seas
Minke Whale or Little Piked Whale (*Balaenoptera acutorostrata*)	Shelf to high seas
Sei Whale (*Balaenoptera borealis*)#*	Shelf to high seas
Bryde Whale (*Balaenoptera edeni*)	Shelf to high seas
Fin Whale (*Balaenoptera physalus*)*	Shelf to high seas
Humpback Whale (*Megaptera novaenglaiae*)*	Near Shore to high seas
Sperm Whale (*Physeter catodon*)*	Shelf to high seas
BEAKED WHALES	
Antillean Beaked Whales (*Mesoplodon europaeus*)	Outer shelf to high seas
Goose-beaked Whale or Cuvier's Whale (*Ziphius cavirostris*)	Outer shelf to high seas
SMALL WHALES	
Pygmy Sperm Whale (*Kogia breviceps*)	Shelf to high seas
Dwarf Sperm Whale (*Kogia simus*)	Shelf to high seas
DOLPHINS (Delphinidae)	
Rough-toothed Dolphin (*Steno bredanensis*)	Shelf to high seas
Atlantic Bottlenosed Dolphin (*Tursiops truncatus*)	Coastal zone to inner high seas
Gray Grampus or Risso's Dolphin (*Grampus griseus*)	Shelf to high seas
Long-snouted Dolphin (*Stenella cf. longirostris*)	Shelf to high seas
Bridled Dolphin (*Stennella frontalis*)	Shelf to high seas
Spotted Dolphin (*Stenella plagiodon*)	Coastal zone to high seas
Euphrosyne Dolphin (*Stenella caeruleoalba*)	Shelf to high seas
Common Dolphin or Saddleback Dolphin (*Delphinus delphis*)	Shelf to high seas

TABLE C-22 (Continued)

DOLPHINS (Delphinidae) (Continued)	
Pygmy Killer Whale (*Feresa attenuata*)#	Shelf to high seas
False Killer Whale (*Pseudorca crassidens*)#	Shelf to high seas
Short-finned Pilot Whale or Blackfish (*Globicephala macrohyncha*)	Shelf to high seas
Killer Whale (*Orcinus orca*)	Shelf to high seas
SIRENIANS	
Manatee or Sea Cow (*Trichechus manatus*)*	Coastal zone
PINNIPEDS	
California Sea Lion (*Zalophus californianus*)	Coastal zone to inner shelf (Introduced)
Caribbean Monk Seal (*Monachus tropicalis*)*	Coastal zone (Probably Extinct)

Note: The Blue Whale (*Balaenoptera musculus*) has been recorded from the western Gulf, but the records have been questioned. It has not been reported from the eastern Gulf.

Those marked with a # are known from the western Gulf and consequently should be expected on the eastern side, although they are not yet reported from there. Those marked with an asterisk are considered by the U.S. Environmental Protection Agency to be "endangered."

extremely severe to bring the latter about although it has been suggested for areas outside the eastern Gulf. It is more likely that they would be adversely affected by loss of food than by poor water. Unusual shipping activity might well cause them to depart a restricted area, but the mere presence of docks and/or deepened channels probably would not.

6. Marine Birds

The eastern Gulf of Mexico, and especially the varied saline habitats along the Gulf coast of Florida, are important to the existence of large populations of numerous species of birds. In all, almost 400 avian species have been recorded in or flying over the eastern Gulf of Mexico. However, many are either passage migrants, which are little affected by these saline environs, or rare stragglers whose numbers in the Gulf of Mexico amount to small and insignificant portions of their world populations. This report identifies and presents facts on the 81 avian species that in our opinion are importantly affected by the existence and condition of the saline habitats of the eastern Gulf.

In assembling the list of 81 species, we chose only those birds of saline habitats that occur annually in or on the shore of the eastern Gulf of Mexico in numbers large enough to be important to the North American population as a whole. Certain of the omissions, notably among the shorebirds, family Scolopacidea, and waterfowl, family Anatidae, include species seen every year in Florida at numerous localities, however, never in large numbers. In such cases always our list includes common species of similar ecology; our reasoning is that if the Gulf coast environment is acceptable for the abundant species, then those of rare occurrence will continue to appear. A few species that occur in low numbers along the Gulf coast of Florida are included because these individuals may represent important portions of the total populations of certain subspecies.

The life history and ecology and even detailed information on current distribution, is not known for any common bird found along the Gulf coast of Florida. Closest to an exception to this statement is the Brown Pelican (see Table C-23 for scientific names), which because of its recent fate in Louisiana and California has aroused the interest of conservationists and pesticide ecologists. Primarily through the field work of Ralph W. Schreiber and Lovett E. Williams, Jr., something is known about Florida Brown Pelicans, and its status provides a case history for the kinds of information needed on other birds of the area. Only after such information is gathered can valid predictions be made regarding the effects of altered environmental conditions.

The 81 avian species common along the eastern Gulf of Mexico are classified in 23 families. Birds of the same family often have similar feeding habitats, and the table that follows is a family list. Seventy-three of the 81 Gulf coast species are either permanent or winter residents. We have prepared indices of relative abundance in winter for four regions along the Gulf coast area of Florida and for the entire area for the last 15 years based on counts available from 17 localities (Table C-24). Details regarding scientific names for the 81 species are given in Table C-23 only. Where other species are first mentioned in the text their scientific name is listed.

As noted in our introductory remarks and as is obvious when reading through the tables, few data exist on the bird populations of the eastern Gulf of Mexico. Exceptions are the Brown Pelican, being studied by Schreiber and Williams, and Sooty and Brown Noddy Tern being studied by Robertson (see Bibliography). Perhaps the current best source of quantitative data is the Christmas Bird Counts organized by National Audubon Society and published in *American Birds*. Problems exist with the interpretation of these data, which are gathered annually by thousands of individuals most of whom are amateur bird watchers. Recently the editor of *American Birds*, R.S. Arbib, Jr. (1972) wrote:

TABLE C-23

GULF COAST MARINE BIRDS

Common Name	Scientific Name	Panhandle	Peninsula	Coot Bay	Keys	Total
Common Loon	Gavia immer	12	1	t	t	3
Horned Grebe	Podiceps auritus	17	1	3	2	5
Wilson Petrel	Oceanites oceanicus	0	0	0	0	0
White Pelican	Pelecanus erythrorhynchos	t	3	142	2	25
Brown Pelican	Pelecanus occidentalis	t	52	37	54	39
Gannet	Morus bassanus	t	0	0	t	t
Double-Crested Cormorant	Phalacrocorax auritus	40	63	98	121	71
Magnificent Frigatebird	Fregata magnificens	0	1	t	6	1
Great White Heron	Ardea occidentalis	0	t	19	12	5
Great Blue Heron	Ardea herodias	5	8	26	6	10
Green Heron	Butorides virescens	t	1	13	2	3
Little Blue Heron	Florida caerulea	5	14	54	14	19
Reddish Egret	Dichromanassa rufescens	0	t	2	3	1
Common Egret	Casmerodius albus	13	15	129	9	32
Snowy Egret	Leucophoyx thula	2	14	132	7	29
Louisiana Heron	Hydranassa tricolor	4	7	40	14	13
Black-crowned Night Heron	Nycticorax nycticorax	1	1	7	t	2
Yellow-crowned Night Heron	Nyctanassa violacea	t	4	3	3	3
Wood Stork	Mycteria americana	t	5	65	1	13
White Ibis	Eudocimus albus	3	34	267	11	62
Roseate Spoonbill	Ajaia ajaja	0	t	19	8	4
Canada Goose	Branta canadensis	114	t	0	0	25
Mallard	Anas platyrhynchos	26	1	t	0	6
Black Duck	Anas rubripes	4	t	0	0	1
Mottled Duck	Anas fulvigula	0	3	7	t	2
Gadwall	Anas strepera	9	1	t	0	3
Pintail	Anas acuta	28	8	170	t	38
Green-winged Teal	Anas carolinensis	4	3	81	1	15
American Widgeon	Mareca americana	49	7	45	1	21
Shoveler	Spatula clypeata	3	1	44	t	8
Redhead	Aythya americana	88	t	t	0	19
Canvasback	Aythya valisineria	2	t	t	0	1
Lesser Scaup	Aythya affinis	203	185	175	t	163
Common Goldeneye	Bucephala clangula	9	t	0	0	2
Bufflehead	Bucephala albeola	26	t	t	0	5
Ruddy Duck	Oxyura jamaicensis	3	t	43	0	8
Red-breasted Merganser	Mergus serrator	26	27	30	33	28
Bald Eagle	Haliaeetus leucocephalus	t	1	2	1	1
Osprey	Pandion haliaetus	t	1	7	5	2
Clapper Rail	Rallus longirostris	1	t	1	1	1
Sora	Porzana carolina	1	t	t	t	t
American Coot	Fulica americana	159	32	241	3	89

TABLE C-23 Continued

Common Name	Scientific Name	Panhandle	Peninsula	Coot Bay	Keys	Total
American Oystercatcher	Haematopus palliatus	t	1	0	0	1
Semipalmated Plover	Charadrius semipalmatus	1	7	10	19	8
Piping Plover	Charadrius melodus	1	1	t	2	1
Snowy Plover	Charadrius alexandrinus	t	1	5	0	t
Wilson Plover	Charadrius wilsonia	t	4	2	6	3
Black-bellied Plover	Squatarola squatarola	7	13	29	42	18
Ruddy Turnstone	Arenaria interpres	2	8	6	24	9
Willet	Catoptrophorus semipalmatus	11	11	45	6	16
Greater Yellowlegs	Totanus melanoleucus	1	1	8	5	3
Lesser Yellowlegs	Totanus flavipes	t	26	1	4	13
White-rumped Sandpiper	Erolia fusiocollis	0	0	0	0	0
Least Sandpiper	Erolia minutilla	2	6	115	35	26
Dunlin	Erolia alpina	59	49	211	37	76
Short-billed Dowitcher	Limodromus griseus	5	11	54	134	33
Semipalmated Sandpiper	Ereunetes pusillus	12	18	153	54	43
Western Sandpiper	Ereunetes mauri	1	6	62	21	59
Marbled Godwit	Limosa fedoa	1	1	7	t	2
Sanderling	Crocethia alba	10	26	1	12	17
American Avocet	Recurvirostra americana	t	t	8	t	1
Black-necked Stilt	Himantopus mexicanus	0	t	t	t	t
Parasitic Jaeger	Stercorarius parasiticus	t	0	t	t	t
Herring Gull	Larus argentatus	39	35	3	15	28
Ring-billed Gull	Larus delawarensis	76	316	38	74	183
Laungning Gull	Larus atricilia	15	104	92	132	86
Bonaparte Gull	Larus philadelphia	19	1	t	1	5
Gull-billed Tern	Celochelidon nilotica	t	1	1	t	t
Forster Tern	Sterna forsteri	10	8	5	7	8
Roseate Tern	Sterna dougallii	0	t	t	1	t
Sooty Tern	Sterna fuscata	0	0	0	t	0
Least Tern	Sterna albifrons	t	t	0	0	t
Royal Tern	Thalasseus maximus	3	29	12	56	24
Sandwich Tern	Thalasseus sandvicensis	t	5	1	4	3
Caspian Tern	Hydroprongne caspia	t	1	7	2	2
Black Tern	Chidonias niger	0	0	0	0	0
Brown Noddy	Anous stolidus	0	0	0	0	0
Black Skimmer	Rynchops nigre	3	41	161	28	50
Mangrove Cuckoo	Coccyzus minor	0	t	t	t	t
Seaside Sparrow	Amonspiza maritima	2	t	t	0	t

Number of individuals per 10 party hours based on Christmas Bird Count Data, 1957-1971, from 19 selected localities grouped in four regions, and for all counts combined (t = trace, less than 0.5 individuals; lines separate the families)

TABLE C-24

INDICES OF ABUNDANCE FOR MARINE BIRDS

	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Common Loon	6	8	2	2	2	2	2	2	3	4	2	1	3	3	3
Horned Grebe	11	8	4	4	4	4	2	3	4	5	6	4	7	5	8
Wilson Petrel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White Pelican	5	12	43	32	16	24	30	41	40	26	21	23	18	14	20
Brown Pelican	27	24	40	22	23	51	32	32	50	28	40	35	48	36	61
Gannet	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t
Double-created Cormorant	49	60	64	45	53	75	65	97	78	75	70	48	83	88	59
Magnificent Frigatebird	t	1	1	2	2	1	t	1	t	t	1	1	2	3	5
Great White Heron	7	8	9	3	4	3	5	5	5	4	5	4	4	3	4
Great Blue Heron	6	9	13	11	12	12	10	11	10	8	11	8	9	11	12
Green Heron	9	2	4	6	1	3	4	2	3	3	3	4	4	3	3
Little Blue Heron	15	19	14	24	19	20	14	14	25	23	20	17	19	18	18
Reddish Egret	t	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Common Egret	22	43	36	39	20	30	21	20	61	53	30	26	27	20	28
Snowy Egret	16	53	41	36	10	39	17	20	80	40	23	15	20	23	19
Louisiana Heron	9	19	14	17	12	15	10	10	18	20	12	7	10	12	10
Block-crowned Night Heron	2	2	3	3	1	2	1	2	3	2	2	2	2	1	1
Yellow-crowned Night Heron	1	2	2	1	3	3	3	2	3	3	3	3	3	2	3
Wood Stork	122	12	14	24	7	14	16	14	34	8	12	11	15	3	5
White Ibis	29	45	54	40	27	59	59	37	104	25	77	153	93	49	53
Roseate Spoonbill	t	2	6	7	3	4	4	5	5	5	6	4	4	3	3
Canada Goose	111	154	23	29	37	55	22	7	13	11	9	10	3	7	3
Mallard	1	13	2	2	2	8	15	1	5	10	3	9	10	5	3
Black Duck	1	1	1	1	3	1	1	t	t	1	1	2	1	1	1
Mottled Duck	t	3	3	4	2	3	2	2	3	3	3	2	3	2	2
Gadwall	3	7	1	2	3	2	2	2	2	1	1	7	6	2	1
Pintail	7	14	41	16	8	31	38	20	23	55	65	51	85	46	32
Green-winged Teal	1	2	6	2	2	4	17	5	4	24	72	31	27	12	2
American Widgeon	6	15	11	4	6	8	36	14	22	25	32	43	51	14	14
Shoveler	1	1	4	9	1	9	9	11	13	15	10	9	10	9	3
Redhead	47	16	30	6	9	50	12	4	4	25	21	11	22	13	24
Canvasback	t	1	t	1	t	t	t	t	t	1	1	1	1	1	t
Lesser Scaup +	228	556	199	59	200	95	318	120	58	140	337	105	349	125	189
Common Goldeneye	0	2	1	1	1	1	8	2	2	1	t	2	2	3	1
Bufflehead	5	5	11	2	7	4	5	5	11	4	2	7	4	7	7
Red-breasted Merganser	17	23	25	32	32	19	25	24	25	63	34	24	23	24	21

The 81 common birds of saline habitats of the eastern Gulf of Mexico based on birds per 10 party hours for each year, 1957-1971, for all the selected Christmas Bird Counts combined. Coexisting, difficult to-identify sibling species occur for the four birds marked with pluses, and some of the individuals included under these names no doubt actually are misidentified. (Lines separate the avian families; t = trace, less than 0.5 individuals)

TABLE C-24 (Continued)

	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Ruddy Duck	9	2	2	17	2	5	4	10	1	17	2	7	12	t	21
Bald Eagle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Osprey	9	2	2	2	1	2	2	3	3	2	3	2	3	2	3
Clapper Rail	1	1	1	t	1	1	1	t	1	t	1	1	1	1	5
Sora	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t
American Coot	47	45	54	56	25	38	47	42	36	118	86	133	219	82	205
American Oystercatcher	8	t	t	t	t	t	1	1	1	1	1	t	2	1	1
Semipalmated Plover	2	13	6	5	7	6	10	8	11	7	6	6	12	6	7
Piping Plover	1	1	1	1	1	t	1	1	1	t	1	t	1	1	t
Snowy Plover	t	t	t	t	t	1	1	t	1	t	t	t	t	t	t
Wilson Plover	2	3	2	2	2	3	4	3	4	4	3	2	4	3	3
Black-bellied Plover	20	19	21	18	13	16	12	21	22	19	25	16	17	14	18
Ruddy Turnstone	9	11	10	9	6	10	8	10	9	8	9	5	9	8	10
Willet	20	72	20	17	10	8	11	15	12	10	9	19	19	12	16
Greater Yellowlegs	2	3	2	2	2	3	2	6	2	2	5	4	2	2	1
Lesser Yellowlegs	1	1	1	1	1	2	2	2	3	6	4	4	5	2	2
Knot	4	20	3	11	1	4	32	7	3	16	3	5	38	10	23
White-rumped Sandpiper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Least Sandpiper	62	24	24	14	17	24	30	30	22	32	28	26	25	16	21
Dunlin	80	71	88	97	33	66	50	120	130	50	72	54	98	64	67
Short-billed Dowitcher +	24	32	34	21	17	49	36	41	31	33	36	19	51	28	32
Semipalmated Sandpiper +	96	38	32	37	18	25	40	52	38	45	60	59	31	30	39
Western Sandpiper	49	22	24	21	3	9	16	16	5	15	28	16	9	14	8
Marbled Godwit	1	t	1	3	1	1	2	2	2	1	1	3	1	2	2
Sanderling	9	16	10	13	20	18	18	15	23	18	17	10	21	13	26
American Avocet	0	t	1	2	t	t	t	t	1	2	4	3	3	2	t
Black-necked Stilt	t	0	0	t	0	0	t	t	t	t	t	0	0	0	t
Parasitic Jaeger	0	t	0	0	t	t	0	0	0	0	0	0	0	t	0
Herring Gull	56	32	36	58	28	37	30	23	35	16	29	12	17	21	20
Ring-billed Gull	219	317	253	434	322	213	225	199	246	136	144	90	83	85	93
Laughing Gull	59	57	59	80	61	149	88	63	80	55	77	74	128	76	154
Bonaparte Gull	2	11	1	2	5	7	4	8	3	4	4	6	2	7	6
Gull-billed Tern	1	t	t	t	0	t	t	t	t	t	t	0	0	0	1
Forster Tern +	24	11	9	7	6	11	8	11	8	6	7	4	10	8	14
Roseate Tern	t	0	t	0	0	0	0	0	t	0	0	0	0	0	0
Sooty Tern	0	0	0	t	0	0	0	0	0	0	0	0	0	0	0
Least Tern	0	0	0	0	0	0	0	t	0	0	t	0	0	0	0
Royal Tern	30	29	24	31	31	22	26	21	32	22	24	13	16	20	32
Sandwich Tern	t	2	1	t	2	4	2	1	3	1	1	1	1	2	19
Caspian Tern	4	2	3	2	1	2	2	2	2	2	1	1	5	1	2
Black Tern	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brown Noddy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black Skimmer	29	73	54	64	34	54	58	37	62	43	64	49	62	35	47
Mangrove Cuckoo	0	0	t	0	t	0	t	t	t	t	0	0	t	0	0
Seaside Sparrow	t	t	0	t	t	t	t	t	t	t	t	t	t	t	t

"The apparent increases in numbers of species and individuals on the Christmas Bird Count, have, in most cases, nothing to do with real population dynamics. They are the result of ever-increasing numbers of birders in the field, better access to the Count areas, better knowledge of where to find the birds within each area, and increasing sophistication in identification.

"With increased local coverage by the press of Christmas Bird Count activities, it is important that Count spokesmen reiterate the simple and truthful fact that what we are seeing is result of not more birds, but more birders. Any time you hear a scientist say the opposite, you are in the presence of someone who is being paid to lie, or is parroting something he knows little about."

To reduce the effect of some variables, we have used the procedure adopted by those producing the early winter range maps that appear in *American Birds*. With this method the number of individuals of each species recorded on each count is divided by the number of party hours x 0.1. To further reduce variation from one region (defined below) to another we combine the results of several counts. The one exception to this last step is the southern tip of the peninsula, represented only by the Coot Bay count. We deem this region distinct enough from the other three to be considered alone. Fortunately, the Coot Bay Count has consistently been of extremely high quality.

For virtually every species recorded on the counts more individuals exist in the area than are seen; therefore, the resulting figures are not total counts, but indices. It is the number of birds recorded per unit time. As the same formula is used for each group of counts, the indices should be roughly comparable. Unfortunately, it also is true that not all individuals recorded were in saline habitats. This especially is true of the Coot Bay counts. We found no way to eliminate this problem.

The 17 Christmas Bird Counts used in our analyses are plotted as circles in Figure C-9. The names of these counts are followed by the number of years analyzed (1957-1971 inclusive). The original data are in *Audubon Field Notes*, 12-24 (number 2 each year), 1958-1970, and its successor *American Birds*, 25-26 (2), 1971-1972. In Figure C-9 the three heavy lines separate the 17 counts into four regions. From north to south the names given these regions, and the number of count areas included are Panhandle, 4; peninsula, 8; Coot Bay, 1; and Keys, 4.

This report pertains to birds of saline habitats, but we suspect these birds are more affected by aerial than aquatic physical factors; therefore our four regions correspond to terrestrial life zones as shown in Howell (1932, map facing p. 66), and not the marine life zones of the Gulf.

The preceding portion of this report on marine birds represents excerpts from an article, "The Common Birds of the Saline Habitats of the Eastern Gulf of Mexico: Their Distribution, Seasonal Status, and Feeding Ecology," initially prepared by Dr. Glen E. Woolfenden and Mr. Ralph W. Schreiber, University of South Florida, as part of the API report referred to previously.

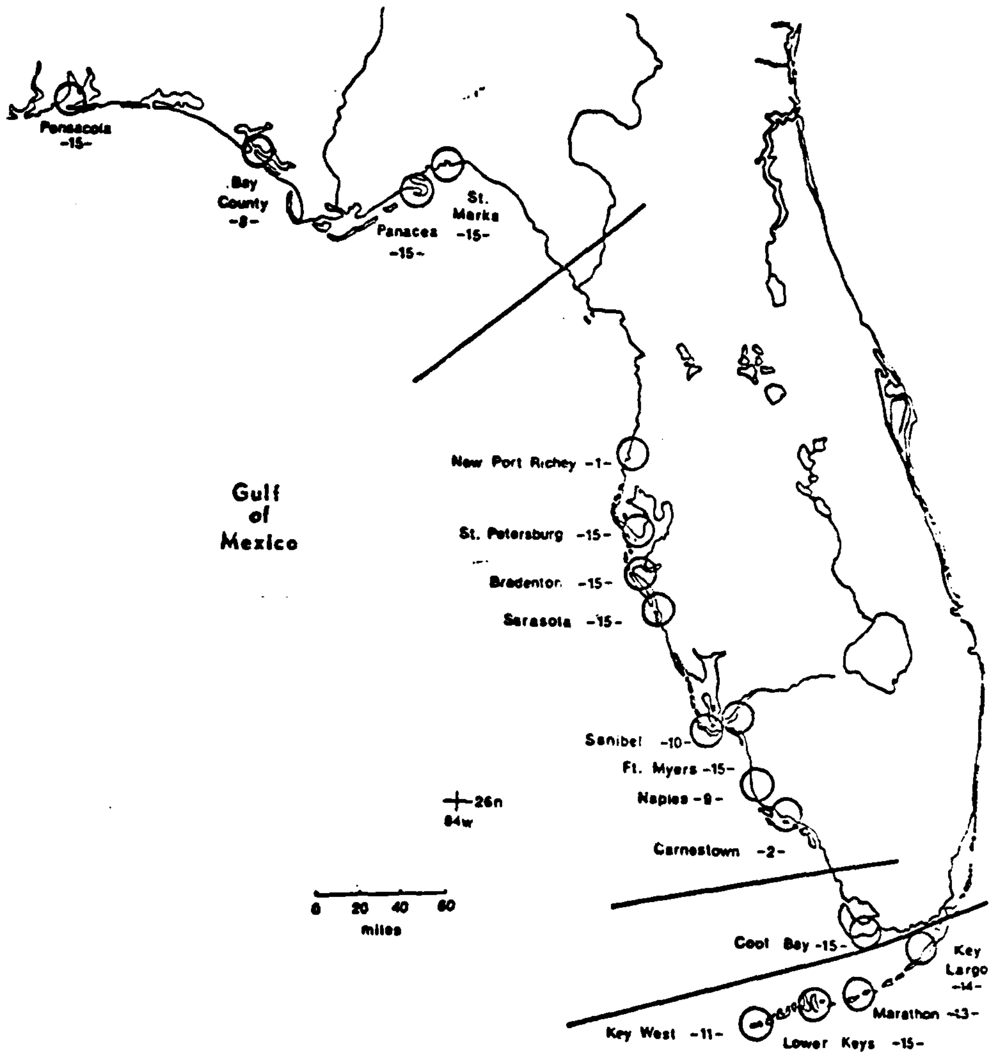

FIGURE C–9 CHRISTMAS BIRD COUNTS

7. Rare and Endangered Species

Table C-25 lists the prominent species of rare and endangered wildlife that occur or have occurred in Florida and the eastern Gulf of Mexico. The table is compiled from the Federal Government list. A complete list of endangered American wildlife, which is periodically revised, is available from the U.S. Fish and Wildlife Service.

TABLE C-25

ENDANGERED SPECIES OF FLORIDA

Mammals	
Black Right Whale	(Balaena glacialis)
Sei Whale	(Balaenoptera borealis)
Sperm Whale	(Physeter catodon)
Humpback Whale	(Megaptera novaeangliae)
Fin Whale	(Balaenoptera physalus)
Manatee or Sea Cow	(Trichechus manatus)
Caribbean Monk Seal	(Monachus tropicalis)
Florida Panther	(Felis concolor coryi)
Key Deer	(Odocoileus virginianus clavium)
Birds	
Great White Heron	(Ardea o. occidentalis)
Eastern Brown Pelican	(Pelecanus occidentalis carolinensis)
Everglade Kite	(Rostrhamus sociabilis plumbeus)
Southern Bald Eagle	(Haliaeeters l. leucocephalus)
American Osprey	(Pandion haliaetus carolinensis)
Florida Sandhill Crane	(Grus canadensis pratensis)
Ivory Billed Woodpecker	(Campephilus p. principalis)
Dusky Seaside Sparrow	(Ammospiza nigrescrens)
Cape Sable Sparrow	(Ammospiza mirabilis)
Reptiles	
American Alligator	(Alligator mississippiensis)
American Crocodile	(Crocodylus acutus)
Fish	
Atlantic Sturgeon	(Acipenser oxyrhynchus)

Except for the listed whales, which are discussed in more detail under marine mammals, the endangered species are found in the nearshore, bays, lagoons, and estuarine regions or further inland.

There has not been a confirmed sighting of the Caribbean Monk Seal or the Ivory Billed Woodpecker in several years and many consider them to be extinct. The Everglades Kite, among the rarest birds in the United States, along with the Florida Sandhill Crane are associated with the freshwater marsh areas and thus would probably be disturbed by secondary efforts of deep water port development rather than the primary development activity. The Dusky Seaside Sparrow are known only on Merritt Island off the east coast of Florida and thus not of concern on this effort.

Florida is considered to be the predominent producer of the Southern Bald Eagle for continental United States. In 1962, Florida contained approximately half of the active nests and 14% of all eagles tallied. The Everglades National Park, with about 50 pairs of eagles, is perhaps the only place in the country outside of Alaska where bald eagles are managing to maintain their numbers. *South Florida (Zone VIII) is also the main habitat of the Key Deer (restricted to the Florida Keys), the American Osprey, the Great White Heron, the Cape Sable Sparrow and the American Crocodile.*

The Eastern Brown Pelican are found predominently in the nearshore and estuary areas of peninsular Florida (Zones VI-VIII and XVII-XIX).

The Florida Sea Cow is now restricted to the estuarine and inland areas of peninsular Florida but it is considered that the population may now be stabilized. The American Alligator may be found in the less developed estuarine areas of the entire Florida Gulf coast with decreasing frequency from the southeast to the northwest. The Florida panther once roamed throughout the southeastern portion of the United States. Today its range has shrunk to the most remote sections of a few Florida counties frequently within the Florida Gulf coastal zone. The Atlantic Sturgeon range includes the northern Gulf coast.

C. MAN'S ACTIVITIES

Analysis of developments having or possibly having a major impact on the Florida coastal zone will benefit from inclusion of the information contained within publications of the Florida Coastal Coordinating Council. The Council, which was created by the 1970 Florida Legislature, unites in one body the directors of the four state departments with the primary concern for the coastal environment, namely, the Department of Natural Resources, Department of Pollution Control, the Trustees of the Internal Improvement Trust Fund, and the Department of Administration (State Planning). The Executive Director of the Department of Natural Resources serves as chairman. The Council, which has its own staff, has four primary assignments: (1) develop a comprehensive coastal zone management plan for Florida, (2) coordinate state coastal zone research, (3) coordinate federal, state and local agencies with responsibilities in the coastal zone, and (4) act as a clearinghouse for coastal zone information.

The *Florida Coastal Zone Management Atlas*, published by the Council in December 1972, combines and delimits in one document a great deal of the available information on areas of critical environmental concern as well as areas now developed by man and the potential of vacant land for development.

Basically, the referenced Atlas classifies the Florida coastal region into three categories or zones of concern which reflect natural suitability for development and present use. These zones are:

Preservation	– no development suitable
Conservation	– carefully controlled development suitable
Development	– intensive development suitable

Eight basic factors are considered before including any given area A category:

1. Ecological significance of the area and its tolerance to alteration.
2. Water classification of adjacent water bodies.
3. Soil suitability of the area.
4. Susceptibility of the area to flooding, both from storm surge and runoff.
5. Archaeological and historical significance of the area.
6. Unique environmental features that may warrant protection.
7. Geological information, where available.
8. Present use of the area.

Each of the primary categories are divided into sub-categories (Table C-26): each of which are delimited on the Atlas maps. *It will be noted that many of these sub-categories are of specific concern to the analysis of deep water port development.* They also directly demonstrate and justify the division of the Florida coastal zone into the four hydro-biological dissimilar zones (V-VIII).

A second publication of the Florida coastal Coordinating Council that might be of assistance to analysis of deep water port development is *Florida Coastal Zone Land Use* and *Ownership*, November 1970. The Atlas delimits for each coastal county land ownership in the categories of federal, state, county, city and private ownership. The classifications and scope of land uses delimited in the Atlas are listed in Table C-27.

TABLE C-26

DELIMITED FLORIDA COASTAL ZONES

Subcategories

Preservation	Conservation	Development
Class I Waters	Class III Waters	Class IV Waters
Class II Waters	Aquatic Preserves	Class V Waters
Marine Grass Beds	Aquaculture Leases	Presently Developed Areas
Selected Coastal Marshes	Spoil Islands	Non-Conflict
Selected Coastal Mangroves	Scenic Vistas	Conflict
Selected Freshwater Swamps and Marshes	Forestry & Game Management Areas	Undeveloped Lands Suitable for Intensive Development with Corrections
Gulf & Atlantic Beaches and Dunes	Wildlife Refuges Parks & Recreation Areas	
Selected Estuarine Beaches		
Designated Wilderness Areas	River Flood Plains	Portions of Hurricane Flood Zone
Historical and Archaeological Sites	Marginal Lands	
Other Unique Environmental Features	Portions of Hurricane Flood Zone	
Portions of Hurricane		
Flood Zone		

Delimited Areas Contained in the Florida Coastal Zone Management Atlas, December 1972.

The *Florida Coastal Zone Management Atlas*, published by the Council in December 1972, combines and delimits in one document a great deal of the available information on areas of critical environmental concern as well as areas now developed by man and the potential of vacant land for development.

Basically, the referenced Atlas classifies the Florida coastal region into three categories or zones of concern which reflect natural suitability for development and present use. These zones are:

Preservation	– no development suitable
Conservation	– carefully controlled development suitable
Development	– intensive development suitable

Eight basic factors are considered before including any given area A category:

1. Ecological significance of the area and its tolerance to alteration.
2. Water classification of adjacent water bodies.
3. Soil suitability of the area.
4. Susceptibility of the area to flooding, both from storm surge and runoff.
5. Archaeological and historical significance of the area.
6. Unique environmental features that may warrant protection.
7. Geological information, where available.
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TABLE C-27

CLASSIFICATIONS OF DELIMITED LAND USE

Classification	
Agriculture	Includes cattle raising, citrus, mixed farming.
Residential	Includes single and multiple housing units and mobile home communities.
Industry and Power Generation	Mining, manufacturing, etc.
Business and Commerce	Includes retail and wholesale trade areas, banks and offices, but excludes tourism.
Transportation and Communication	Includes ports, airports, major railroad terminals, etc.
Recreation, Tourism, and Historical	Includes motels, parks, public attractions, and areas of cultural and historical interest.
Educational Institutions	Primarily colleges, universities, and their associated research laboratories.
Government	Includes all government activities except military bases, government owned parks and preserves.
Military	Includes Army, Navy, Air Force, but not NASA, DOD, or other government agencies.
Undeveloped	Includes preserves not used primarily for recreation, also timber land even though being selectively cut and subsequently replanted.

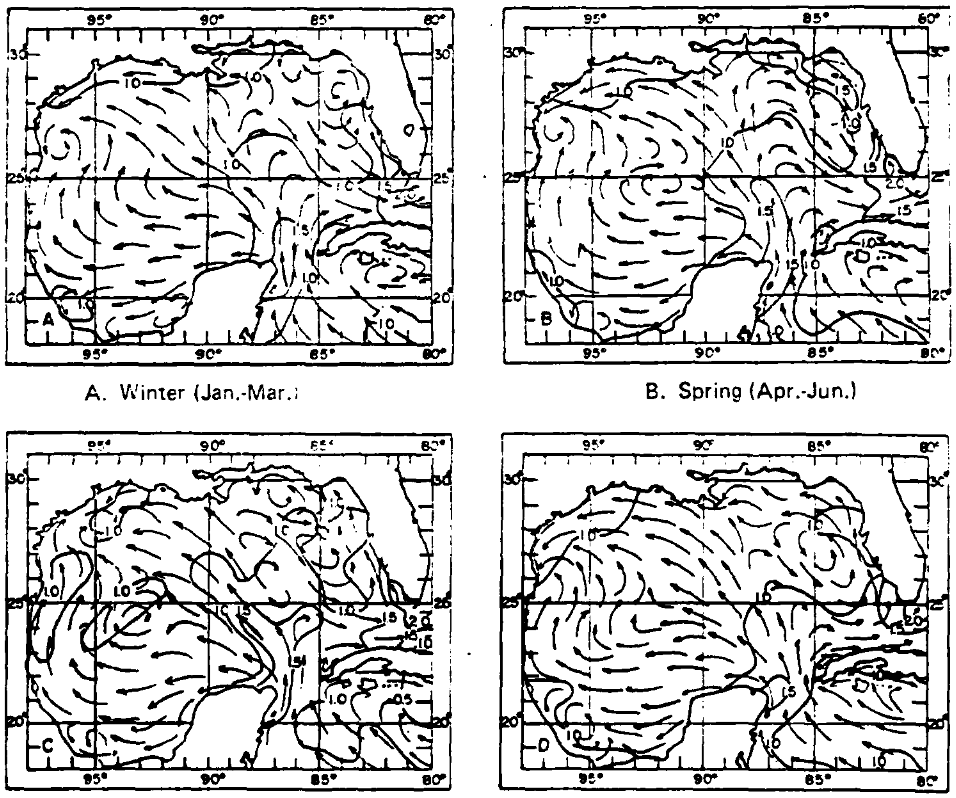
Delimited Areas of Land Use Contained in Florida Coastal Zone Land Use and Ownership, November 1970.

III. THE INTERMEDIATE SHELF

A. PHYSICAL CHARACTERISTICS

1. Hydrology

Except for gross generalities and studies limited to small selected areas, little has been published on the circulation patterns of the *Western Florida Shelf*. The published *current patterns*, based mainly on pilot chart data, *indicate a general northward drift of the current during most of the year* (Figure C-10a, b, c, and d). Leipper (1954) states that this current is produced by single and multiple cyclonic eddies in the shelf water which are driven by the Loop Current and modified by the winds.



A. Winter (Jan.-Mar.)

B. Spring (Apr.-Jun.)

C. Summer (Jul.-Sep.)

D. Fall (Oct.-Dec.)

Prevailing current isotachs were constructed from mean speed (knots) tabulated form data by 1° quadrangles. From Environmental Acoustics Atlas-August, 1972-U.S. Naval Oceanographic Office.

FIGURE C–10 PREVAILING SURFACE CURRENT PATTERNS

It is difficult to relate the circulation patterns of drogue and drift bottle results, which are all seasonal and yearly studies, with the circulation patterns shown in Figures C-10a, b, and c that show a predominant cyclonic flow on the shelf. It is obvious that the wind *current effects, small size eddy considerations, and the seasonal variations in the Loop Current will have to be understood in greater detail before a satisfactory picture can be determined in the shelf circulation.*

The important interface reactions, boundary conditions, and diffusion processes also have not been determined for the shelf waters. When the complete analyzation of the data gathered in the Western Continental Shelf Program is completed, an evaluation of the effects of both the fresh-water discharge and the Loop Current on the shelf environment might be possible.

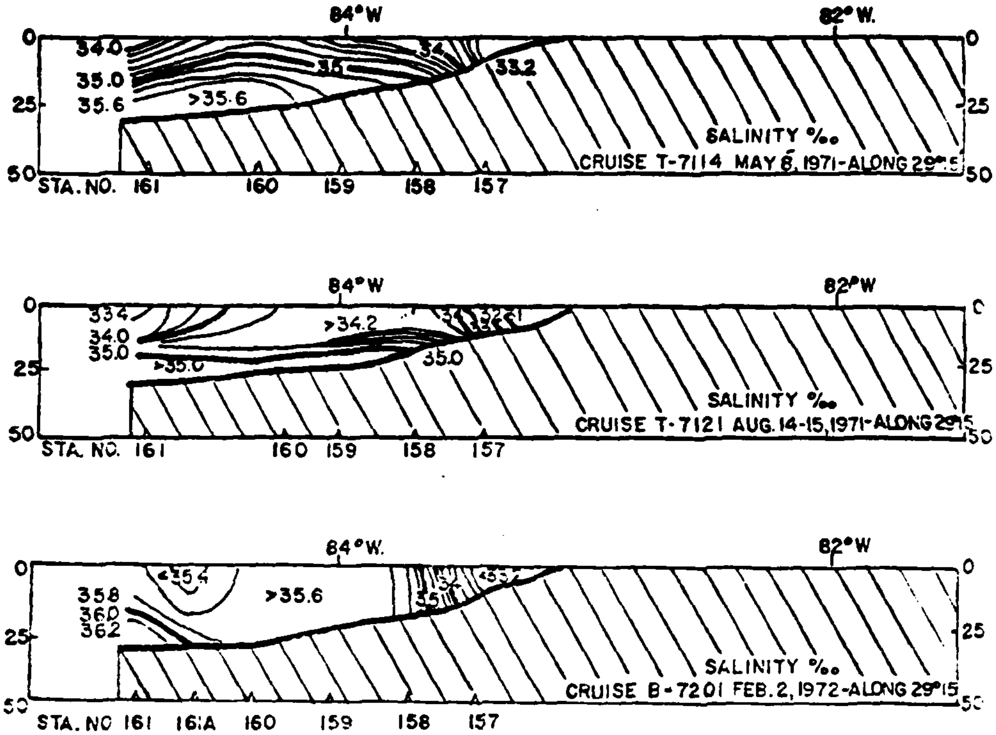
Examination of the 52 vertical sections indicates that from *Mobile Bay to the Straits of Florida the Western Continental Shelf can be divided into four areas, which have similar environmental features (temperature and salinity).* Cursory examination of the November cruises and the February cruise south of 27°N indicates that these divisions occurred throughout the seasonal study.

The *divisions agree remarkably well with the geological, bottom fauna, and bottom plant regimes* as documented in other sections of this report. These areas can be defined by a line drawn from the Cape San Blas-Cape St. George area southward to 28°N (Zone XVI) and between the Clearwater-Tampa Bay area westward to the outer edge of the continental slope (Zone XVII) and from the Cape Romano area westward to the edge of the Continental Shelf (Zones XXIV and XVIII) and Cape Romano southward to the Straits of Florida (Zones XIX and XXIV).

While the distribution of temperature within each area is similar, it is easier to infer the currents from the salinity distribution because of the salinity values associated with the Loop Current and eastern Gulf waters.

Figures C-11 to C-14 are selected vertical salinity sections which are representative of the features of each area. Figure C-11 is a composite of salinity sections from the May and August 1971, and February 1972, cruises within the area defined by a line running south from Cape San Blas-Cape St. George and west from the Clearwater-Tampa Bay (Zone XVII). Unlike the zones to the west and south, this is a *remarkably simple pattern in which interface reactions are occurring near the shore from the runoff and the eddy structures* occurring along the line westward from Cape St. George. This is the area in which an insignificantly small number of drift bottle recoveries were recorded from the 28-month studies at Panama City and the Hourglass cruises.

Figure C-12 is representative of the structure between the Clearwater-Tampa Bay area and Cape Romano (Zone XVIII and the northern part of Zone XXIV). To present as much information as possible, a section along 27°N in June has been inserted with data collected in May, August, and February along 27°15'N. This is the area in which a distinct seasonal pattern occurred in the drift bottle releases from the Hourglass cruises. It is possible in the May and August data to actually

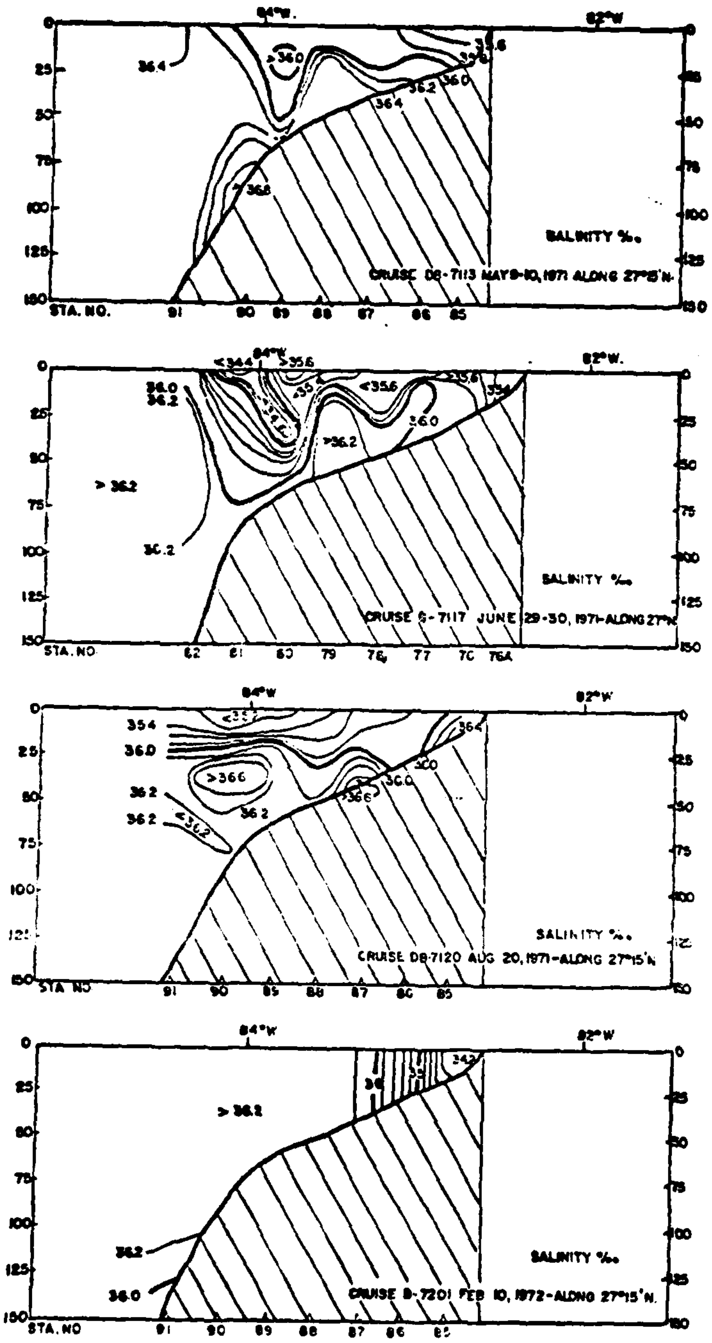


R/V TURSIOPS T-7114, May, 1971, R/V TURSIOPS T-7121, August, 1971, and R/V BELLOWS B-7201, February, 1972. Depth in meters. Hashed area represents ocean bottom. Contour interval 0.20 °/oo unless compression is too great.

FIGURE C-11 VERTICAL SALINITY SECTIONS ALONG 29°15'N

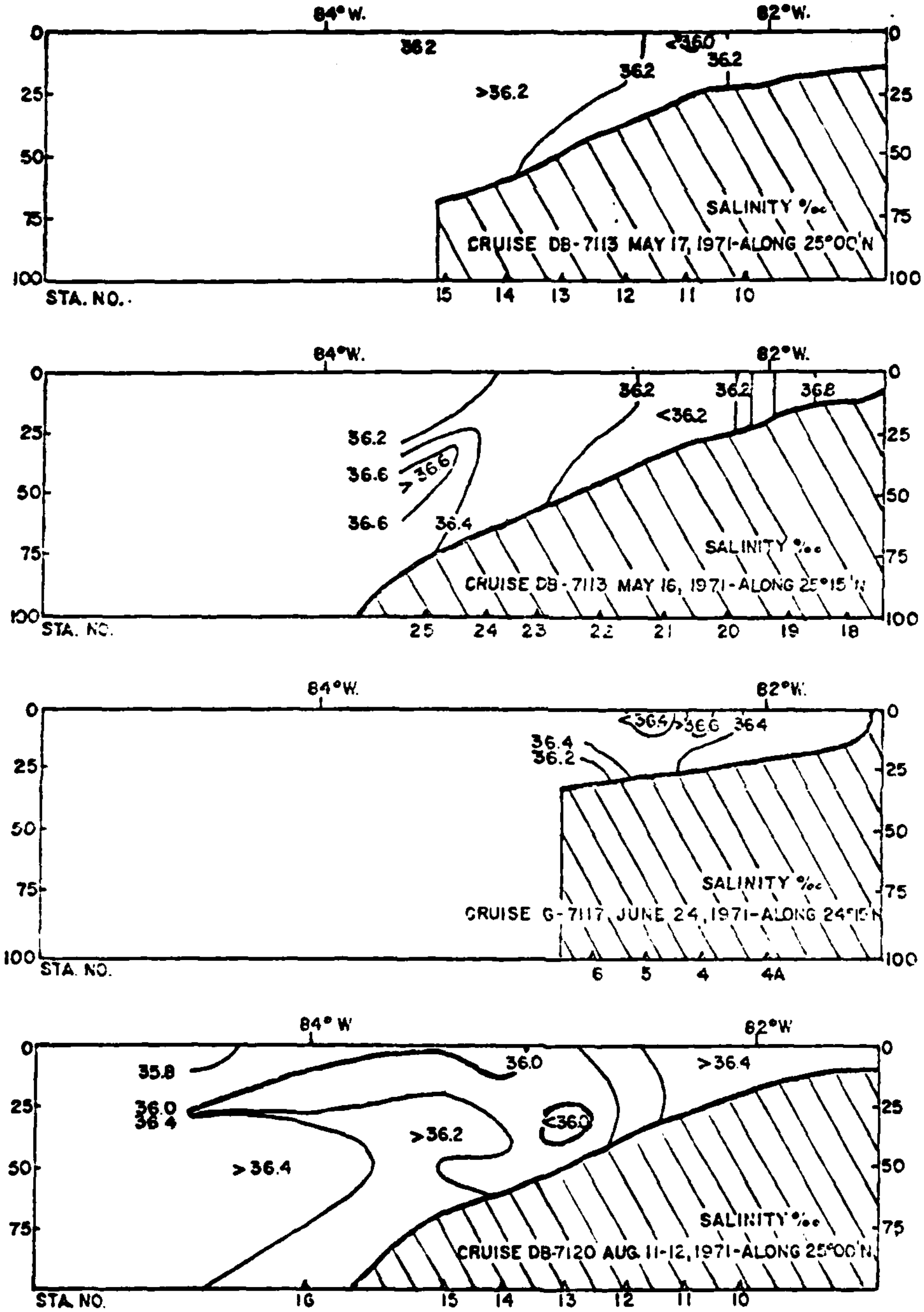
track rings of Loop Current and Loop Transition Waters (Figure C-14) entering at the shelf at 28°N and exiting between 25°30' and 26°N. These rings are very similar to those noted in the microstructure of the Gulf Stream and are on the order of 20 to 40 miles in width. *The entire area is extremely complex with rings or cells of salinity distributions, which indicate interface reactions between the Loop Current and shelf waters.* The May, June, and August sections indicate the presence of an anti-cyclonic circulation pattern. The complexity of the structures means that the forcing of the surface circulation is a combination of wind stress and the Loop Current. The progression of the Loop Current northward during the spring and summer of 1965-66 agrees very well with the drift bottle data. Predictions of current flow within this area are going to be difficult unless a complete understanding of the forcing factors of the Loop Current are understood.

Figure C-13 is representative of the distribution between Cape Romano and the Straits of Florida (Southern part of Zone XXIV and Zone XIX). Again additional sections have been added at 25°14'N and 24°15'N to illustrate the circulation



R/V DAN BRAMAN DB-7113 along 27°00'N, May, 1971, R/V DAN BRAMAN DB-7120, along 27°15'N, August, 1971, and R/V BELLOWS B-7201, aong 27°15'N, February, 1972. Hashed area represents ocean bottom. Contour interval 0.20 °/oo.

FIGURE C–12 VERTICAL SALINITY SECTIONS ALONG 27°00'N



R/V DAN BRAMAN DB-7113, May, 1971, along 25°00'N and 25°15'N, R/V GERDA G-7117, June, 1971, along 24°15'N, and R/V DAN BRAMAN DB-7120, August, 1971, along 25°00'N. Hashed area represents ocean bottom. Contour interval 0.20 ‰.

FIGURE C–13 VERTICAL SALINITY SECTIONS ALONG 25°00' N

features associated with the May and August data along 25°N. *The influences of the major discharge from the Everglades drainage area are indicated by the isohaline structure observed in the shore area. An indication of its east-westward movement can be seen.* On the continental shelf slope appears Loop-Transition water (May and August). This salinity distribution agrees with the three years of current data taken by the drogues.

The final area is represented by Figure C-14. The complex eddy structure within the northeast shelf (Zone XVI) can be seen from two sections of the August Cruise. On the section 87°08'W the pockets of low salinity water near the surface can be identified as Mississippi Delta water, and based on data from ESCAROSA I in September, Mobile Bay water. The appearance of Loop Current water can be noted at a depth of approximately 50 meters. Inter-comparison of these sections with the horizontal surface *distribution of salinity illustrated in Figure C-15 shows that an extremely complex eddy system can be present within the area.* The presence of such eddy structures within the area can explain the distribution of the drift bottles in westerly, southerly, and southeasterly directions from the 28-month drift bottle survey at Panama City.

The results shown here indicate the importance of a complete understanding of the relation between the Loop Current and the shelf circulation. It is too early to determine the exact details of the inter-reactions, and these data are presented to graphically illustrate the magnitude of the problem. The fact that the May and August operations were conducted in conjunction with major EGMEX studies might allow a better understanding in the future of the circulation structure on the shelf.

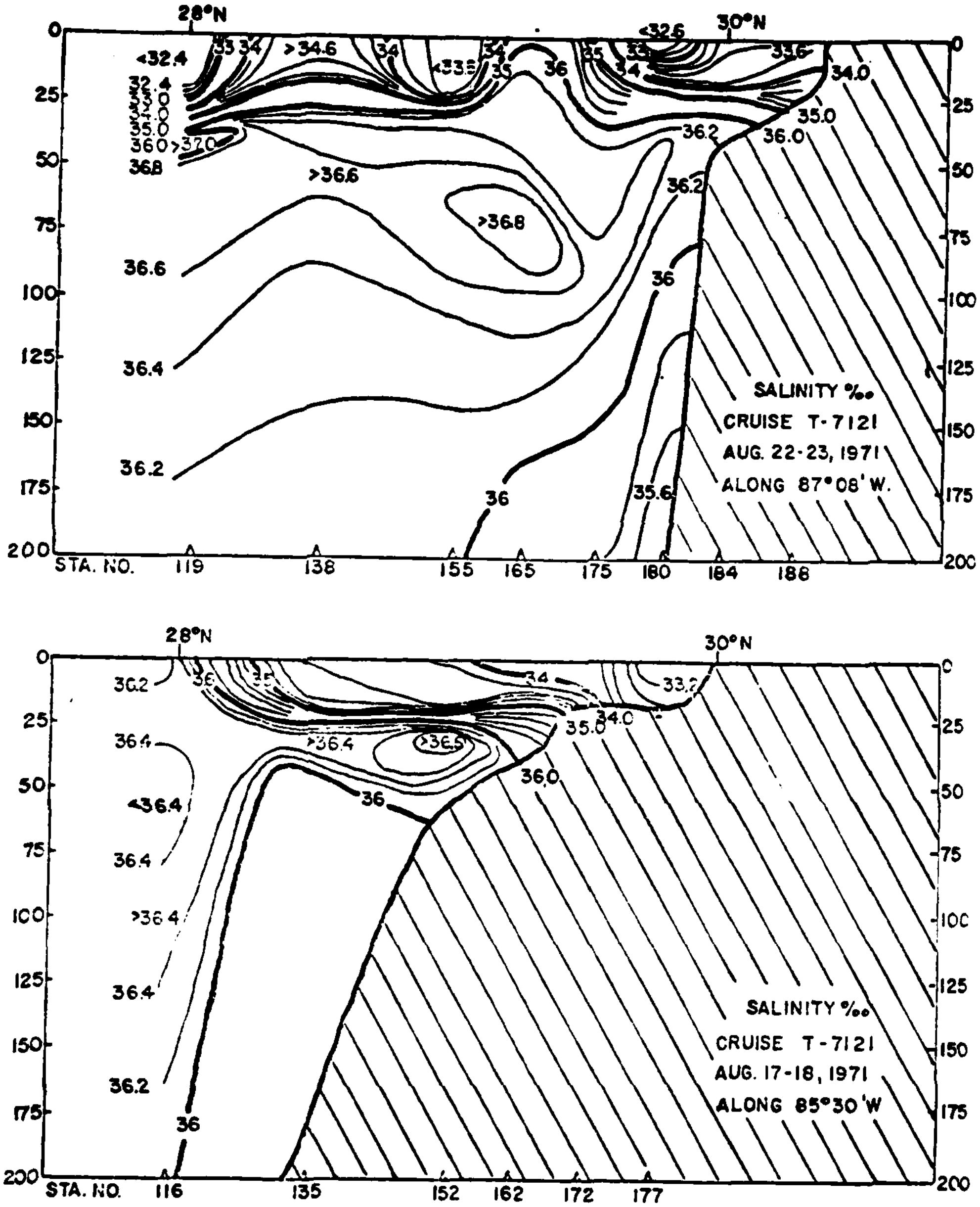
2. Chemistry

Chemical aspects of the Intermediate Shelf Region are directly related to and affected by the chemistry of the Oceanic Gulf; rather than attempt to differentiate between the two, the discussion is covered in Section IV, The Oceanic Gulf.

B. RESIDENT AND TRANSIENT MARINE BIOTA

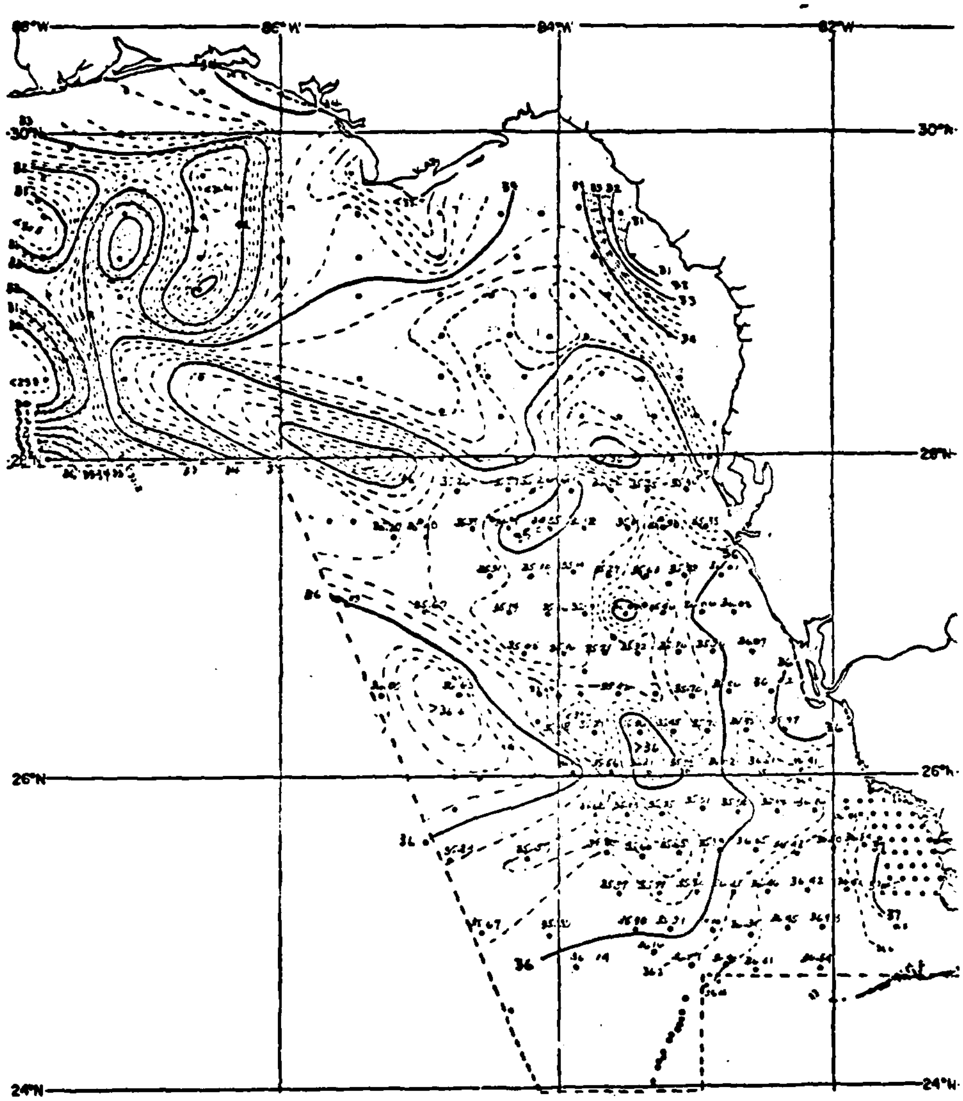
1. Plankton

It was earlier stated that in many coastal areas there is a reduction in primary production and/or standing crop from the estuary head to the mouth. This reduction of primary production continues seaward so that *the coastal region is generally the most fertile, followed by the Intermediate Shelf region and finally the open oceanic Gulf* (Tables C-12 and C-28). *The seaward progression of reduced primary production is accompanied by greater species diversity* (Thomas and Simmons, 1960; Saunders and Glenn, 1969; Steidinger and Williams, 1970).



R/V TURSIOPS T-7121, August, 1971, along 87°08'W and 85°30'W. Hashed area represents ocean bottom. Contour interval 0.20 °/oo unless compression is too great.

FIGURE C–14 VERTICAL SALINITY SECTIONS ALONG 87°W AND 85°30'W



(August, 1971; surface salinities)

FIGURE C–15 WESTERN FLORIDA CONTINENTAL SHELF PROGRAM

TABLE C-28

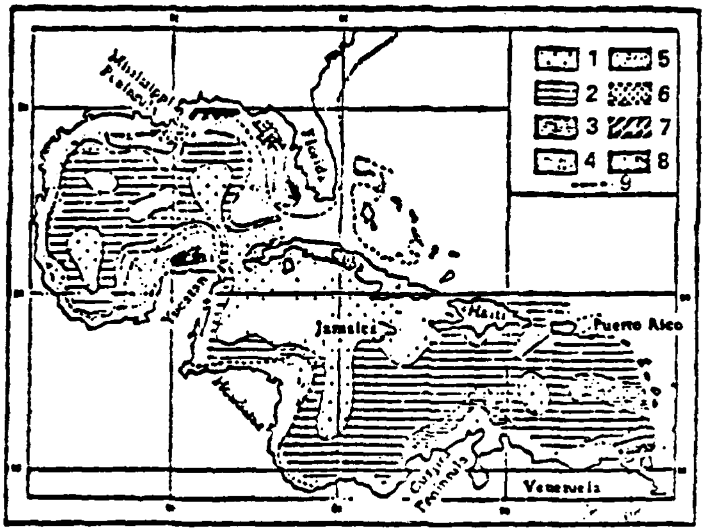
YEARLY COMPUTATION OF PRIMARY PRODUCTION
(Grams carbon/m^2/yr)

Location	Method	Gross	Net	In-between or Unspecified	Reference*
North Carolina estuaries	O_2	99.6	52.5		1
Denmark estuaries	^{14}C			58 (6-105)	1
Denmark estuaries	O_2	39-175			1
Tampa Bay complex	O_2	401			2
Off Long Island	^{14}C			165	1
Continental Shelf					
Long Island Slope	^{14}C			120	
Long Island Sound	O_2	380	170		1
Sargasso Sea	^{14}C			72	
Caribbean Sea	?			20	3
Western Central Atlantic	?			5-100	3
Gulf of Mexico	^{14}C			27	3

*1) Williams, 1966; 2)Sykes, 1969; 3)El-Sayed (in press).

Bogdanov *et al.* (1969) have *identified three areas of high productivity on the eastern shelf (Figure C-16): 1) east of Mississippi River mouth, 2) northern part of the Florida shelf, and 3) southwestern section of the Florida shelf.* Areas 1 and 2 are directly influenced by river run-off, principally that from the Mississippi River. Nutrient-rich run-off from the Mississippi peaks in the spring and fall. Also, the northern part of the shelf during winter is exposed to cold winds and relatively cool coastal drainage which facilitate mixing with nutrient-rich deep waters. Standing crop in these waters reflects these strong seasonal influences (Figures C-17a and C-17b), with highest zooplankton biomass occurring in fall and winter. According to Bogdanov *et al.* (1969) area 3, the southwest Florida shelf, is minimally influenced by run-off or winter mixing. Instead, waters over this section of the shelf are enriched by Loop Current-generated upwelling in summer, which results in the annual biomass peak occurring in this season rather than in winter (Figure C-17c).

Annual ranges of biomass for the three shelf regions (Khromov, 1964; Bogdanov, *et al.*, 1969) are 0.3 to 1.0 ml/m^3 for areas 1 and 2 and 0.3 to 0.6 ml/m^3

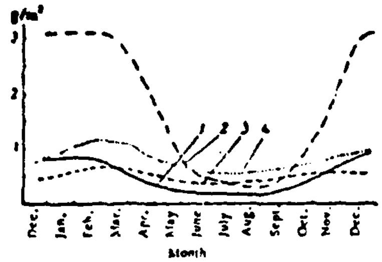


(from materials collected 1962-1966) in the upper 100m layer (mg/m^3)
1. 30-100
2. 50-150
3. 100-200
4. 100-300
5. 200-600
6. 200-1000
7. 100-3000
8. 300-1000
9. Edge of shelf
(After Bogdanov, *et al.* 1969)

FIGURE C–16 MEAN PLANKTON DISTRIBUTION

for area 3. These authors noted as did Austin and Jones (in press) for the "Middle Ground" that standing crop locally can be quite high. Maximum values for area 1 east of the Mississippi exceeded 2.0 mg/m^3, and biomass in the southwest shelf section in the area of summer upwelling can also be in this range.

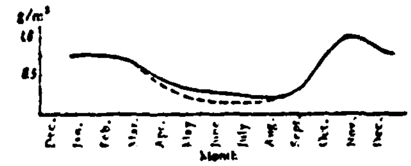
Basically, the eastern Gulf waters are inhabited by cosmopolitan coastal species of phytoplankton that constitute resident populations (spore formers or non-spore formers) which fluctuate in dominance according to such parameters as: 1) salinity gradients caused by run-off or rain; 2) temperature changes with seasons; 3) changes in nutrient and growth factor levels; 4) light; 5) availability of trace metals by chelation; 6) selective grazing by zooplankters or phytophagous fishes, e.g., mullet; 7) inhibitory external metabolites; 8) physical factors concentrating or dispersing populations; 9) reproductive rates and competitive exclusion; and 10) biological rhythms, e.g., diurnal periodicities or spore formation. Occasionally there is intrusion of deeper waters (upwelling) or Gulf surface waters (Loop Current eddies) that deposit "visitors." *Skeletonema coastatum* dominates the phytoplankton throughout most of the year and has different seasonal peaks in different areas, while *Rhizosolenia alata*, even though widespread, has a summer peak in Apalachee Bay vicinity (Curl, 1959). Another important diatom, *Thalassionema nitzschioides*, appears to have a fall peak (Hopkins, 1966) in the St. Andrews Bay system. Margalef (1967) suggested that the spring phytoplankton bloom common to temperate

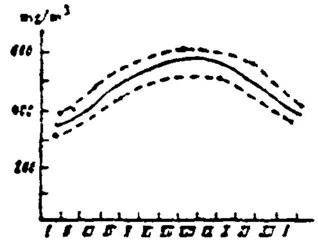


A) Quantitative Variations in Plankton on the Norther Shelf of the Gulf of Mexico:

Average (1) and maximum (2) for the area east of the mouth of the Mississippi: average (3) and maximum (4) for the area west of the mouth of the Mississippi.

B) Seasonal dynamics of the average amount of plankton in the northern part of the western shelf of Florida above depths of 30-100m (period of March-August indicated by dashed line as a possible variation because of the irregular sampling methods used for collecting materials in June)





C) Seasonal Changes in Plankton Biomass on the Southwest Part of the Florida Shelf

(After Khromov, 1965 and Bogdanov, et al. 1969)

FIGURE C–17 SEASONAL VARIATION OF PLANKTON IN SHELF WATERS

coastal waters follows a sequence; first, small diatoms and flagellates in spring, then *Chaetoceros* and *Rhizosolenia* and eventually, dinoflagellates. There could be a similar sequence for eastern Gulf waters; however, Hopkins (1966) and Simmons and Thomas (1962) pointed out that in northeast Gulf areas phytoplankton successions were not "clear-cut."

Gymnodinium breve, the causative organism of red tides, blooms annually in selected parts of coastal Gulf waters, but many interrelated parameters must be optimal for the bloom to be supported and developed into a major red tide outbreak. *Nutrients, particularly chelated trace metals, have been implicated with the initiation of red tides in Florida waters following heavy rainfall and land run-off.* Using iron as an index, researchers suggest that monitoring of certain river discharges can be used to predict major red tides. Red tides appear to have their severest effects on local and state economy in the form of reduced tourism and the expense of dead fish removal. Commercial fisheries are reportedly not affected while isolated sports fisheries, i.e., reef fishing, are only temporarily affected in a red tide area.

As regards taxonomic composition of intermediate Shelf zooplankton, Khromov (1965) and Bogdanov (1969) found the copepods *Nannocalanus minor, Euclaanus monachus, Undinula vulgaris,* and *Temora* ssp along with chaetognaths and decapod larvae constituted 70-80 percent of the standing crop in the southwest sector in summer. In the northern region east of the Mississippi chaetognaths were the principal component of biomass in January while *Temor stylifera, Temora turbinata* along with chaetognaths constituted a large share of the standing crop in June.

2. Benthic Invertebrates

The benthic fauna of the Intermediate Shelf and slope areas is clearly West Indian in composition and is best characterized by hard bottom sponge communities. Species associated with rocky substrates are listed in Table C-14a, and the sandy substrate fauna is characterized in Table C-14b. The bathymetric distribution of decapod crustaceans is very wide in this area, and it is likely that other groups have similarly wide distributions. Although the outer shelf and slope of the eastern Gulf are poorly known, there is doubt that a faunal boundary exists between Zones V and VI. The region was characterized by Pequegnat and Chase, 1970; Dexter, 1969; Galtsoff, 1964; Hedgpeth, 1954; Parker, 1956, and Pearse *et al.*, 1942.

3. Fish

The Intermediate Shelf communities of fishes extend from nearshore to the 100-fathom contour. Rationale for using the 100-fathom isobath as the outer boundary has been developed by Thompson (1963). The "open shelf" here implies those areas of unconsolidated sediments and low relief.

Although a number of Intermediate Shelf species also frequent the adjacent coast-estuarine region, many do not tolerate fluctuating estuarine conditions and are excluded from strictly inshore waters. The open shelf harbors and benthic fauna heavily represented by flatfishes (Pleuronectiformes), sea robins (Triglidae), lizardfishes (Synodontidae), scorpionfishes (Scorpaenidae), and other such groups are typically associated with a substrate of unconsolidated sediments. Proceeding seaward, change in faunal composition is gradual, with no demonstrably distinct or abrupt boundaries paralleling the coast.

The Florida Shelf is particularly homogeneous, with demonstrable similarities between the ichthyofauna of the northern and southern portions, no doubt a reflection of the similar calcareous nature of the substrate. Continuity of this biotope has been emphasized by Hedgpeth (1954), Briggs (1958), and Topp and Hoff (1972).

The zones making up the Florida Shelf (XVII, XVIII, XIX, and XXIV) can, therefore, be regarded, insofar as the benthic open shelf ichthyofauna is concerned, as a fairly homogeneous community. Faunal transition from south to north is gradual, with Zone XIX containing a greater proportion of sea basses (Serranidae), snappers (Lutjanidae), porgies (Sparidae), and others of a more tropical affinity. Toward the north the fauna is richer in drums and seatrouts (Sciaenidae) and other groups more characteristically associated with temperate climate (Reid, 1954).

Dominant species in trawl catches analyzed by Moe and Martin (1965) from the shallow shelf off Tampa Bay (Zone XVIII) were, in order of abundance, pinfish, *Lagodon rhomoides* (Sparidae); pigfish, *Orthopristis chrysoptera* (Pomadasyidae); silver perch, *Bairdiella chrysura* (Sciaenidae); leopard sea robin, *Prionotus scitulus* (Triglidae); and blackcheek tongue-fish, *Symphurus plagiusa* (Cynoglossidae). All are common and widespread, typifying the benthic fish fauna of this region. In addition, the eastern end of the Zone XVI in the vicinity of Cape San Blas supports a number of species seldom encountered elsewhere east of the Mississippi Delta (e.g., the flounders *Paralichthys lethostigma, Trichopsetts ventralis,* and *Syacium gunteri).* This extra-limital distribution might derive its influence from terrigenous materials delivered by the Apalachicola River, producing substrates locally similar to those at the Mississippi Delta and westward (Topp and Hoff, 1972).

The narrow shelf and ample rock outcroppings provide anglers with easy access to reef-oriented fishing. This has resulted in development of a large party boat fishery relying chiefly on snappers, groupers, porgies, and the like. Tropical reef fishes occasionally encountered in and near the bays and passes are likely recruited from these offshore reef areas.

Most shelf areas of the eastern Gulf bear limestone ridges and outcroppings supporting a rich sessile biota and a benthic ichthyofauna clearly of tropical affinity. One of the best known and most heavily exploited examples of this biotope is the Florida Middle Ground (in Zone XXIV), characterized by Moe (1963) as an area of high relief where hills and cliffs of up to seven fathoms have been recorded. The most conspicuous fin-fishes of such areas include the commercially important groupers of the genera *Epinephelus* and *Mycteroperca,* and snappers of the genus *Lutjanus.* Collectively, these species make up one of the most valuable fin-fisheries of the eastern Gulf.

Substantial populations of pelagic fishes, both resident and migratory, occupy the open shelf waters of the eastern Gulf. Prominant representatives of this group are the "baitfishes," which occur both on the open shelf and in coastal-estuarine regions. This group includes the herrings (notably *Clupea harengus* and *Opisthonema oglinum)* the menhadens *(Brevoortia* ssp.), shads (*Alosa* spp. and *Dorosoma petenense*), and anchovies (Anchoa spp.). All are important forage fishes for the larger pelagic piscivores, and most range throughout the eastern Gulf.

Also important and widespread are the valuable stocks of large pelagic fishes, prominent among which are the mackerels and tunas (Scombridae) and the billfishes (Istiophoridae). King and Spanish mackerel *(Scomberomorus cavalla* and *S. maculatus),* for example, form the staple of the Florida west coast charter boat industry (Moe, 1963), while tunas and billfishes are exploited by both sports and commercial interest along the shelf edge (Zones XXIII, XXIV, and XXVI).

4. Marine Mammals

Past records have shown that there is considerable influence from more inshore zones, especially in the more northern or inshore parts of it. Species such as the common dolphin, the bottlenosed dolphin, and the spotted dolphin have been reported rather further offshore in Zone XXIII than in others in the eastern Gulf – probably due in part to the faster bottom-depth drop-offs in this area than off Florida, and thus the ecological boundaries as far as dolphins are concerned are not as strict. The more offshore species would also be expected here, and this list would include some "endangered" species of large whales (Table C-22).

IV. THE OCEANIC GULF

A. PHYSICAL CHARACTERISTICS

1. Hydrology

The eastern Gulf of Mexico can be divided into a number of areas based on the similarity of their physical, biological, and geological features, as shown in Figure C-1. It should be pointed out that selected physical features might be present within more than one of the areas designated as XXIII, XXIV, XXV, and XXVI.

One of these features is the circulation below the sill depth of the Yucatan Channel. This circulation is below 2000 meters, and such deep water is found in areas XXIII, XXIV, and XXV.

There are little or no current measurements at these depths. Therefore movement has been defined by the characteristics of the water masses and is identified by anomalies of one or more of the physical properties such as salinity, temperature or oxygen concentrations. Within the water column there are no measurable (within the state of the art) horizontal variations in the salinities, potential temperatures, and dissolved-oxygen concentrations (Nowlin, 1972).

Comparison of the T-S relationship, below 2000 meters, for winter and summer, shows the lack of any discernible tendency toward horizontal variation in salinity or temperature within the basin. A comparison of the T-S characteristics of the Gulf of Mexico and Yucatan Basin waters and the relationship of the potential temperature versus salinity near the Yucatan Channel sill depth, which are similar, is consistent with the idea of present-day displacement of the Gulf Deep water by North Atlantic Deep Water (Nowlin, 1972) from the Yucatan Basin.

There is no discernible horizontal variation in dissolved oxygen in the basin waters of the Gulf of Mexico. Moreover, horizontally uniform oxygen concentrations are consistent with the horizontal uniformity of salinity and potential temperature observed for the basin water. The oxygen concentration between 1500 and 2000 meters in the Yucatan Basin, near the Yucatan Straits, depths from which waters could enter and fill the Gulf of Mexico Basin, is similar to those observed in the eastern and western Gulf of Mexico.

On the basis of vertical distribution of potential temperature and salinity the water appears to be stable to the bottom.

The Gulf of Mexico basin waters have either a common source (Yucatan Basin) or their residence time is of a magnitude sufficient to insure that the horizontal gradients have been destroyed by exchange processes. Existing data indicate the waters could be coming from the Yucatan Basin. Up to 1972, no studies of the bottom currents in the deep aspects of the Gulf have been published. Pequegnat (1972) has established bottom currents with substantial velocities up to 19 cm/sec exist in the eastern Gulf of Mexico. Not enough is known to relate bottom current to the Gulf of Mexico basin waters.

The circulation above 2000 meters is dominated by the Yucatan Current and the Loop Current (Nowlin and Hubertz, 1972). *The main feature of the surface circulation of the eastern Gulf of Mexico is the Loop Current* (Leipper, 1970). As such, it is another of the general features and affects the areas XXIII, XXIV, XXV, and XXVI.

This current is largely influenced by the upper layer transport system of the western North Atlantic (Figure C-18). A westward flow from the North Equatorial and Guiana Currents enters the Caribbean Sea through the channels between the lesser Antilles, crosses the Caribbean Sea as the Caribbean Current, and flows northward from the northwestern portion of the Cayman Sea through the Yucatan Straits as the Yucatan Current. The Yucatan Current moves northward into the Gulf of Mexico, turns clockwise in the eastern central Gulf and then issues into the Straits of Florida. As this flow is a loop-like feature, which often extends far into the eastern Gulf, it is referred to as the Loop Current of the eastern Gulf.

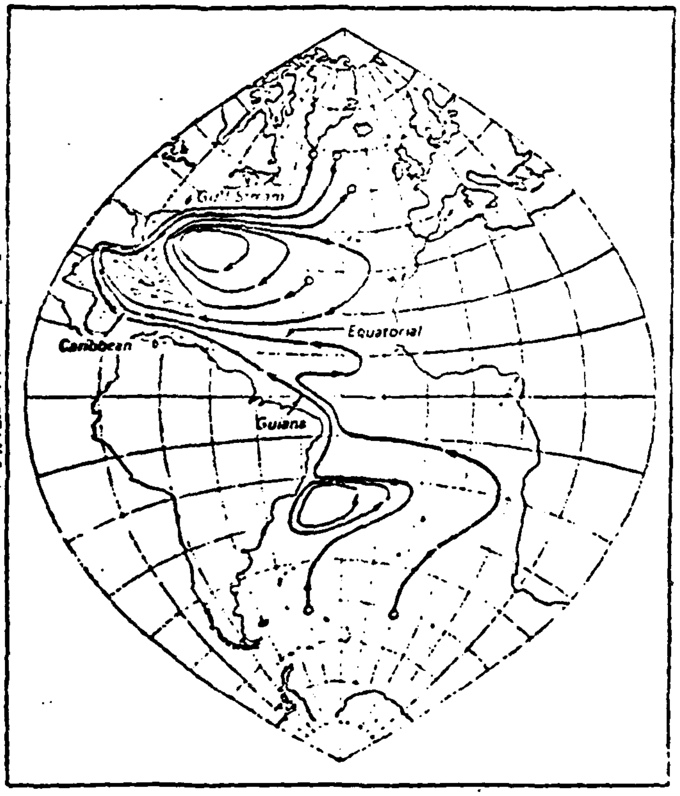
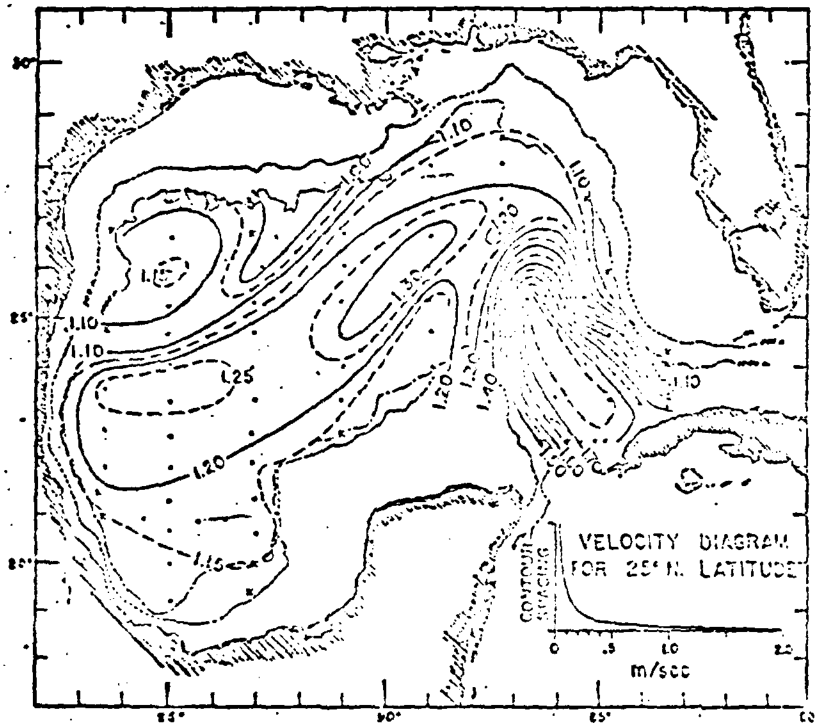


FIGURE C–18 UPPER LAYER TRANSPORT SCHEMATIC FOR THE ATLANTIC

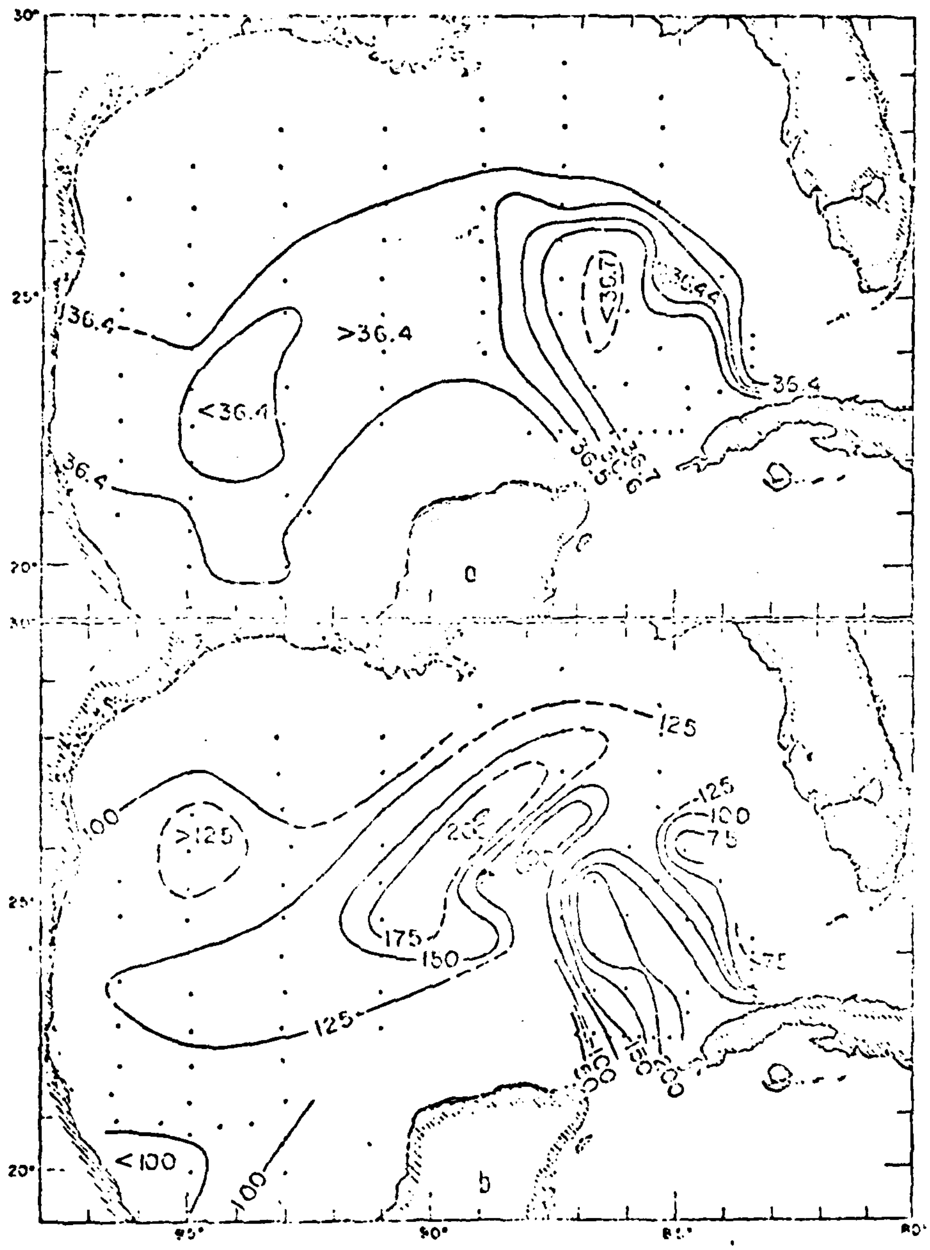
The configuration of the Loop Current can be defined by dynamic computation (Figure C-19), by subsurface salinity core maximum (Figure C-20), by the characteristics of T-S relationship of the subtropical underwater (Figure C-21), by the depth of the 22° isotherm (Figure C-22), and/or distribution of biomass (Figure C-23).



Relative to the 1000-db surface; HIDALGO 62-H-3; x's indicate some extrapolation. Contour interval, 0.05 dynamic meters. (From Nowlin, 1972)

FIGURE C–19 DYNAMIC SEA-SURFACE TOPOGRAPHY

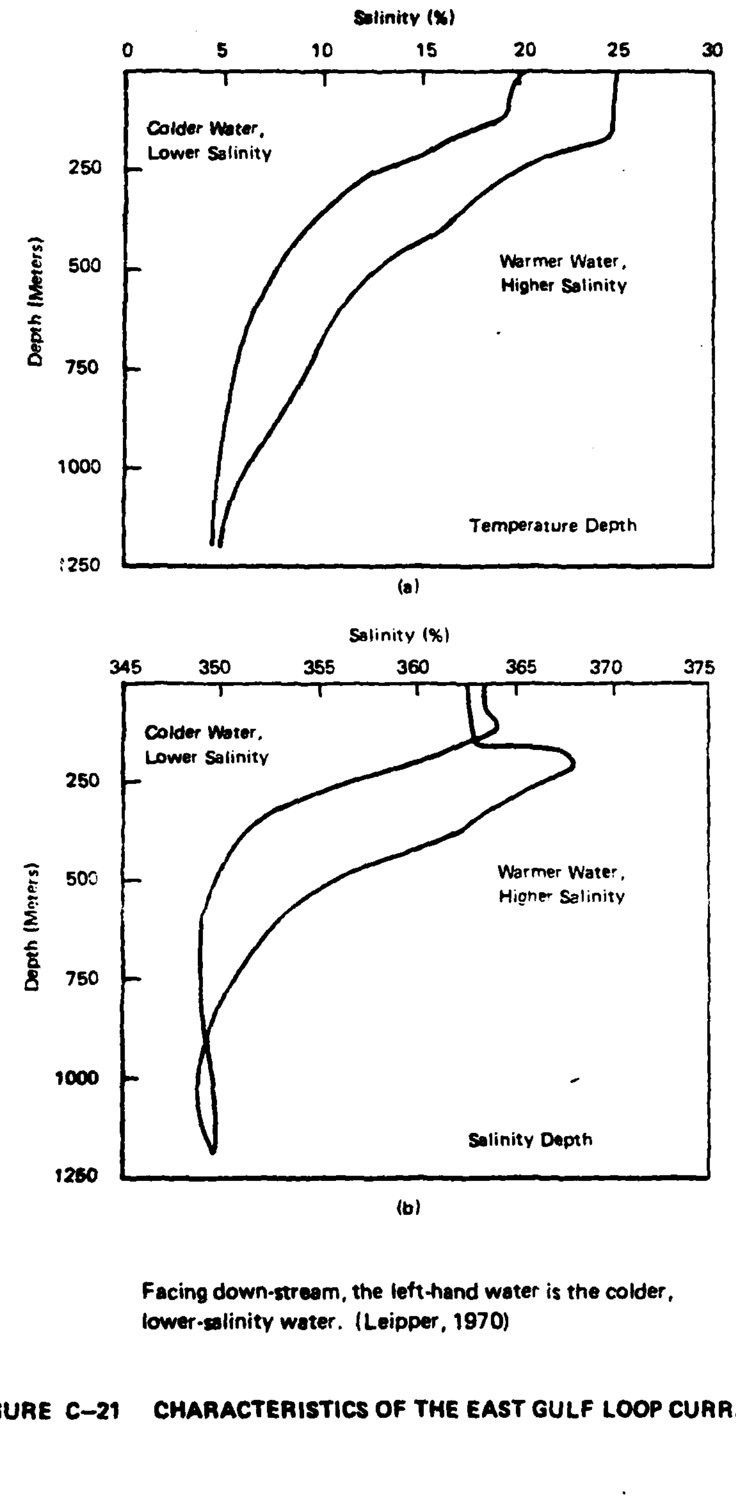
The Loop Current appears as a distinct subsurface salinity maximum. This salinity maximum can be traced from the tropical North Atlantic (Nowlin, 1972) through the Caribbean (Wüst, 1964), through the Yucatan Straits (Leipper, 1970) into the eastern Gulf of Mexico. This central Loop water has the same temperature-salinity characteristics as subtropical underwater as defined by Wüst having a temperature of 18 to 25°C and salinities of 36.5 to 36.8 parts per thousand. Austin (1971) outlined the water masses for the eastern Gulf of Mexico (Figure C-24).



HIDALGO 62-H-3: Location of maxima indicated by dots. (From Nowlin, 1972)

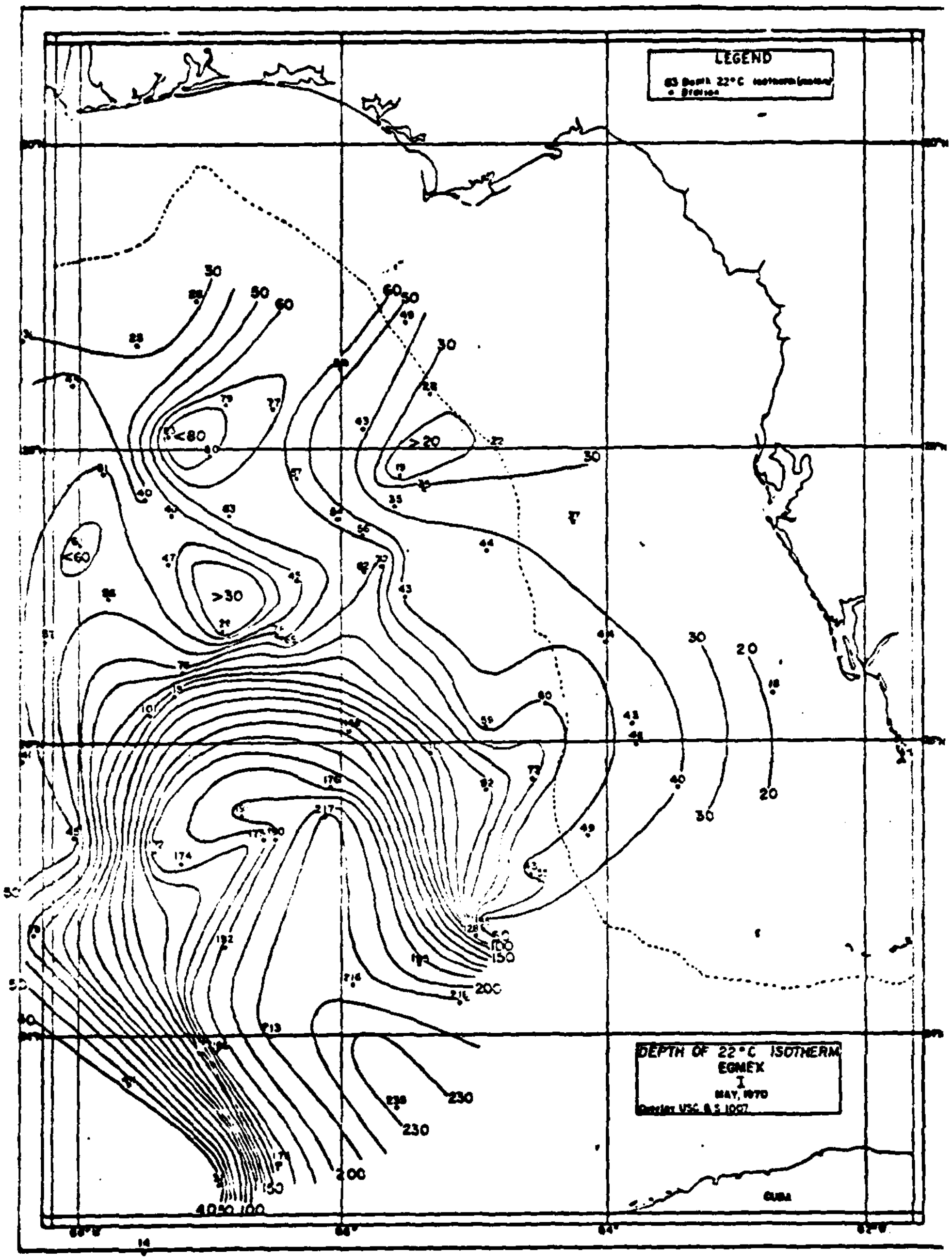
Salinity (0.1 per mil intervals) | Depth (25-m interval)

FIGURE C–20 CORE OF SALINITY MAXIMUM



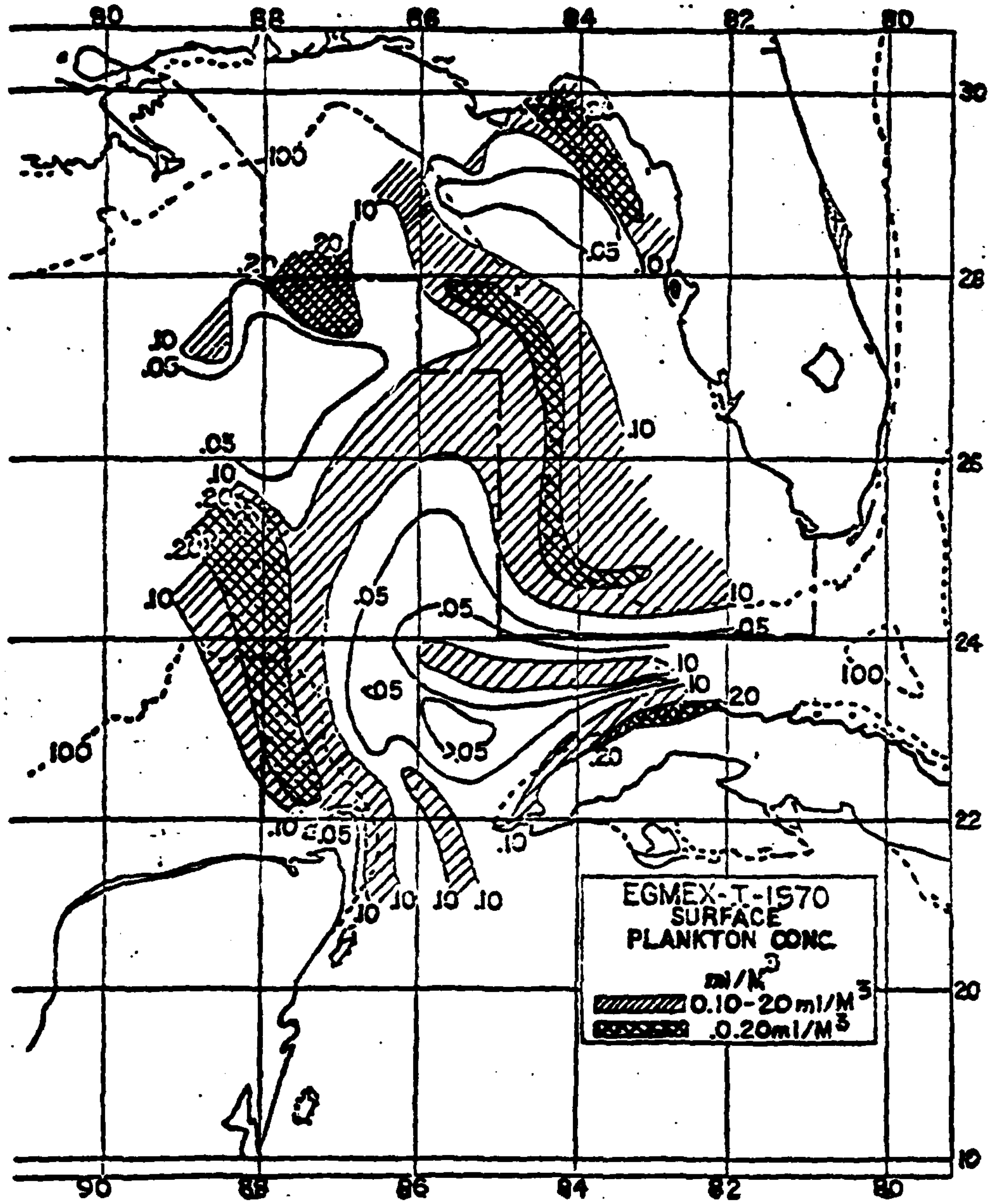
Facing down-stream, the left-hand water is the colder, lower-salinity water. (Leipper, 1970)

FIGURE C–21 CHARACTERISTICS OF THE EAST GULF LOOP CURRENT



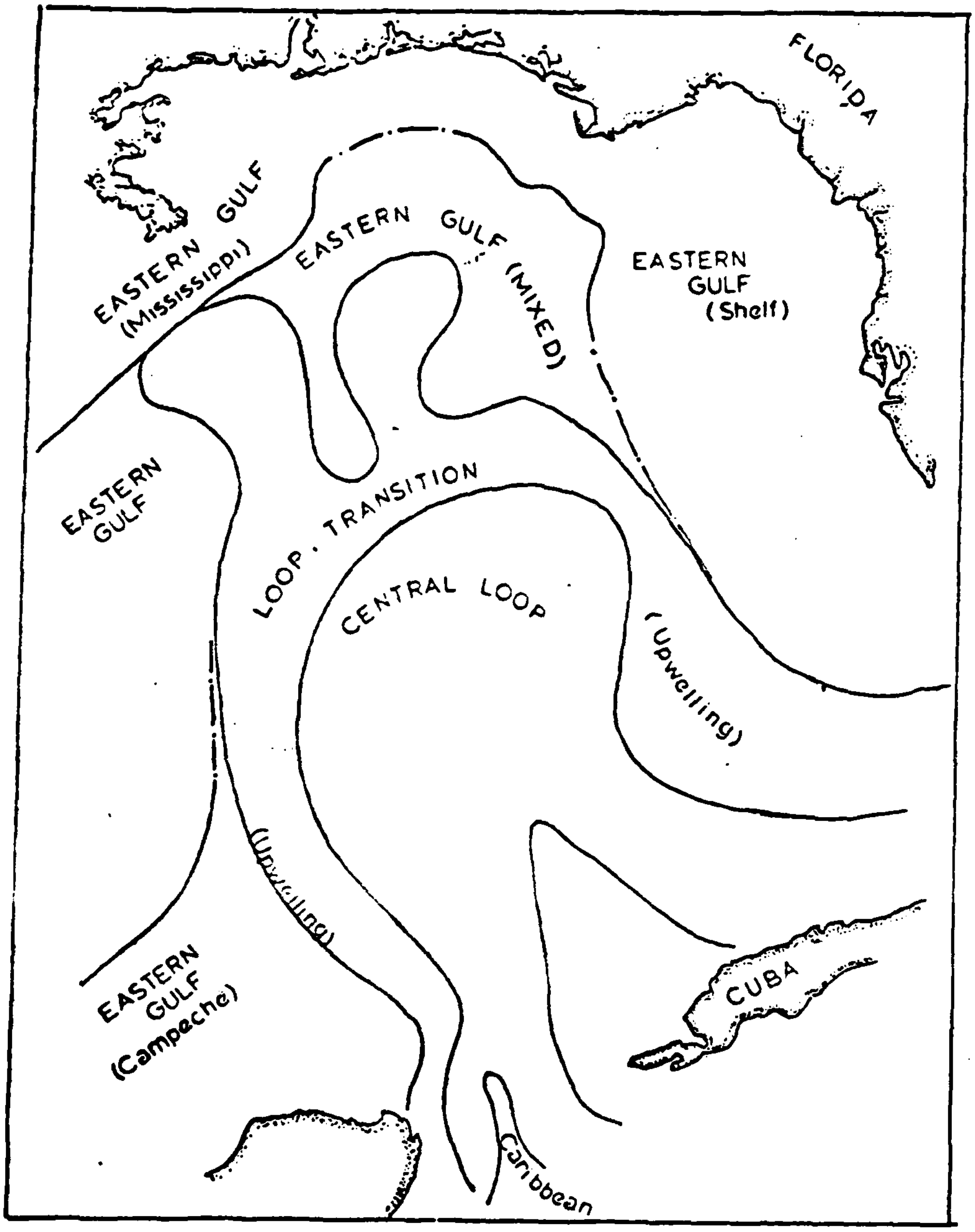
Along the eastern edge of the loop current, shaded area is location of current as indicated by the 150 to 200-meter gradient of the 22°C isotherm. Data from EGMEX I, May, 1970.

FIGURE C–22 DEPTH OF THE 22°C ISOTHERM



Milliliters of plankton per cubic meter of water for May, 1970 (From Austin, 1971, and based on data from EGMEX I). Central loop of the loop current is defined by lower *concentrations* (0.05-0.10 ml/m^3).

FIGURE C–23 SURFACE DISTRIBUTION OF PLANKTON BIOMASS

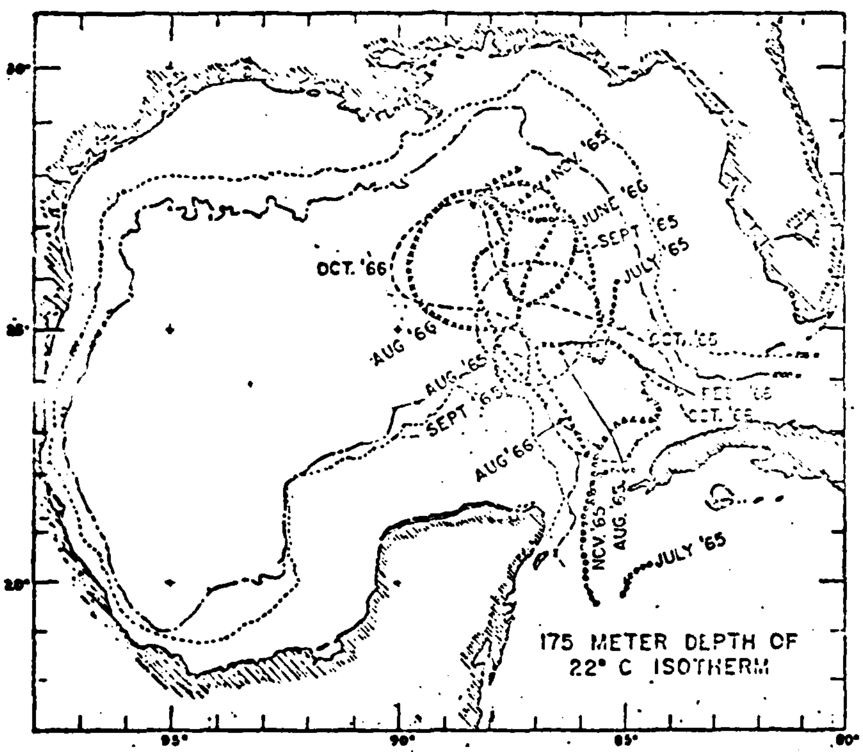


(From Austin, 1971, based on EGMEX I data, May, 1970)

FIGURE C–24 WATER MASSES IN THE EASTERN GULF

The central loop water has the characteristics of subtropical waters. The Loop transition water has surface temperatures between 25-27°C in a steep slope to the isotherm. The subsurface temperatures of the Loop transition range between 23-27°C, and the water is a mixture between the eastern Gulf water and the central Loop water with salinity ranging between 36.0 and 36.5 parts per thousand. The outer edges of the eastern Gulf water on the northern Florida and western Florida Continental Shelf are a modification of the Loop transition water, the eastern Gulf water, and the eastern Continental Shelf water. This type of a reaction can occur seasonally in areas XXIII and XXIV.

Leipper (1970) used the depth of the 22°C isotherm included between 150 and 200 meters to locate the Loop Current because these depths remain in the current at all times of the year. *The Loop Current varies significantly seasonally and annually in areal extent* (Figure C-25, Leipper, 1970). *It can have a systematic growth and decay pattern.*



Right-hand edges of the current as indicated by overlays of the 175 meter contour lines from 22°C topographies of all cruises of the 1965-1966 sequences (From Leipper, 1970).

FIGURE C–25 LOCATION OF THE LOOP CURRENT AT 175 METERS

One of the seasonal developments might be the progressive expansion and intrusion of the Loop Current into the Gulf reaching as far as the Continental Shelf off the Mississippi River Delta (area XXIII) *by late summer or fall.* Leipper calls this development a "spring intrusion." These intrusions interact with the topography of the northern (area XXIII) and western (area XXIV) Florida Continental Shelf and together with a general decrease in the Yucatan transport (Cochrane, 1965) often cause the Loop to form a neck somewhere along its axis. *This necking eventually results in a detached eddy, which decays as it migrates westward.* The remaining portion of the Loop slowly grows again repeating the above development. Although the attachment process is believed to occur in late summer or fall in area XXVI. detachments occasionally occur at other times of the year. One such detachment was recorded in May 1972.

While the above-described seasonal development is considered to be normal for the Loop Current. there were observations that indicated that there can be yearly variations. Figure C-22 and Figure C-23. for May. show two extremes. which have occurred with a continuous loop and a two-eddy system. Further, there is increasing evidence that small perturbations might periodically break off and move onto the northern and west central Florida Continental Shelf.

As the Loop Current waters enter the Gulf of Mexico through the Yucatan Channel. the core of the current attains a velocity of more than 200 cm/sec (approximately 4 knots) in summer and diminishes to 50 cm/sec (approximately 1 knot) in October or November (Cochrane, 1965, 1966). Geostrophic-flow computations, based on data taken in May 1970 (EGMEX I). show that the major flow of water is to the north through the Yucatan Straits flowing 144 cm/sec along the western side. However, along the eastern side of the Yucatan Channel there was a small southerly flow of water at 19-22 cm/sec. As the main body of water progresses northward into the Gulf, the velocity decreases abruptly to 60-67 cm/sec after passing the confines of the Campeche Banks. Within the Gulf the current on each side of the Loop is largely contained in a band 90 to 150 km in width (Leipper. 1970). The data from EGMEX I show that the Loop Current velocity increases to 159 cm/sec as it flows southward along the western Florida coast in the "upwelling" area of Figure C-24. In the Straits of Florida. the velocity remains the same (150 cm/sec).

The above-mentioned geostrophic velocities agree with the current velocities of the EGMEX III survey which were measured directly with drogues drifting in the Loop Current at 150-200 meters depth (22° isotherm). The directly measured current velocities were 175-200 cm/sec in the Yucatan Straits; the velocity decreased to 50 cm/sec where the Loop Current turns east and increased again to 175 cm/sec as the waters moved south and flowed out in the Straits of Florida (Chew, 1972).

About 25 to 30 million cubic meters of water per second flow into the Gulf through the Yucatan Straits, and approximately an equal rate and volume of water flows out through the Straits of Florida (Hubertz. 1967; Nowlin and McLellan. 1967; Leipper, 1970). In comparison. the amount of water discharged into the Gulf by the Mississippi River and numerous streams is small, being less than 25,000 cubic meters per second (Holeman, 1968). The amount lost to evaporation is not known.

Current patterns of the Subtropical Underwater and Subantarctic Intermediate Water reflect those of the surface water. Depth to the core of the Subtropical Underwater (Figure C-20) indicates that it contacts the shelf bottom near its outer edge in approximately 100 meters of water (55 fathoms) throughout the Gulf. Speeds to the northeast of 70 cm/sec along 90°W longitude were computed by Nowlin and McLellan (1967), with southwesterly counterflow of about 30 cm/sec along the north flank of the large gyre in the western Gulf. Along the northeastern boundary of the Loop Current, the transport increases in a downstream direction, not only in the surface waters but also in waters as deep as 1000 meters (555 fathoms). At the surface, velocities can reach 200 cm/sec but decrease to 4 cm/sec at 1000 meters depth.

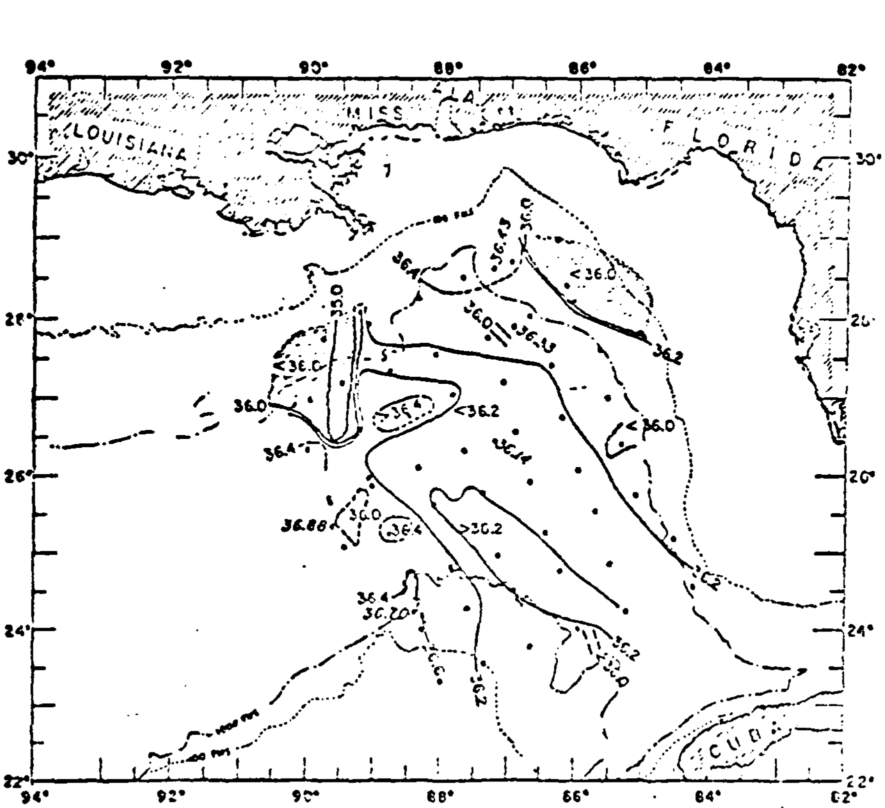
The oxygen-minimum layer shown by Wüst (1964) in the Caribbean can be followed into the Gulf, where it occurs at a depth of some 700 meters (390 fathoms) in the vicinity of the Loop Current. In the western Gulf, however, it is very thick (600 meters) and has lower extreme values (2.4 m/liter or less), which indicates a considerable residence time for this water.

The Subantarctic Intermediate Water must contact the Gulf bottom all along the continental slope in water depths between 500 and 700 meters (280-380 fathoms). Its current pattern is similar to that of the shallower layers, but computed velocities are less than 10 cm/sec (Nowlin, 1972).

2. Chemistry

Using an STD to measure salinity and temperature versus depth, a physical oceanographic survey was made of the eastern Gulf of Mexico during June 1966. The results of this survey are shown in Figures C-26 and C-27. Figure C-26 shows the distribution of surface salinity from samples taken on station and at hourly intervals. The salinities vary from 34.1 ppt to 36.7 ppt with most of the values between 36.0 and 36.4 ppt. These values are lower than those found previously by the HIDALGO in 1962, and by other earlier investigators. Hubertz attributes the low surface salinities found to several factors: 1) river run-off (Chew, 1962), 2) proximate passage of hurricane ALMA, and 3) above-average rainfall in the coastal region of Guatemala.

The surface temperatures in the month of June 1966 are shown in Figure C-27. In general, the temperature distribution is similar to that found by Fuglister in 1947, except that the 28°C isotherm extends to 27°N, about 2° farther north than usual (Nowlin and McLellan, 1967). The T-S relationships found in 1966 were similar to those found in 1962 during the HIDALGO cruise.

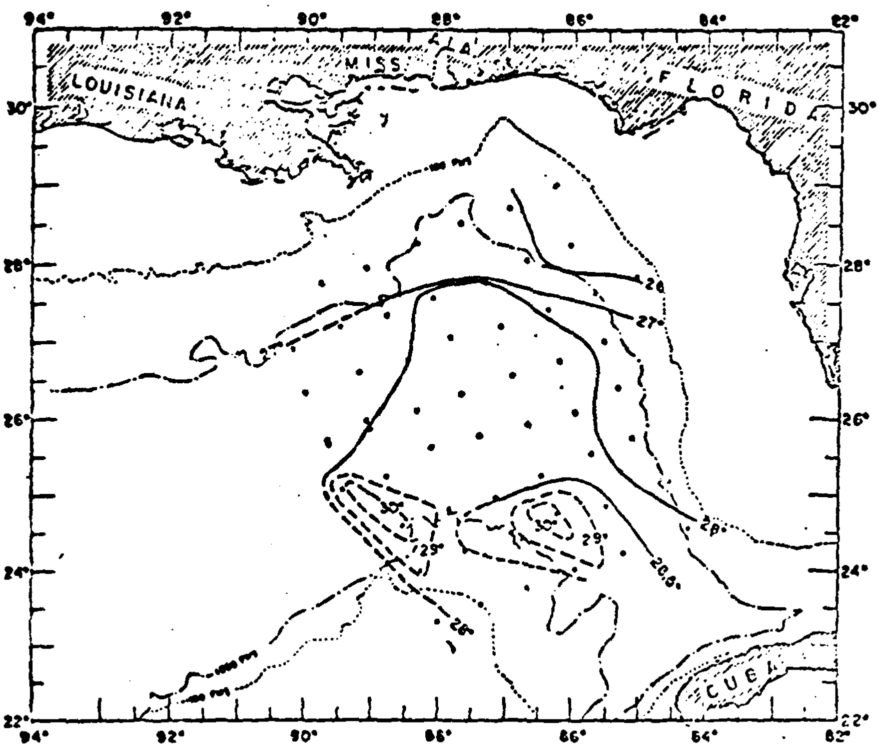


ALAMINOS Cruise 66-A-8. Source: Technical Report 67-4T by Hubertz, Texas A & M University, 1967.

FIGURE C-26 DISTRIBUTION OF SURFACE SALINITY

During 1970-1972, a set of unique conditions occurred which resulted in three interdisciplinary expeditions. These were termed the EGMEX series of cruises and provided an integrated and synoptic study which has continued over a three-year period, including as many as eight vessels at a single time, and over all seasons. For the first time, information on the seasonal distribution of temperature and salinity in the eastern half of the Gulf of Mexico is available. And also, for the first time, water structure from synoptic data can be determined. Prior to 1970, results from a number of cruises over a span of several years were used to define the water masses in the eastern Gulf.

Wennekens (1959) has used phosphate data in his study of the water structure of the waters found in the Gulf of Mexico and the Straits of Florida. He saw a marked difference in phosphate content of the Edge and Yucatan Waters. The Edge Water seems to have a higher concentration at shallow depths. While Wennekens would not comment on the meaning of this feature, it was probably due to the phosphate being added from river and land run-off in the Tampa Bay area. Waters of some of the rivers entering Tampa Bay contain as high as 300 microgram atoms per liter of PO_4-P. However, the phosphate content of Tampa Bay water decreases quickly as it enters the Gulf of Mexico.



ALAMINOS Cruise 66-A-8. Source: Hubertz, Technical Report 67-4T, Texas A & M University, 1967.

FIGURE C–27 DISTRIBUTION OF SURFACE TEMPERATURE

During the EGMEX program, inorganic phosphate data were taken on all stations. At the present time this information is unpublished but available from the State University System Institute of Oceanography (SUSIO), St. Petersburg. Additional unpublished phosphate data on the waters of the northeast Gulf of Mexico are in the ESCAROSA I report (available from SUSIO also). The most extensive measurement of phosphate concentrations in the Gulf of Mexico is being carried out at the present time. George Berberian, AOML/MOAA, Miami, Florida, has obtained samples from the EGMEX program, ESCAROSA I program, the Shelf Study, and several cruises of the DISCOVERY, and is using a Technicon Autoanalyzer to determine the phosphate as well as other nutrient concentrations. He will compare the nutrient findings with the hydrographic features of the area for a doctoral dissertation.

The numbers of trace metal determinations of Gulf of Mexico waters are extremely sparse, and even sparser are accurate determinations. Using neutron activation, Slowey and Hood (1971) analyzed 84 samples from 28 stations in the Gulf of Mexico for zinc, copper, and manganese. Their findings, which are shown in Table C-29, compared favorably with those of Hood (1963) and Rona, *et al* (1962). Moritas' (1961) values for copper were much less than Slowey and Hood's as his work was done by dithizone extraction. This method would only determine the ionic species. In this study *they found coastal waters to have about an order of magnitude greater concentration than open ocean waters. They also found that all of these metals exist as organic complexes in the sea and that interesting concentrations were found at intermediate depths.* These findings are in keeping with those of our laboratory (Corcoran and Alexander, 1964; Alexander and Corcoran, 1967).

(The major portion of the preceding discussion on Chemistry of the Oceanic Gulf Region was extracted from the American Petroleum Institute report, *A Summary of Knowledge of the Eastern Gulf of Mexico.* The original article is titled "Chemical Oceanography," and was prepared by Dr. Eugene F. Corcoran, University of Miami.)

B. RESIDENT AND TRANSIENT MARINE BIOTA

1. Plankton

Much of the central Gulf consists of relatively warm, nutrient-poor Loop Current waters derived from the Caribbean. The area covered by the Loop is constantly changing and varies significantly with season. Because of low concentrations of biogenic elements and resulting low primary productivity, zooplankton standing crop is quite low in the Oceanic Gulf region (0.01-0.05 g/m^3 in the top 100 m) in the summer when intrusion of the Loop Current is maximal. In fall, when more of the east central Gulf is covered by transitional water, biomass is somewhat higher (0.05-0.10 g/m^3). Khromov (1965), however, could detect no seasonal change within the Loop Current itself.

Bogdanov, *et al* (1969) show the average biomass for the period 1962-1966 for the Loop Current and adjacent transitional waters were 0.03-0.10 g/m^3 and 0.05-0.15 g/m^3, respectively. Arnold's (1958) data from BCF cruises are in the same range 0.12 ml/m^3 for March 1951, to July 1953, as are data from EGMEX I which show biomass in May to be 0.05-0.10 ml/m^3 in the Central Loop and 0.10-0.20 ml/m^3 in surrounding transitional waters (Figure C-23).

There is yet no information on the principal taxonomic component of zooplankton biomass in the east central Gulf though research on this is currently in progress at the University of South Florida.

TABLE C-29

DISTRIBUTION OF MINERALS IN THE GULF

Location	Date	Depth (m)	S°/oo	Cu (μg/1)	Mn (μg/1)	Zn (μg/1)
21°38'N	5-18-58	100	36·62	0·50	0·30	1·6
86°15'W		1500	34·99	0·52	0·29	2·5
23°40'N	6-25-58	100	36·48	0·20	0·14	1·5
82°52'W		500	35·35	0·11	0·21	1·1
		1250	35·01	0·34	0·23	0·2
25°26'N	6-26-58	125	–	0·20	0·34	0·7
85°01'W		300	–	0·72	0·19	0·3
		500	34·82	0·70	0·29	2·2
28°57'N	8-2-63	10	–	1·0	19·0	2·6
95°20'W						
27°50'N	5-4-63	10	–	4·9	3·1	5·6
97°00'W						
25°27'N	10-11-62	10	36·60	3·5	0·61	10·5
95°53'W		310	35·71	1·6	0·11	3·8
		900	34·90	2·8	0·42	9·7
		1200	34·95	1·4	0·15	5·0
		2250	34·96	0·3	0·05	3·6
		3400	34·97	0·6	–	1·6
20°25'N	11-18-63	10	–	2·0	2·4	10·0
94°02'W						
28°58'N	11-18-63	10	–	0·08	1·5	2·4
94°00'W						
25°30'N	11-19-63	10	36·50	0·88	0·54	2·7
93°50'W		125	36·26	0·00	0·44	5·3
		350	35·35	0·38	0·68	0·8
		450	35·00	0·14	0·24	0·1
		700	34·92	1·2	0·66	2·3
		1000	35·96	0·62	0·26	6·9
		2000	34·93	0·42	0·38	3·1
		3000	34·95	0·72	0·22	1·8
26°56'N	11-21-63	10	36·53	0·40	0·64	1·6
94°05'W		470	35·12	0·18	0·42	–
		750	35·26	0·14	0·26	1·7
		1000	35·01	0·60	0·40	4·9
26°00'N	11-21-63	10	36·57	0·12	0·56	1·6
93°50'W		250	35·45	0·50	0·60	3·1
		500	34·95	0·92	0·86	9·5
		700	34·88	0·30	0·32	2·1
		1100	34·96	0·10	0·24	2·3
		1500	34·97	1·0	0·28	0·0
		2000	34·97	0·20	0·30	1·4
29°00'N	4-16-64	10	–	1·3	2·4	6·0
94°40'W						
24°57'N	4-18-64	10	–	2·1	0·44	2·9

TABLE C-29 (Continued)

Location	Date	Depth (m)	S°/oo	Cu (μg/1)	Mn (μg/1)	Zn (μg/1)
91°00'W						
24°57'N	4-22-64	10	36·31	0·68	0·20	2·0
80°59'W		300	36·33	0·88	0·22	3·7
		600	36·22	1·1	0·15	2·5
		1000	34·90	3·5	0·18	5·8
		2250	34·98	2·5	0·12	3·5
		3050	34·98	1·2	0·15	5·5
27°10'N	4-24-64	10	36·44	0·70	0·26	3·0
87°45'W						
28°30'N	4-25-64	10	36·05	1·0	0·4	3·3
88°00'W						
29°26'N	4-25-64	10	36·28	2·1	1·3	2·1
88°31'W						
28°50'N	4-27-64	10	–	1·4	7·5	3·6
89°35'W						
28°20'N	4-27-64	10	–	0·94	0·68	6·6
89°40'W						
25°35'N	4-28-64	10	–	0·44	0·28	4·2
89°58'W						
27°28'N	4-27-65	10	–	0·50	0·38	3·7
94°18'W		40	–	0·43	0·33	2·9
		70	–	1·3	0·59	3·4
27°28'N	4-27-65	10	–	0·80	0·34	7·7
94°09'W		300	–	0·70	0·88	1·7
		600	–	0·90	0·19	2·3
26°30'N	4-27-65	10	–	1·0	0·23	1·8
94°00'W		700	–	0·38	0·24	6·4
		1500	–	0·74	0·17	4·5
22°49'N	3-1-65	100	36·53	0·47	0·37	2·9
93°45'W		300	35·58	0·45	0·41	1·6
		600	34·91	4·6	0·20	7·2
		900	34·91	0·32	0·13	0·8
		1200	34·96	0·48	0·14	2·2
		1800	34·96	0·37	0·21	1·8
		2500	34·98	0·44	0·11	0·9
		3400	34·97	0·28	0·19	0·5
21°55'N	5-4-65	10	36·45	0·36	0·18	3·2
92°25'W		75	36·38	1·6	1·3	4·5
		150	36·03	0·63	0·42	2·3
21°55'N	5-4-65	10	36·50	0·53	0·22	5·7
92°29'W		350	36·50	1·6	0·18	3·5
		700	34·72	5·4	0·34	6·2
22°03'N	5-4-65	10	36·53	1·3	0·18	1·1
92°29'W		500	34·85	0·4	0·24	2·5
		1000	34·78	1·5	0·22	3·8
		1500	34·80	1·7	0·25	2·0
23°10'N	8-20-65	10	36·18	4·1	0·29	5·2
85°18'W		300	35·54	2·0	0·15	4·7
		500	35·09	0·98	0·08	2·7
		750	34·90	12·3	0·31	15·1
		1000	34·95	3·5	0·13	5·1
		1500	34·97	2·3	0·11	3·1

Source: Slowey and Hood (1971)

In view of the significance of the Loop Current to plankton dynamics in the Oceanic Gulf region and the eastern Gulf Intermediate Shelf it is essential to characterize seasonal geographic patterns of this water mass. *Austin (1971) has shown that water masses of the eastern Gulf of Mexico can be recognized and differentiated by occurrence of certain shellbearing planktonic organisms.* He concluded that biological characteristics of water permit a finer definition of water masses than do physical or chemical parameters. Austin determined that areas of upwelling could be recognized by the presence of particular species of pteropods (*Peraclis* and *Clio*) and foraminiferans (*Globorotalia*). Further, Austin found that the velocity core of the Loop Current could be defined by the presence of eight species of foraminiferans and pteropods (Figure C-28).

Cruise (1971) using the same EGMEX I collections found that the sergestid shrimp *Lucifer saxoni* can be used as an indicator of eastern Gulf waters (Figure C-29), and *Lucifer typus*, a Caribbean species, can be used as a biological indicator of the Loop Current.

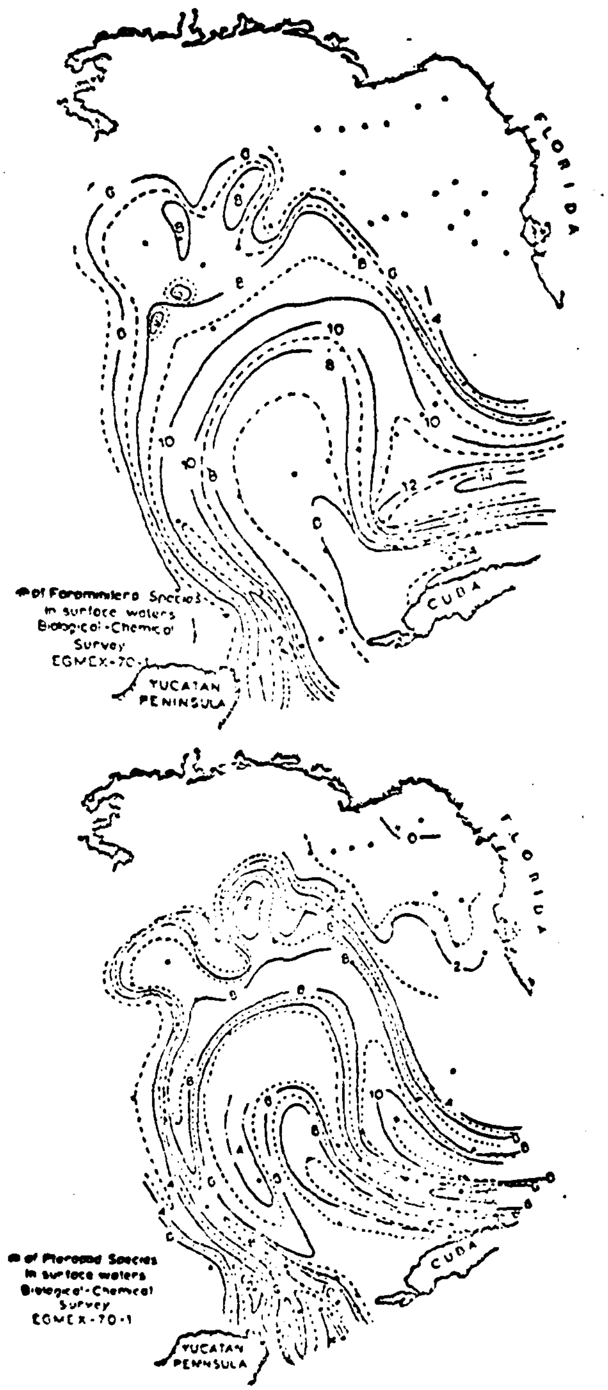
An open Gulf assemblage of phytoplankton would include the dinoflagellate genera *Triposolenia*, *Heterodinium*, *Amphisolenia*, *Murrayella*, *Histioneis*, *Ptychodiscus*, *Cladopyxis*, *Kofoidinium*, certain *Ceratium* spp., *Pyrocystis* and the diatom genera *Gossleriella*, *Ethmodiscus*, and *Planktoniella* (P. sol has a salinity tolerance of 33.76 to 39.15 percent, Smayda, 1958). Even though dinoflagellates might be more diverse in open Gulf waters, they might not dominate the standing crop.

2. Benthic Invertebrates

The deep water benthic fauna of the Oceanic Gulf Region contains both Atlantic and Caribbean species. Though this fauna is imperfectly known, it seems certain that no faunal boundary exists between Zones XXVI and XXV. Therefore the two have been combined and, basically, represent West Indian type areas. It is probable that fairly narrow bathymetric faunal zones are associated with sediment types and concentrations of organic nutrients on the deep slope. The number of individuals per species decreases rapidly below a depth of 130 meters and is depauperate compared to the deep Atlantic fauna. For example, of 220 brachyuran species reported from the Gulf, only one (an oxystome) was found to occur below a depth of 1000 meters. It is likely that other macro-invertebrate epifaunal groups are similarly scarce in deep water. The area was partly characterized by Rowe and Menzies, 1969; Parker, 1960; Rowe and Menzies, 1971; and Pequegnat and Chase, 1970. (Species associated with hard substrates on the slope, and in the deep basins, are listed in Table C-13a. Species associated with muddy bottoms are listed in Table C-13b.)

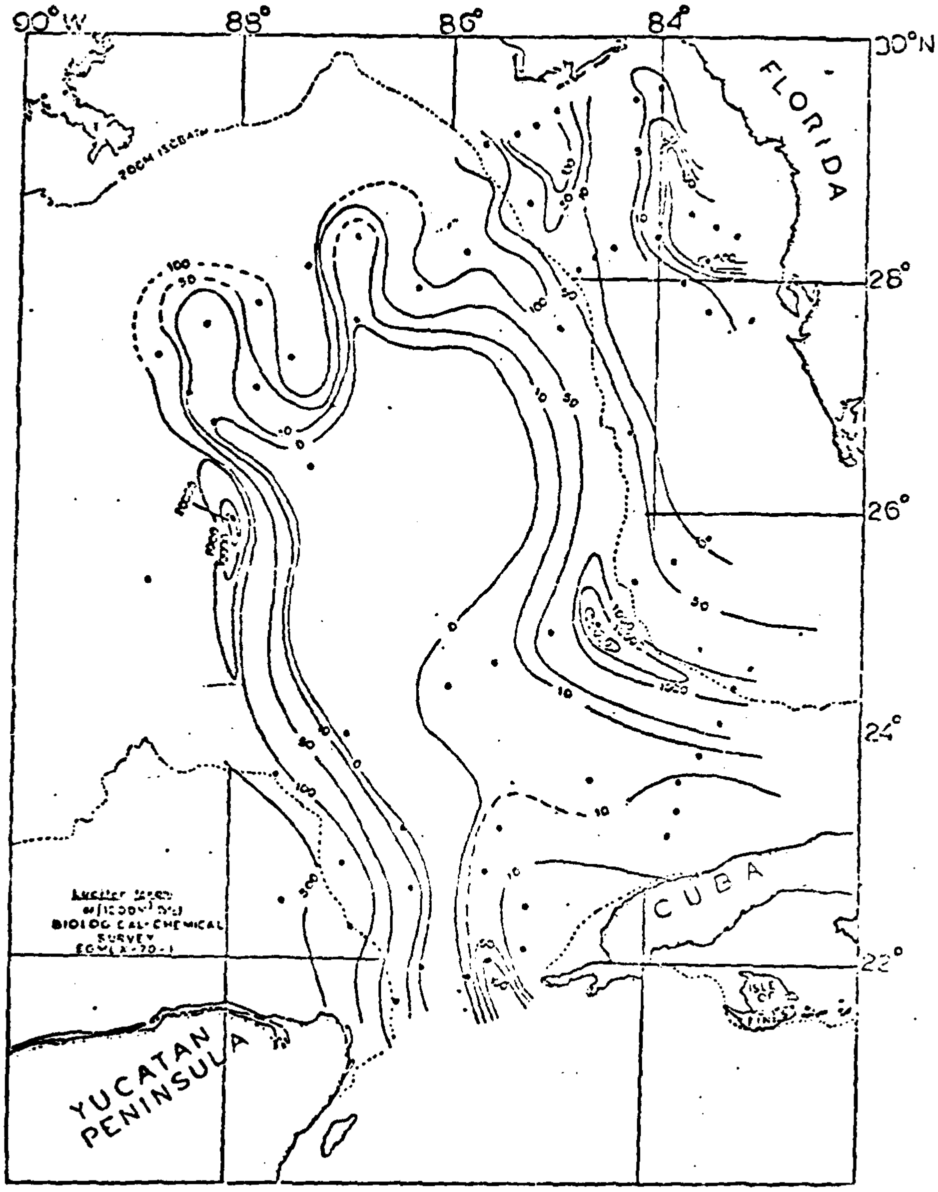
3. Fish

Inasmuch as Zone XXIII extends from relatively shallow shelf waters to beyond the 1000 fathom isobath, it includes a variety of biotypes, which insofar as the fishes are concerned, cannot be treated collectively. The Intermediate Shelf



(After Austin, 1971)

FIGURE C–28 BIOINDICATOR DELINEATION OF LOOP CURRENT WATERS



(After Cruise, 1971)

FIGURE C–29 BIOINDICATOR DELINEATION OF LOOP CURRENT region, here delimited as a rather narrow band between 20 and 100 fathoms, supports an ichthyofauna similar to that of the nearshore. Its shallower portions contribute both to the northern Gulf menhaden fishery (Reintjes, 1970) and to an industrial bottomfish fishery (Roithmayr, 1965). Significant inclusions in the latter are four species of Sciaenidae (Atlantic croaker, *Micropogon undulatus;* spot, *Leiostomus xanthurus;* sand seatrout, *Cynoscion arenarius;* silver seatrout, *C. nothus*), sea catfish *(Arius felis)*, long-spine porgy *(Stenotomus caprinus)*, and cutlassfish *(Trichiurus lepturus)*.

Limestone outcroppings on the shelf of Zone XXIII support a reef fauna qualitatively similar to that of the Florida Middle Grounds. These areas of hard bottom have long supported a valuable fishery based on red snapper and form the mainstay of the northern Gulf party boat fishery (Camber, 1955).

In addition to supporting the stocks of tuna and billfish mentioned for Zone XXVI, the highly productive waters over the outer shelf and slope also constitute a primary spawning ground for mackerel, dolphin, cobias, and other important species.

This deep-water area of the eastern Gulf, Zone XXVI, supports a varied pelagic fish fauna, including species of sport and commercial interest.

According to Bright (1968), the Gulf of Mexico deep-sea bottom-fishes are primarily benthopelagic. This fauna is primarily an extension of the Caribbean ichthyofauna with a small element derived from the Atlantic Ocean north of the Gulf and with no significant amount of endemism. Species diversity and abundance is greatest in depths less than 1500 meters. Judging from Bright's collections at stations within Zone XXVI, dominant bottom-fishes include the families Brotulidae, Macrouridae, and Stephanoberycidae. Of the 219 species of bottom-fishes known from the Gulf of Mexico below 350 meters, 64 have ranges extending below 1000 meters.

Collections of mesopelagic fishes from within and outside the Loop Current were reported by Zaburance *et al* (1970). Sixty-eight species of 23 families were collected, the most abundant belonging to the families Myctophidae (laternfishes) and Gonostomatidae (bristlemouths).

The eastern border of Zone XXVI supports seasonal populations of tunas and billfishes. These have been of interest to both domestic and foreign long-lining enterprises (Wise and Davis, in press) and are receiving considerable attention from sportsmen.

In terms of importance to the fish and fisheries of the eastern Gulf, Zone XXV is the primary avenue of transport for planktonic organisms of Caribbean origina (Ingle *et al*, 1963), as well as for certain large migratory fishes (tunas, billfishes, etc.) exploited seasonally along the shelf edge. Zone XXV also includes the eastern portion of the Yucatan Shelf, a broad area of calcareous substrate supporting a benthic ichthyofauna similar to that of the Florida Shelf.

4. Marine Mammals

As an offshore region, the marine mammals to be expected there are all cetaceans and include primarily the large whales. In addition, one might expect to encounter the rough-toothed dolphin and the common dolphin, as well as the long-snouted dolphin and possibly the pygmy and dwarf sperm whales, the pygmy killer whale, and the beaked whales. *Some of the larger whales are listed* (Table C-22) *as "endangered," but all of these, as well as the smaller whales and dolphins would be capable of swimming out of any sort of environmental disturbance caused by human activities.*

V. ZONAL ANALYSIS

Selected information. already presented, is repeated within the summary and discussion of the *lowest numbered zone of each region,* to point out similarities and dissimilarities of the zones. Such information is *not* repeated for the individual zones of the subject region.

Environmental conditions and associated phenomena vary yearly, seasonally, and daily due to climatic, physical, biological, and associated changes. In addition, there is often disparity in recorded values or observations due to the "man-machine interface." Therefore, we recommend that the reader study the cited references to gain a better understanding of the extremes and norms of environmental values that have been reported for the subject zones by various investigators.

A. ZONE V

1. Summary

Storms and hurricanes are the most important of the natural environmental quality problems affecting the eastern Gulf coast. Wind, flooding, and storm surges are shown to have caused extensive damage to coastal areas over the years. These destructive elements have taken their toll on beaches, vegetation, development and water supplies. Hurricane and storm damage becomes more extensive when it occurs below the hurricane flood line as it has in recent years.

Improperly planned coastal construction leads to critical beach erosion problems Beach erosion is both a natural and man-made environmental problem. In Florida, 351 miles of Gulf and estuarine shoreline are critically eroded. Ross's work suggests that tidal prisms, tidal exchange and fresh water replacement times are not sufficient criteria upon which to judge the flushing of a bay, estuary, or nearshore area. *The existence of gyres within a bay or an estuary or nearshore area (common in Florida) is shown to be the important factor in the capability of a body of water to flush contaminating substance to the open Gulf.*

Zone V is characterized by barrier islands and relatively large estuaries, lagoons and bays. The estuaries, lagoons, and bays of Zones V-VIII are sediment traps and are silting rapidly. Little or no sediment from the land is being contributed to beach nourishment. Through erosion and deposition the existing coastal features are continually being modified. A thin veneer of sediments, mostly relic, covers the continental shelf.

The eastern Gulf of Mexico supports a diverse flora of benthic algae from the inter-tidal zone to depths of 200 meters. Quantitatively, however, the flora is limited by the relative scarcity of rocky substrata, with the result that seagrasses produce a greater biomass than do benthic algae. Algae of the eastern Gulf coastal region (Zones V-VIII) are a resource of great potential value for their useful cell wall polysaccharides, their physiologically active compounds, and for the remarkable the other coastal zones of western Florida. The exceptions are ducks and geese which winter in large numbers in Zone V.

Many sections of the eastern Gulf coast have been developed as valuable tourist and recreational areas. *The beaches of Zone V are of a white medium to fine sand and are proclaimed to be the "most beautiful in the world." As a result, tourism is prominent.* The recreational resources of the eastern Gulf support a tourist industry that adds over $5 billion per year to the economy of the region in addition to providing recreational facilities for residents of the three states. Beach facilities are an especially valuable recreational asset and additional beaches available to the public are needed. Recreational facilities on the Gulf coast do not presently meet the demand for public recreation; beach facilities are in especially short supply.

2. Physical Characteristics

a. Hydrology

Zone V extends from the western edge of Apalachee Bay to the western edge of Perdido Bay. The area is characterized by intermediate sized watersheds with appreciable fresh water flow. The tidal range for the area is lower than other zones discussed. Escambia Bay is a bay in Zone V that is very similar to Tampa Bay (Zone VII). That is, it is a bifurcated body of water composed of Escambia and East Bays. Escambia Bay has a much larger flow of fresh water than does Tampa Bay, yet the flushing of Escambia does not appear to be as good as Tampa Bay. It is suspected that many gyres exist in Escambia Bay as may be the case in many of the bays and sounds in Zone V. Pertinent information for Zone V is contained in Table C-30.

b. Geology

The Barrier Islands and Ria Coast of the Florida Panhandle are dominated by the Pleistocene Apachicola Delta. The estuaries of all the associated rivers are silting rapidly with fine grained clastic sediment and oyster shell. The beaches, dunes, and barrier islands are composed of medium to fine sand. *The estuaries are acting as sediment traps; as a result the coastal waters are remarkably clear.*

c. Chemistry

Nutrients are among the best documented chemical elements in the nearshore Gulf. Phosphorus in particular has received considerable attention in part because of its possible role in red tide outbreaks (Ketchum and Keen, 1948), and because of the extensive phosphate deposits in Florida. For other elements, such as mercury, the data is scanty, and one can only provide accounts of occasional determinations.

The nitrogen species reported in Perdido Bay were found to be significantly lower than the values reported by Dragovich and May (1962). Perdido Bay, in the northern Gulf on the Florida-Alabama border, is a long, narrow body of water two to three miles in width and about thirteen miles long from the headwaters to the

TABLE C-30

HYDROLOGY OF ZONE V

	Mean Discharge (cfs)	Watershed Area (Sq. Mi.)	Diurnal Tide Range (ft.)
Perdido Bay			
Perdido River	761	394	0.5
Jacks Branch	27.1	23.2	
Styx River	170	93.2	
Additional Area	–	507.6	
Total	958.1	1,018.0	
Pensacola Bay System			1.1 - 1.6
Escambia Bay			1.5
Escambia River	6,544	4,200	
Additional Area	–	600	
Blackwater Bay			1.6
Blackwater River	290	305	
Additional Area	–	400	
East Bay			1.6
Yellow River	2,228	1,210	
Additional Area	–	1,200	
Pensacola Bay	–	70	1.1
Total	9,062	7,985	
Choctawhatchee Bay			0.6
Choctawhatchee River	7,063	4,384	
Additional Area	–	800	
Total	7,063	5,184	
St. Andrew Bay			1.3 - 1.6
Econfina Creek	535	122	
Additional Area	–	1,300	
Total	535	1,422	
Apalachicola Bay			1.4 - 2.2
Chipola River	24,960	17,600	
Apalachicola River	1,531	781	
Additional Area	–	100	
Total	26,491	18,481	

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mouth of about ten feet and receives partially treated wastes from a pulp mill. Nitrogen data obtained during seven days in September 1969, by the U.S. Department of the Interior (1970) indicate most of the nitrogen is introduced at Eleven Mile Creek, the point of entry of the pulp mill effluent.

The total phosphorus concentrations in Perdido Bay tend to be lower than other north Florida streams (Zones V and VI).

3. Resident and Transient Marine Biota

a. Benthic Plants

Four species of mangroves are native to the eastern Gulf of Mexico: red, black, white, and buttonwood. *Mangroves are characterized by an ability to grow in saline, waterlogged soils of the intertidal zone or on its edge.*

The three most abundant inshore seagrasses species, turtle grass, manatee grass, and shoal grass, grow from the lower intertidal zone out to depths of 10 to 20 meters and may occupy several thousand square miles of the inner continental shelf (Zones V-VIII). The other two species, *Halophia baillonis* and *H. engelmannii,* occur in greater depth (to 70 meters), although they grow in shallow water in some places.

Earle (1969) shows the coastal hydro-biological zone of the eastern Gulf of Mexico as indicated by the current knowledge of the *distribution of benthic marine algae. The principal environmental factors are water temperature, turbidity, and light penetration, depth, slope, substrate, salinity regime, water movement, and tidal regime.*

These zones are separated by transition zones rather than distinct boundaries, and they vary in distinctiveness with season. They become relatively less distinctive from coastal waters with depths of less than three meters to open Gulf waters with depths of 10 to 100 meters.

b. Benthic Invertebrates

The benthic invertebrates of the Zone V marshes are equivalent to those of the Big Bend coastal type (Zone VI, Table C-28a). A cross section of conspicuous species found in the large bays and sounds is presented as Table C-21b.

Oyster reefs and marine grass beds are the dominant sessile invertebrate communities of the northeastern Gulf. Large numbers of organisms find protection, forage, and suitable attachment sites in and among oyster shells and grass. Representative species are listed in Tables C-18a and C-21d. Seasonal temperature fluctuations in northern Gulf inshore environments play an important role in the distribution of such motile grass bed inhabitants as *Penaeus setiferus* (white shrimp) and *P. aztecus* (brown shrimp). These species essentially replace the pink shrimp which prefer warmer climates.

The northern Gulf coastal zone is difficult to characterize because of the pollutional conditions. The benthic biota in most estuarine systems has been seriously degraded due to eutrophication, pesticides, and petrochemical loads present in sediments. *The Pensacola-Escambia-East Bay system has been gravely damaged. About the only major bay system in the area that remains in fairly healthy shape is Choctawhatchee Bay.* Both permanent and transient species have been eliminated from heavily polluted coastal zone area, and it is no longer feasible to treat them as similar ecosystems. Rather, it is now necessary to consider the survivors in terms of resistance to various pollutants.

c. Fish and Fisheries

The most abundant fish in east Gulf estuaries is the bay anchovy, *Anchoa mitchilli.* In the northern Gulf other abundant estuarine fishes are the creaker, *Micropogon undaltus;* menhaden, *Brevoortia patronus;* and spot, *Leiostomus xanthurus* – while on the west central and southern coasts of Florida other species of high abundance include pinfish, *Lagodon rhomoides;* tidewater silversides, *Menidia beryllina;* silver jenny, *Eucinostomus gula;* pigfish, *Orthopristis chrysopterus;* silver perch, *Bairdiella chrysura;* and sand seatrout, *Cynoscion arenarius.* This list contains the most valuable fish in Gulf fisheries in terms of both value and poundage (menhaden), the most important species in the industrial fishery of the northern Gulf (croaker, spot and sand seatrout), as well as a variety of small bait fishes that, together with juvenile shrimp and other benthic invertebrates, comprise the major food supply of other species taken in all major fisheries.

As noted by Reid (1954), ichthyofaunal transition within the coastal-estuarine biotope along the eastern Gulf is a gradual one in which the southern forms begin to appear somewhat irregularly and seasonally while species density of the northern fishes decreases.

Comparisons of the species composition at six coastal and estuarine localities, based on percentages of coincident species of the families Sciaenidae (drums and seatrouts), Cyprinodontidae (killifishes), Gobiidae (gobies), Blenniidae (Blennies), Gerreidae (morjarras), and a few others representative of this biotope have been made for the following localities:

VIII: Florida Bay (Tabb and Manning, 1961)

VII: Charlotte Harbor-Calooshatchee Estuary (Wang and Raney, 1971); Tampa Bay (Springer and Woodburn, 1960)

VI: Cedar Keys (Reid, 1954)

V: St. Andrews Bay (Vick, 1964)

I-II: Texas coastal waters (Gunter, 1945; Hoese, 1958).

The matrix of values (Table C-31) so derived reveals no pronounced distributional "barriers" for the coastal-estuarine fish fauna of the eastern Gulf. Insofar as the fishes as a diagnostic feature are concerned, the divisions between Zones V, VI, VII, and VIII should not be regarded as "faunal boundaries," but rather as convenient but artificial breaks in an otherwise gradual transition.

TABLE C-31

PERCENTAGES OF SPECIES COINCIDENCE FOR COASTAL-ESTUARINE FISH FAUNAS

	Charlotte Hbr. Caloosahatchee Es.	Tampa Bay	Cedar Keys	St. Andrews Bay	Texas Coastal Waters
Florida Bay	61	61	52	43	34
Charlotte Harbor-Caloosahatchee Estuary		69	56	50	45
Tampa Bay			64	54	52
Cedar Keys				55	47
St. Andrews Bay					50

Prominent inshore fisheries are located in this zone; i.e., Apalachicola Bay has an extensive oyster fishery. Estimates have been made that this bay could supply the world demand for oysters if properly managed. Oysters are also found in the other bays and estuaries of the region, but many of these areas are off-limits to shellfishing because of water pollution.

In 1970, 386 boats were involved in oyster harvesting in Franklin County. There were 50 shucking houses and 17 repacking houses. Approximately 54 percent of the oysters harvested were used as fresh shucked oysters, 32 percent as half shell stock, and 14 percent as frozen or breaded oysters.

Oyster leases on the Gulf coast of Florida cover 4649 acres in 137 leases granted by the Florida Department of Natural Resources. Major oyster and shellfish leases are mapped, and the maps are available from the Florida Department of Natural Resources. The Florida Health and Rehabilitative Services Department, Bureau of Shellfish, maps oyster beds that are polluted and off-limits to harvesting.

Other major shellfish and crustacean species that are of value to Florida's Gulf Coast fisheries are blue crabs, stone crabs, and spiny lobsters. The bay scallop fishery has been developing, and for the first time in several years, concentrations of scallops were found in 1970 in the Apahalachee Bay area.

In 1971 the oyster population of Escambia Bay was almost completely destroyed by fungi, which were probably triggered by industrial discharges into the bay. Pollution in Escambia Bay has also caused decreases in the populations of a number of finfish, and commercial fishing in the area has changed considerably in the last several years. In 1968 and before, half the catches unloaded at docks in the region came from Escambia Bay. In 1971, less than one-fifth of the catches came from the bay. While the majority of commercial fishing five years ago was done from "bay boats," the majority is now done from large boats equipped to stay at sea from two to four weeks. Shrimp, oysters, and snapper, which used to be plentiful in the immediate area, now must be caught off the Mississippi Delta and westward.

4. Man's Activities

Zone V has extensive beach shoreline suitable for public recreation and tourism. According to the Corps of Engineers Shoreline Inventory, from a total shoreline of 1138.5 miles, there are 743.3 miles of Gulf and estuarine beaches in the region.

The tourist season for the Zone runs primarily from May through September, and is heaviest from Ft. Walton Beach to Panama City. There is a large amount of tourist activity immediately west of Panama City. There is also some tourist activity on Santa Rosa Island near Pensacola. The establishment of the Gulf Islands National Seashore will undoubtedly increase the tourist business in this area.

In addition to the National Seashore, state parks and recreation areas in the zone include:

John C. Beasley Recreation Area near Ft. Walton,
Grayton Beach Recreation Area near Destin,
Basin Bayou and Fred Gannon Rocky Bayou Recreation
Areas on Choctawatchee Bay,
St. Andrews State Park near Panama City,
St. Joseph State Park near Port St. Joe, and
St. George Island Recreation Park.

Several state Aquatic Preserves are in the region. They are located in:

Santa Rosa Sound near Fort Pickens,
Escambia Bay near the Yellow River marsh,
Choctawatchee Bay at Rocky Bayou,
St. Andrews Bay near the entrance to the bay,
St. Joseph Sound,
Apalachicola Bay, and
Alligator Harbor

National Wildlife areas are located at St. Vincent Islands and at St. Marks. An extensive state wildlife management area runs along or near the coast from Destin to Panama City.

Vacation homes and some permanent homes are located all along the shoreline of Zone V, with the heaviest concentration of such development near the towns. St. George Island is becoming a popular summer home colony.

Industry in Zone V is located at Pensacola, Panama City, and Port St. Joe. *The coastal waters in the areas near the industrial facilities are extensively polluted and control equipment is presently being installed in many of the facilities. The Pensacola area is highly industrialized.*

Dredge and fill operations are one of the artificial environmental factors that have caused problems in the eastern Gulf. Statewide, Florida has lost 796.000 acres of original habitat to dredge and fill; 23,521 acres of Florida's Gulf coast were filled through 1967. Dredging and filling have destroyed many grass beds and much marine habitat in Florida. Many wetlands have been filled. and the extensive dredging necessary for the maintenance of the harbor has caused much turbidity and sediment in the bays, lagoons and estuaries. *Dredging is now discouraged in Florida waters.*

B. ZONE VI

1. Summary

Zone VI is characterized by an exceptionally broad continental shelf, its gentle slope resulting in low energy coastline. The depth along most of this zone is only about three meters, 15 miles offshore, and only about 20 meters, 50 to 60 miles offshore. The bottom is a limestone plateau covered by a thin layer of sandy sediments with numerous limestone outcroppings from the intertidal zone outward. Only in the extreme western segment off the Apalachicola River are there well-developed barrier islands and bays. Along much of the rest of the coast there are numerous low and small islands, these often with good stands of black mangroves and a few red mangroves in the southeastern segment.

There are a number of spring-fed rivers and underwater springs throughout the zone that dilute the inshore Gulf waters at a rather constant rate. Only the Apalachicola River and relatively local run-off fluctuate considerably with rainy periods. *This highly productive zone, which includes several large wildlife refuges, represents the last relatively undisturbed coastal zone in Florida.* Due to the low relief, the Big Bend coastal ecosystems are labile and would be affected by surface film pollutants in the same manner as the Everglades.

The Corps. of Engineers have temporarily shelved consideration of building the "missing link" of the Intercoastal Waterway through this zone, because of the potential biological destructiveness that could result. There has been very little development of this zone by man.

2. Physical Characteristics

a. Hydrology

Zone VI extends from Tarpon Springs to Apalachee Bay. The region is characterized by larger watershed areas and larger flows of fresh water into the near shore areas. Tidal ranges generally are higher than in the previous regions discussed. The specific information concerning watershed area tidal range and mean fresh water discharge can be found in Table C-32.

TABLE C-32

HYDROLOGY OF ZONE VI

	Mean Discharge (cfs)	Watershed Area (Sq. Mi.)	Diurnal Tide Range (ft.)
Apalachee Bay			2.7 - 3.3
Ochlockonee River	1,832	1,720	
St. Marks River	736	535	
Aucilla River	385	747	
Econfina River	134	198	
Fenholloway River	125	110	
Additional Area	–	2,300	
Total	3,212	5,610	
Deadman Bay			3.4
Steinhatchee River	326	350	
Additional Area	–	450	
Total	326	800	
Suwannee Sound			3.4
Suwannee River	10,560	9,730	
Additional Area	–	800	
Total	10,560	10,530	
Waccasassa Bay			3.5
Waccasassa River	80	400	
Additional Area	–	600	
Total	80	1,000	

The wetlands resources of Zone VI support the fisheries and are valuable ecological assets for the region. They provide protection for the upland and play important role in the ground-water systems and environmental quality of the area.

b. Geology

The Big Bend Drowned Karst is an area of coastal swamps and marshes in which the land grades into the sea. There are virtually no beaches or barrier islands. Oyster bars are found in the shallow coastal water. The Cedar Keys are drowned sand dunes and constitute the main body of clastic sediments in this limestone terrain.

c. Chemistry

The total phosphate concentration in the Waccasacca River in North Florida as presented in two reports ranged between 0.06 (Putman, 1966) and 0.15 mg/l (Saville, 1966). Note that the Waccasacca is considered to be an unpolluted river. In general, the phosphorus content of North Florida Rivers is one to two orders of magnitude less than the concentrations encountered in the Alafia River (Zone VII) and approximately 1/5 that of the Peace River (Zone VII) based on Alberts (1970) data.

The Ochlocknee River has its head waters in Georgia and receives domestic and agricultural sewage as it flows through Florida to the Gulf. The river was dammed in 1930 forming lake Talquin. Below the dam the river passes through approximately 35 miles of marsh land in the Apalachicola National Forest before reaching the estuary. Alberts (1970) established a series of stations and surveyed the river between 1969 and 1970. The first two stations were above the Talquin Reservoir and the remaining stations below it. Alberts found that (1) the inflow of phosphorus to the reservoir was greater than the outflow, (2) when the river was at flood stage (September), this trend is reversed, and (3) the marsh appears to have no effect on the phosphorus concentration.

3. Resident and Transient Marine Biota

a. Benthic Plants

Biologically, Zone VI is distinctive for the most extensive salt marshes and the most extensive seagrass beds extending outward to depths of about 40 feet in some areas, with one or two species in patches at much greater depth. The "Big Bend" coastal region gradually changes from pine-flatwoods to extensive *Spartina-Juncus* marshes.

b. Benthic Invertebrates

Significant ecosystems for benthic invertebrates include *Spartina-Juncus* marsh, marine grass beds, unconsolidated substrates, oyster reef communities and mangrove habitats (which extend only to Cedar Key). Overall the zone is characteristically Carolinian, especially in the marshy habitats, where indicator species such as *Littorina irrorata, Neritina reclivata, Polymesoda cardiniana* and *Modiolus demissus* predominate. (These and other dominant species are listed in Table C-19.)

c. Fish and Fisheries

Inshore commercial fishery resources for the zone include mangrove snapper, red snapper, grouper, bluefish, spotted seatrout, southern kingfish, red drum, Spanish mackerel, black mullet, flounder, blue crab, stone crab, pink shrimp, and oysters.

d. Marine Mammals

The manatee is restricted to the coastal zone and in addition it is an "endangered species" – the only one in the eastern Gulf of any great concern. Manatees are found primarily in Zones VI, VII, and VIII, but there are records in Zone V as well. They are usually found in the waterways associated with marshes and around bays and estuaries. In addition, they are sometimes found along the open ocean beaches near inlets. One of their more important habitats, however, appears to be the springs and their associated outflows and adjoining waterways that are located primarily in Zone VI. In fact, *the Crystal River area within that zone has been proposed as a National Manatee Sanctuary*

4. Man's Activities

There is little tourism in Zone VI and little development. Some vacation homes are found, but they are widely scattered along the shoreline.

Recreation and preservation areas in the region include:

- The Tide Swamp Wildlife Management Area in Taylor County (State)
- The Cedar Key National Wildlife Refuge and Wilderness Area in Levy County
- The Waccasassa Bay Aquatic Preserve
- Gulf Hammock Wildlife Management Area in Levy County
- St. Martin's Marsh Aquatic Preserve in Citrus County
- The Chassahowitzka National Wildlife Refuge in Citrus County

There is little industry in the zone. A large pulpmill is located at Foley in Taylor County. Pollution from this mill has completely "killed" the Fenholloway River and its estuary supports little life.

C. ZONE VII

1. Summary

Zone VII is characterized by mainland beaches, dunes (now mostly eliminated by coastal development), and sandy islands. The continental shelf of Zone VII though wide, is less so than Zone VI and the slope somewhat greater. *There are two large estuaries in Zone VII, Tampa Bay and Charlotte Harbor, into which most of the rivers of the area empty. Tampa Bay is surrounded by a metropolitan area while*

Charlotte Harbor is still in a highly natural condition. The zone is bordered by a discontinuous line of barrier islands with high-energy beaches that protect shallow sounds and bays fringed by mangroves. All of the nearshore areas, the bays and estuaries are shallow and well mixed bodies of water. They are flushed by a combination of fresh water through flow and tidal action.

In the nearshore areas tidal forces and bottom friction forces are much larger than wind forces. Field testing in the Tampa Bay region indicates that wind effects penetrate the upper foot and a half of the surface waters in the nearshore regions. The predominate current patterns even in the presence of prevailing winds were those determined by tidal flow, runoff and bottom topography.

The characteristics of the subject subregions implies that mathematical models can be developed to assist in understanding of the hydrology and hydrodynamics of the subregions and in projecting proposed changes. Quantitative estimates may be derived from such models. For example, a running total of pounds of nutrients discharged, pounds of nutrients in the bay, and pounds of nutrients flushed out of the bay can be made for each hour, each day, or each year if it is desired; calculations and confirmations of salinities, temperature, hurricane times, normal tide heights, current flows, water quality, and the effects of mechanical changes in Tampa Bay can also be made. The existence and significance of gyres in the flushing of a bay has been established. *It is evident in Tampa Bay that the existence of gyres is the predominate influence in delaying the flushing of contaminants from the bay.* There are numerous limestone outcroppings, especially from depths of about ten meters and deeper.

Both the offshore algae flora, supported largely by limestone substrate, and the inshore flora are well-developed. Mangrove stands consisting of four species – red, black, white, and buttonwood – replace the herbaceous vegetation of salt marshes to the north, and are especially abundant in estuaries and on fringing islands. *Seagrass beds are abundant in the estuaries and to some extent in the open Gulf, but are much reduced in comparison to Zone VI.* Salt marshes occur in intertidal coastal areas of low energy and gentle slope. In the eastern Gulf of Mexico they cover vast areas from Tarpon Springs northward to Port St. Joe, Florida. They exhibit a distinct zonation with salt marsh grass, *Spartina alterniflora* forming the outer band, *Juncus roemerianus,* black rush, forming the next and most extensive zone, and a third zone of the grasses *Distichlis spicata* or *Spartina patens* or a mixture of the two. Certain vegetational modifications or irregularities may occur in any of the three zones. Salt marshes are highly productive in terms of photosynthesis and they contribute to coastal fisheries. Their relative importance in this respect, however, is not yet known. Instead of gradual seepage as in the Everglades (Zone VIII), fresh water flows mainly through large rivers and bays in Zone VII.

The basic known ecology of red tides is outlined and suggests that *Gymnodinium breve,* the causative organism, blooms annually in selected parts of coastal Gulf waters, but many interrelated parameters must be optimal for the bloom to be supported and develop into a major red tide outbreak. *Pollution is another factor* *that seems to have an increasingly detrimental effect on fish populations and the Florida Gulf coast fishing industry.* About 43 percent of the area of Florida's Gulf coast estuaries is adversely affected by pollution (McNulty, 1971), omitting the area of Florida Bay because it lies mainly within the Everglades National Park. *Over one-half of the 402 point sources of pollution listed by McNulty in his estuarine inventory are located in Sarasota and Tampa Bays.* The eleven estuarine areas most affected by pollution are the Caloosahatchee River, Sarasota Bay system, Hillsborough Bay, Old Tampa Bay, Boca Ciega Bay, Fenholloway River, St. Joseph Bay, St. Andrew Bay, Escambia Bay, Pensacola Bay and Perdido Bay. *Fish kills of various sizes have been noted in each of the areas listed. Fish kills in Tampa Bay and Escambia Bay have become fairly common in recent years.*

2. Physical Characteristics

a. Hydrology

Zone VII is an area comprising the Gulf Coast from Crystal River to Cape Romano. Most of the enclosed bodies of water in this zone have been modeled and verified by Ross for hydraulic behavior. current velocities and tide heights. flushing. biochemical oxygen demand, dissolved oxygen temperature, salinity, nutrients, and hurricane effects.

What is not shown in Table C-33 is a factor that has proven to be the *most important single factor in the flushing of Zone VII.* This factor *is the existence of gyres.* The existence of gyres has been demonstrated by the mathematical models. It is suspected that the existence of gyres is of equal importance for other nearshore regions.

In explanation of gyres and their influence on flushing the following is offered. The calculated current velocities in Tampa Bay were calibrated over one tidal cycle by comparison with field data furnished by the U.S. Corps of Engineers. Net velocities existing at each point in the bay were determined. The results clearly showed the existence of gyres.

b. Geology

The Central Barrier Islands have developed on a coast of moderate energy (Tanner, 1960) on which two prominent estuaries, Tampa Bay and Charlotte Harbor, exist. *The rivers are carrying little particulate load,* thus quartz sand is being introduced into the bays from the open Gulf. Oysters and other mollusk shells constitute a significant portion of the sediment. Mangrove and mangrove deposits are associated with the low energy estuarine and lagoonal strands. *Turbidity of the water occurs in portions of the estuaries and occasionally for considerable distance offshore.*

The beaches are discontinuous on the barrier island chain. Fine sand and coquina shell are the principal component. Dunes are lacking.

TABLE C-33

HYDROLOGY OF ZONE VII

	Mean Discharge (cfs)	Watershed Area (Sq. Mi.)	Diurnal Tide Range (ft.)
Tampa Bay System			2.0 - 2.8
Old Tampa Bay			2.3 - 2.8
Sweetwater Creek	25	29.5	
Rock Creek	45	38.2	
Double Branch	40	19.2	
Lake Tarpon			
Brooker Creek	28.6	68.3	
Additional Area	–	117.1	
Hillsborough Bay			2.8
Hillsborough River	671	646.4	
Palm River	62	45.2	
Alafia River	384	418.2	
Additional Area	–	92.6	
Lower Tampa Bay			2.0 - 2.3
Little Manatee River	186	205.2	
Manatee River	109	365.3	
Additional Area	–	124.4	
Boca Ciega Bay	–	65.3	2.1 - 2.3
Total	1,550.6	2,234.9	
Charlotte Harbor			1.7 - 1.9
Myakka River	359	540	
Peace River	1,267	1,367	
Additional Area	–	750	
Total	1,626	2,657	
San Carlos Bay			2.4 - 2.6
Caloosahatchee River	1,044	1,150	
Additional Area	–	200	
Total	1,044	1,350	

c. Chemistry

Nitrogen and phosphorus enter the water from the atmosphere, municipal and industrial wastes, fertilizers, and animal wastes. In Hillsborough Bay and Charlotte Harbor phosphate mining operations contribute major phosphorus burdens to the receiving waters (Alberts, 1970: U.S. Department of Interior, 1969). The available data indicate the greatest contribution of phosphorus to water is the direct result of the activity and interference of man. (Task Group Report, 1967).

The distribution and concentration of dissolved orthophosphate in Florida streams was summarized by Kaufman (1969). He indicated that the *orthophosphate content of streams in parts of the state can be correlated with phosphatic-rock formations in the drainage area. A secondary cause of elevated phosphorus was pollution*, a conclusion that was reported earlier by Odum (1953). The Alafia, Peace, and Fenholloway Rivers carried the greatest orthophosphate burdens in Florida although it should be noted that Kaufman's estimates of phosphate concentrations are greater by a factor of 2 to 3 than similar measurements made on the Alafia and Peace Rivers by the Department of Interior (1969) and Alberts (1970) respectively. The discrepancy may be a result of differences in the analytical methods used.

Dragovich (1963) indicated the concentrations of nitrate-nitrite nitrogen in 66 water samples collected between 1956 and 1957 ranged from 0.0 to 4.4 μg/l with a mean of 0.7 μg/l. The monthly distribution of nitrate-nitrite nitrogen was very irregular, and the concentration observed off Naples, Florida, was considered low by comparison to other marine environments. *Complete depletion of nitrate and nitrite in July, August, and October of 1956 was ascribed to phytoplankton utilization.* Nitrogen determinations in Boca Ciega Bay indicated the area has about four times as much total nitrogen as other estuarine systems of the Gulf and Atlantic coasts according to Dragovich and May (1962).

Alberts (1970) found the *phosphorus concentration in Charlotte Harbor was a function of salinity, and thus dilution was the major factor controlling the distribution of phosphorus in the water.* Albert's values for phosphate concentration in the Peace River are substantially lower than those reported by Donnelly *et al.* (1967) and the Department of Interior (1969) and averaged about 0.6 mg/l at the mouth of the Peace River.

The Department of Interior study of pollutional burdens in Tampa Bay shows that the major sources of phosphate are the Alafia River and U.S. Phosphoric Products. These sources discharge respectively 43,470 and 8,810 pounds per day of phosphates. Together these two sources account for 93.8% of the total phosphorus input into Hillsborough Bay from waste sources. The corresponding chlorophyll *a* measurements throughout the Bay averaged 35.15 μg/l indicating a high trophic level exists.

Concentrations of total phosphate in Hillsborough Bay ranged from 3/5 mg/l at the mouth of the bay to 7 mg/l at the mouth of the Alafia. Comparison of filtered and unfiltered samples indicated that greater than 95% of the phosphate was in soluble form.

Dragovich *et al* (1968) reported similar phosphate concentrations in Hillsborough, Old Tampa, and Upper Tampa Bays and that the phosphate concentration in the little Manatee River was approximately 2/3 that of the Alafia River.

The publication of Ketchum and Keen (1948) suggested high phosphorus concentrations as a causative agent in the red tide outbreaks.

While Ketchum and Keen's suggestion on the effect of *phosphorus* has been challenged (Grice, 1957), their *data* do *ilustrate large seasonal fluctuations in the concentration of this element.* It should be noted that Sarasota surface waters contain high phosphorus concentrations although Ketchum and Keen ruled out the possibility of terrigenous contributions because of the high salinity values (32 to 33°/00 of their samples.

In both the Peace and Alafia Rivers the phosphate concentrations showed a seasonal increase between December to the following June (U.S. Geological Survey, 1967).

3. Resident and Transient Marine Biota

a. Benthic Plants

Several recent studies have added significantly to knowledge of the species present and their distribution in the central and southern portion of the Florida Gulf coast. Dawes (1967) published a guide to the marine algae of Tampa Bay and vicinity in which he included 226 species. Dawes, Earle, and Crowley (1967) recorded 164 species from offshore along the southwest Florida coast, a previously unknown area. Dawes and van Breedveld (1969) added a number of new records for offshore species with their list of 115. Ballentine (1972) recorded 65 species as epiphytes of leaves of seagrasses in the Anclote River estuary at Tarpon Springs.

The most significant and scholarly of all publications on benthic algae of the eastern Gulf of Mexico, and the work contributing most to the knowledge of the coastal subregions, is that of *Earle (1969) on the brown algae.* She *divided the Gulf coast from the Mississippi delta to the Florida Keys into six zones or subregions* listed 72 species with distribution data and ecological notes. In 1972, Dr. Earle brought together all records of benthic algae of the Gulf of Mexico in Folio 22, Atlas of the Marine Environment, currently a total of 617 species.

b. Benthic Invertebrates

Benthic invertebrate communities in segments of this zone were evaluated by Gunter and Hall (1965) and Humm (1970). Significant invertebrate dominated ecosystems are *Spartina-Juncus* marsh, mangrove swamps, high salinity bays, marine grass beds, high energy beaches, oyster reefs and man-made substrates. Carolinian influence is most obvious in the marshy areas where *Juncus* and *Rhizorhora* occur together. Under such conditions Carolinian marsh species like *Littorina irrorata* and *Polymesoda caroliniana* occur next to mangroves harboring a West Indian fauna. Characteristic or dominate species for the ecosystems mentioned are listed in Table C-15. *Invertebrate ecosystems are endangered in this zone for more direct reasons than in the National Park. Channelization, dredge and fill operations, sea wall construction and various forms of pollution have altered whole bays and destroyed miles of productive marsh and associated benthic invertebrates.*

c. Fish and Fisheries

Inshore commercial fishery resources for Zone VII include mangrove snapper, red snapper, grouper, bluefish, crevalle, pompano, mojarra, spotted seatrout, spot, red drum, sheepshead, Spanish mackerel, snook, black mullet, flounder, blue crab, stone crab, pink shrimp, oysters, hard clam, and sponges.

Peak periods of fish abundance in estuaries are related to a) adult and juvenile migrations associated with spawning and developmental habits, b) feeding migrations, and c) tolerances and preferences for such other factors as water depth, bottom type, temperature, and salinity. In general, observations have shown that the *fish fauna of the eastern Gulf is more diverse and abundant from Tampa Bay south than in the northern sector.* Along the southern shore, a large number of fishes may be found at any season except in winter during periods of cold weather. Along the northern coast the fish fauna is largely limited to species of the temperate zone, and temperature related migrations consist of an inshore movement in spring followed by an offshore movement at the onset of cool weather in the fall.

Dredged access channels from the Gulf to coastal communities and finger canals within the communities also cause lowered populations of fish. The benthic oozes that collect in these canals support few macro-invertebrates necessary in the food chain of fish.

4. Man's Activities

Region VII is highly developed. Both residential and tourist oriented development is prevalent throughout the region. The total Gulf and estuarine shoreline is 1006 miles. Of this, 157.4 miles are beach, primarily Gulf beach rather than estuarine beach. Development is concentrated in many of the beach areas.

Over 8 million tourists a year visit Zone VII. Tourist activity is primarily water/beach oriented and hotels and lodging facilities are extensive along the Gulf. Tourist development can be found generally everywhere in the zone but is most heavily concentrated along the beaches and shoreline of Pinellas and Sarasota counties.

Public recreation and preservation areas include:

Anclote Key National Wildlife Refuge in Pinellas County,
Bahia Honda State Recreation Area on Anclote Key,
Caladesi Island Aquatic Preserve in Pinellas County,
Caladesi Island State Park,
Boca Ciega Bay Aquatic Preserve in Pinellas County,
Pinellas National Wildlife Refuge,
Passage Key National Wildlife Refuge,
Cockroach Bay Aquatic Preserve in Tampa Bay,
Oscar Sherer State Park in Sarasota County,
Port Charlotte Beach State Park in Charlotte County,
Island Bay National Wildlife Refuge in Charlotte County,
Cape Haze Aquatic Preserve in Charlotte County,
Pine Island Sound Aquatic Preserve in Lee County,
Pine Island National Wildlife Refuge,
Matlacha Pass National Wildlife Refuge in Lee County,
Darling National Wildlife Refuge in Lee County, and
Loreshan State Park in Lee County.

There is residential development all along the shoreline of Zone VII. In Pinellas County, this development is primarily year-round housing units. In the other counties, both year-round and vacation home development has taken place.

Industry in the zone is concentrated in the Tampa Bay area where there is extensive industrial and manufacturing activity. Tampa Bay has pollution problems resulting from industrial discharges as well as sewage contamination.

Over 25,000 acres of wetlands have been destroyed by dredge and fill development on Florida's Gulf coast. Another 27,000 acreas have been drained for mosquito control (McNulty, 1971). *These wetlands have lost their value as cover and food suppliers for fish, and in many areas the fish population has decreased accordingly.* Taylor and Saloman (1968) have studied this phenomenon in Boca Ciega Bay, as have Sykes and Hall (1970).

D. ZONE VIII

1. Summary

Zone VIII is distinctive for its extremely dissected coastline fringed by the Ten Thousand Islands and for one of the world's greatest mangrove stands. It is a unique area for North America. Drainage from the Everglades moves into the Gulf from this coastline, protected by the exceptionally broad continental shelf. There are extensive seagrass beds and significant stands of green algae of the Order Siphonales with the ability to colonize loose sediments. The shallow water of the area is not subjected to the low winter temperatures of more northern subregions with the result that specie diversity is greater, especially where salinites are not too low for marine species. Within the past two decades, the mangrove fringe of the Ten Thousand Islands has been eroding away, instead of expanding as in the past, as a result of the increasing activity of a boring isopod, *Sphaeroma terebrans* Bate (Rehm and Humm, 1972).

The Florida Keys are the most distinctive area and exhibit the greatest diversity of all. This 200-mile-long chain of reefs and islands is another unique area biologically of North America. The Gulf (north) side of this archipelago is shallow because of the broad continental shelf that extends off Zone VIII, but the Atlantic (south) side exhibits an extremely narrow continental shelf along which flows from the tropics one of the world's greatest surface currents, the Florida Current. Consequently, there is much movement of water over the reefs and among the islands, water that is highly stable in both temperature and salinity.

Under these circumstances, the zone has supported an extensive tropical coral reef for a long period of time and an exceptionally diverse algal flora of nearly 500 species. The islands are fringed by mangrove stands, and much of the continental shelf is covered by seagrass beds where loose sediments have accumulated and are sufficiently stable. The enemy of red mangroves, *Sphaeroma destructor*, is not attacking the mangroves of the Florida Keys.

There is concern that suspended sediment from dredging activity is destroying many of the living reefs of the Keys area. Zone VIII must be considered as a series of endangered ecosystems that are rapidly being altered by environmental perturbations resulting from interruption of natural freshwater run-off through the Everglades.

2. Physical Characteristics

a. Hydrology

Zone VIII is composed primarily of the water body known as Florida Bay. The area is bounded on the north and northeast by Florida Everglades; on the east and southeast it is bounded by the Florida Keys. Depths of the water body are exceeding shallow. It is flushed by an undetermined fresh-water flow originating in approximately 1000 square miles of watershed.

Tidal action and a possible west to east current parallel to the Gulf stream are the major factors in flushing of Florida Bay. The normal tidal range for Zone VIII is 0.7 to 2.5 feet.

b. Geology

The Ten Thousand Islands consist of a complex series of mangrove islands behind a poorly developed sand ridge that occurs between Cape Romano and Cape Sable. There is considerable seasonal influx of swamp water. The sediments are peat, muck, marl, and clay. Thus the coastal waters are turbid. Oyster bars and shoals occur in abundance.

c. Chemistry

Studies on phosphorus concentrations in *South Florida below lake Okeechobee* (Freiburger, 1972) *indicated the total phosphorus concentration averaged about 0.5 mg/l during the wet season and increased slightly in the dry season.* Many of the stations sampled had phosphorus concentrations less than 0.01 mg/l in either wet or dry season.

Freiberger's (1972) findings on the various forms of nitrogen in the southernmost portion of the Florida peninsula show ammonia to be the dominant species. During the wet season ammonia concentrations averaged 0.55 mg/l with a range of 0.01 to 14 mg/l. In the dry season, the ammonia concentration averaged 0.50 mg/l and ranged from 0.01 to 25 mg/l. Freiberger reported the average ammonia concentration in the Everglades in the dry season was 1.3 mg/l and probably reflected the activity of animals and waterfowl.

3. Resident and Transient Marine Biota

a. Benthic Plants

In the southern part of the eastern Gulf, centered in the area of the *Ten Thousand Islands* (Zone VIII), *is one of the greatest mangrove forests of the western hemisphere.* Red, white, and buttonwood mangroves generally reach their northern limit between Tampa Bay and Cedar Keys, but the black mangrove is continuous around the shores of the Gulf.

Mangroves exhibit zonation with reds at the edge of the sea, blacks in a second band, and whites and buttonwood as a landside fringe. They tend to accumulate debris, especially organic matter, and to build up the land. They serve as a wind break and protection from storms and contribute to some extent to the welfare of marine animals living along their fringe.

Seaward, the zone is bordered by small barrier islands while inland sea grass, marl prairies, and cypress swamps gradually become dominant. Much of the area is included in Everglades National Park.

b. Benthic Invertebrates

Benthic invertebrate communities in the zone were evaluated by Hudson *et al.*, 1970, and Tabb and Manning, 1961. Several inter-connected habitats or ecosystems with distinctive species can be identified. These include low-salinity marshes and prairies; mangrove dominated channels, sandy bay shores, and islands: marine grass beds: sedimentary bay bottoms and moderate energy sandy beaches on the seaward side of outer barrier islands. This shallow water zone is inhabited by many West Indian species that are increasingly rare north of Cape Romano especially in shallow water. Characteristic or dominant species for the ecosystems mentioned are listed in Table C-16.

It should be noted that the Everglades zone is perhaps the most productive coastal zone in Florida and is a major nursery ground for juvenile pink shrimp. Penaeus duorarum, as well as numerous other commercially important invertebrates and vertebrates. Since surface contours are extremely low and the water is shallow, the whole Everglades estuarine system is open to pollution *via* the surface film. *Oil spills in this zone would cause significant irreparable biological damage to a system that is already being modified.*

c. Fish and Fisheries

Inshore commercial fishery resources include mangrove snapper, red snapper, bluefish, pompano, spotted seatrout, Spanish mackerel, black mullet, blue crab, stone crab, and pink shrimp.

4. Man's Activities

There are few beaches in the region. *The majority of the region falls within the boundaries of the Everglades National Park.*

Except within the Florida Keys, there are almost no tourist or recreational facilities in the zone. Collier-Seminole State Park is located near the southern boundary of Collier County as is the Cape Romano Aquatic Preserve.

There is little residential or vacation home development in Zone VIII except in the Florida Keys.

E. ZONE XVI

1. Summary

Along shore there is clear, blue-green, high-salinity water because of the comparative narrowness of the continental shelf. The greater slope that results in a depth of about 60 feet one mile offshore also promotes greater temperature stability of inshore waters during both summer and winter. *The area is also influenced by the Loop Current of the eastern Gulf, especially during the warmer half of the year.*

Shallow shelf communities in the area are primarily Carolinian in composition. The lower depth limit of these communities extends to the edge of the continental shelf for numerous forms through, as depth increases, Carolinian representatives are gradually replaced by West Indian species. Significant ecosystems inhabited by benthic invertebrates include jetties and occasional rocky outcrops, high-energy beaches, and the sandy shelf zone. The seaward beaches of barrier islands in the northern Gulf are exposed to the full force of ocean waves. Organisms living in these high-energy areas escape the scouring force of wave action by burrowing in the sand. Conspicuous and abundant species are *Donax* and *Emerita*. The shelf fauna of the northern Gulf may be described as warm-temperature rather than tropical, and is comparatively rich with a significant amount of endemism. An anomalous inshore pocket of tropical species has been found in the extreme northeastern Gulf between Panama City and Destin.

Much commercial and sport fishing is done in the region. Commercial fishery resources include ten-pounder, mangrove snapper, red snapper, grouper, warsaw, king mackerel, Spanish mackerel, black mullet, and brown, white, and pink shrimp. In 1968, there were 7,319 fishermen working on 1,394 motor vessels and 2,644 fishing boats operating from Gulf coast ports in Florida. In 1969, approximately 50 vessels were added to the Gulf coast fleet, and in 1970, 33 were added. The trend in new vessels is toward larger, extended-trip vessels with extensive refrigeration equipment. The value of the fishing industry is probably three to four times the value of the catch as paid directly to the fisherman. This would put the value of the *Florida Gulf coast fishery* at anywhere from $94 million to $125 million per year. With the *potential* as predicted by Bullis (1968), *commercial fishing could become a leading industry in Florida.*

2. Physical Characteristics

The Inner Shelf off the Florida Panhandle Ria Coast is characterized by an abundance of relic sand shoals and bars. Off the Apalachicola Delta the ramp is a relatively broad, low energy littoral zone. It narrows westward resulting in a moderately high-energy littoral zone. The Floridan aquifer occurs at a shallow depth westward to beyond Panama City, Florida, where a submarine spring is known to occur.

The greater slope that results in a depth of about 60 feet one mile offshore also promotes greater temperature stability of inshore waters during both summer and winter. The area is also influenced by the Loop Current of the eastern Gulf, especially during the warmer half of the year.

3. Resident and Transient Marine Biota

Shallow shelf benthic invertebrates in the zone are primarily Carolinian in composition. The lower depth limit of these communities extends to the edge of the continental shelf for numerous forms though, as depth increases. Carolinian representatives are gradually replaced by West Indian species. Significant ecosystems inhabited by benthic invertebrates include jetties, and occasional rocky outcrops, high energy beaches, and the sandy shelf zone. Many hard substrate inhabitants are cosmopolitan in the northeastern Gulf, and a cross section of the community would include: *Liygda exotica, Tubularia crocea, Arbacia puntulata,* and *Leptogorgia virgulata.* The seaward beaches of barrier islands in the northern Gulf are exposed to the full force of ocean waves. Organisms living in these high energy areas escape the scouring force of wave action by burrowing in the sand. Conspicuous and abundant species are *Donax* and *Emerita.* The species listed in Table XVIe are distributed throughout the northern and eastern Gulf on high or moderate energy sandy beaches.

The high-energy sandy beach community intergrades with the broad shallow shelf community. Species to be found on rocky substrates in this community are listed in Table C-18d, while those associated with sand substrates are listed in Table C-15a. Unconsolidated bottoms are characterized by *Penaeus setiferus* associates, which include *Renilla mulleri*, onuphid tube worms, the crabs, *Calappa*, *Hepatus* and *Persephona*, the anemone *Paranthus rapiformis*, a number of gastropod species (e.g. *Murex*, *Busycon)*, and in their empty shells the hermit *Petrochirous diogenes*. The anemone *Calliactis tricolor* lives on shells occupied by pagurids. In *Penaeus aztecus* communities *Renilla* is replaced by *Astropecten;* and clams *Pitar chordata* and *Chione* are more abundant than in *P. setiferus* beds (Hedgpeth, 1954).

F. ZONE XVII

1. Summary

This zone is essentially a very shallow drowned karst plain with scattered outcrops of chert that project through a thin layer of sediment. Depths increase very gradually offshore. *Fresh water, discharged through marshes and small rivers, reduces the salinity along the coast and consequently oyster reefs are well developed. Marine grass beds are continuous for miles offshore. Major invertebrate communities are associated with oyster reefs, marine grass beds, unconsolidated substrates, and hard substrates.* Where the water is shallower than ten fathoms, Carolinian species predominate. The shelf fauna may be described as warm-temperate rather than tropical.

Among the fishers, there is a greater species diversity in the northeastern Gulf than in the northwestern part. In the former, many eurythermic tropical species are found that are possibly ecologically dependent upon the coral-sponge bottom community. Commercial fisheries resources for the region include menhaden, mangrove snapper, red snapper, grouper, spotted seatrout, southern kingfish, king mackerel, Spanish mackerel, black mullet, stone crab, and pink shrimp. *The "Florida Middle Grounds" are located in this zone; a natural rock outcropping that provides for a very high concentration of sport and commercial fishes.*

2. Physical Characteristics

The Drowned Karst of the Ocala-Middle Ground Arch is characterized by numerous low rock outcrops especially from depths of about ten meters and deeper and thin discontinuous recent sediments, mostly quartz. *The offshore ramp generally deepens at the rate of one foot per mile offshore.*

The continental shelf, though wide, is less so than in Zone XVII and the slope somewhat greater.

3. Resident and Transient Marine Biota

Along much of the eastern portion of the zone there are numerous low and small islands; these often with good stands of black mangroves and a few red mangroves in the southeastern segment. There are a number of spring-fed rivers and underwater springs throughout the zone that dilute the inshore Gulf waters at a rather constant rate. Only the Apalachicola River and relatively local run-off fluctuate considerably with rainy periods. Both the offshore algae flora, supported largely by limestone substrate, and the inshore flora are well-developed. Fresh water, discharged through marshes and small rivers, reduces the salinity along the coast, and consequently oyster reefs are well developed. Marine grass beds are continuous for miles offshore. Major invertebrate communities are associated with oyster reefs, marine grass beds, unconsolidated substrates, and hard substrates. Where the water is shallower than ten fathoms, Carolinian species predominate. Characteristic species are listed in Table C-27. Additional data are presented in Menzel's (1956) checklist. Distinctive Carolinian indicator species for the region include gogonians *(Leptogorgia virgulata, Muricea pundula)*, ahermatypic corals *(Astrangia solitaria, Phyllangia americana)*, and the hydroid *(Tubularia crocea)*.

Although a number of shelf species also frequent the adjacent coastal-estuarine areas, many do not tolerate fluctuating estuarine conditions and are excluded from strictly inshore waters. The open shelf harbors a benthic fauna heavily represented by flatfishes (Pleuronectiformes), sea robins (Triglidae), lizardfishes (Synodontidae), scorpionfishes (Scorpaenidae), and other such groups typically associated with a substrate of unconsolidated sediments. Proceeding seaward, change in faunal composition is gradual with no demonstrably abrupt boundaries paralleling the coast.

The Florida Shelf is particularly hamogeneous, with demonstrable similarities between ichthyofaunas of the northern and southern portions, no doubt a reflection of the similar calcareous nature of the substrate. Continuity of this biotope has been emphasized by Hedgpeth (1954), Briggs (1958), and Topp and Hoff (1972).

The areas making up the Florida Shelf (XVII, XVIII, XIX, and XXIV) can therefore be regarded, insofar as the benthic open shelf ichthyofauna is concerned, as a fairly homogeneous unit.

G. ZONE XVIII

1. Summary

The Florida acquifer (main potable water source of the area) occurs at shallow depths north of Tampa Bay. Any major dredging project would need to consider this situation. Offshore springs occur in the zone. Although some limestone occurs in this zone, few typical reef species are found in abundance. For example, certain gorgoniids and plexaurids, which are abundant in the Keys, range only halfway through this zone and are few in number. In contrast, certain hermatypic corals such as *Oculina* and *Siderastrea* and demosponges such as *Ircinia*, *Speciospongia*, *Verongia*, and *Hippiospongia* are abundant in the area. *These coral-sponge communities have, in fact, sustained the Tarpon Springs sponge industry for many years.* On at least one part of the shelf, in the vicinity of Sarasota, the offshore fauna below 20 meters has a more tropical facies than that found inshore. Although the continental slope is very poorly known, there are indications that it may harbor an interesting fauna including a number of unique species. Dominant species in trawl catches analyzed by Moe and Martin (1965) from the shallow shelf off Tampa Bay were, in order of abundance, pinfish, *Lagodon rhomboides* (Sparidae); pigfish, *Orthopristis chrysoptera* (Pomadasyidae); silver perch, *Bairdiella chrysura* (Sciaenidae); leopard sea robin, *Prionotus scitulus* (Triglidae); and blackcheek tonguefish, *Symphurus plagiusa* (Cynoglossidae). All are common and widespread, typifying the benthic fish fauna of the three areas. *Seasonally, pelagic schooling fishes* (e.g. baitfishes and mackerels) *contribute significantly to the fauna of the area, as well as to corresponding areas to the north.* Commercial fishery resources in this zone include mangrove snapper, mutton snapper, red snapper, yellow snapper, grouper, warsaw, spotted seatrout, white seatrout, sheepshead, king mackerel, Spanish mackerel, black mullet, pink shrimp, and sponges.

2. Physical Characteristics

The Inner Shelf off the Central Barrier Islands is characterized by quartz sand with some shell, Figure C-4. These sediments characterize the moderately broad littoral ramp offshore to the ten fathom contour. The Floridan aquifer occurs at a shallow depth from Tampa Bay northward; thus due caution should be taken in major dredging projects. Offshore springs occur as far south as Sanibel Island. Unconsolidated sediments, mainly quartz sand containing carbonates of biological origin, form the dominant substrate type. Only in the western segment off the Apalachicola River are there well-developed barrier islands and bays.

3. Resident and Transient Marine Biota

Benthic invertebrates in Zones XVIII and XIX are typically West Indian. Faunal boundaries cannot be established except in very shallow waters near the beach since many species (e.g. *Luidia senegalensis*, a West Indian species that is found as far north as the mouth of Tampa Bay) are wide ranging though their centers of distribution are in southern waters. *Seasonal range extensions accompany warm water intrusions in northern areas, as is the case for instance when repopulation occurs after unusually cold winters. Substrate is a major environmental factor in the distribution of species within the combined zones.*

Extensive grass beds, scattered limestone outcrops, and sediments consolidated by caralline algae provide centers of attachment for sessile invertebrates. On the basis of substrate type, three different, but interrelated communities, can be discerned: those species associated with unconsolidated sediments; those found on hard substrates; and species found in marine grass beds. Characteristic or dominant species found in each area are listed in Table C-15.

Although some limestone occurs in this zone, few typical reef species are found in abundance. For example certain gorgoniids and plexaurids, which are abundant in the Keys, range only halfway through this zone and are few in number. In contrast, certain hermatypic corals such as *Oculina* and *Siderastrea* and demosponges such as *Ircinia*, *Speciospongia*, *Verongia*, and *Hippiospongia* are abundant in the area. These coral-sponge communities have, in fact, sustained the Tarpon Springs sponge industry for many years.

H. ZONE XIX

1. Summary

The Florida Bay area is shallow with extensive seagrass beds and stands of green algae. The salinites are normally lower in this zone compared to other zones in the region due to seepage of low salinity water through the length of the contiguous coastal zone. Cold winter temperatures are rarely experienced with the result that biologically there is greater diversity with a predominance of tropical species.

Faunal transition on the Intermediate Shelf from south to north is gradual with Zone XIX containing a greater proportion of sea basses (Serranidae), snappers (Lutjanidae), porgies (Sparidae), and others of more tropical affinity. Toward the north the fauna is richer in drums and seatrouts (Sciaenidae) and other groups more characteristically associated with temperate climate.

Commercial fishery resources in Zone XIX include mangrove snapper, red snapper, grouper, bluefish, pompano, spotted seatrout, red drum, king mackerel, Spanish mackerel, silver mullet, black mullet, spiny lobster, stone crab, and pink shrimp.

2. Physical Characteristics

Florida Sound is a shallow protected area between the Florida Keys and the mainland southeastward of the Cape Romano Shoals. Fine quartz sand occurs nearly to Cape Sable whereas shell sands and muds are the dominant sediment type. Low energy conditions generally prevail in this area less than ten fathoms deep.

3. Resident and Transient Marine Biota

There are extensive seagrass beds and significant stands of green algae of the Order Siphonales with the ability to colonize loose sediments. The shallow water of the area is not subjected to the low winter temperatures of more northern zones with the result that species diversity is greater, especially where salinities are not too low for marine species.

Benthic invertebrates in Zones XVIII and XIX are similar; consequently, they have been discussed jointly in the Zone XVIII coverage.

Studies of the fish fauna that have been carried out at various places along the Florida west coast all indicated the presence of a warm-temperate assemblage. Even northern Florida Bay, at the southern end of mainland Florida, yielded many warm-temperate species.

I. ZONE XXII

Climatic data from Summary Area A (Figure C-2) can be considered representative of Zone XXIII; for specific baseline data and details the reader is referred to the discussion on climate presented in Section I.

Outer Mississippi-Alabama Shelf and upper portions of the De Soto Slope consist of clastic sediments that have prograded southward from the North American continent. At the present time, carbonate sands and muds blanket the area. There are prominent extinct reefs at the shelf margin.

Areas of upwelling in the Zones XXIII and XXIV are generally along the outer margins of the Loop Current. In the northeastern Gulf upwelling occurs along the edge of the shelf adjacent to the southern half of Florida. This upwelling zone occurs along the eastern boundary of the Loop Current and is generally not seasonal in nature. However, it has been noted that there is a lack of upwelling off southern Florida during years of high salinities in Florida Bay. Investigators at Florida State University and the University of West Florida have suggested that upwelling associated with the Loop Current also occurs in the De Soto Canyon area as well as in the vicinity of the Florida Middle Ground.

The eastern Gulf is markedly different from the western in that the subtropical waters of the Loop Current are responsible for the primary circulation characteristics of the region and also, for both the major shelf and offshore biotic regimes extant within the eastern Gulf. Major perturbations, resulting in eddy or gyre formation, derived from the main body of the Loop Current, are easily recognized and identified through the use of the bio-indicator technique. These occur primarily in Zones XV through XVII and XXIII and XXIV. These appear to be *seasonal occurrences for the most part and relate rather closely with major changes in the velocity field of the Loop Current itself, as well as to its seasonal geographic location. These perturbations have a major effect on regional weather patterns, as well as upon the shelf biota.* They are as yet only poorly known, other than as to their existence on a more or less annual basis. Seasonal variation in these highly important features is as yet undetermined.

The benthic fauna of these shelf and slope areas is clearly West Indian in composition and is best characterized by hard bottom sponge communities. The bathymetric distribution of decapod crustaceans is very wide in this area, and it is likely that other groups have similarly wide distributions. Although the outer shelf and slope of the eastern Gulf are poorly known, there is doubt that a faunal boundary exists between Zones XXIII and XXIV. *Inasmuch as this region extends from relatively shallow shelf waters to beyond the 1,000 fathom isobath, it includes* *a variety of biotopes which, insofar as the fishes are concerned, cannot be treated collectively.*

The shelf region, here delimited as a rather narrow band between 20 and 100 fathoms, supports an ichthyofauna similar to that of the inner shelf. Its shallower portions contribute both to the northern Gulf menhaden fishery and to an industrial bottomfish fishery. Significant inclusions in the latter are four species of Sciaenidae (Atlantic croaker, *Micropogon undulatus;* spot, *Leiostomus xanthurus;* sand seatrout, *Cynoscion arenarius;* silver seatrout, *C. nothus)* and sea catfish *(Arius felis),* longspine porgy *(Stenotomus caprinus),* and cutlass fish *(Trichiurus lepturus). Limestone outcroppings on the shelf of Zone XXIII support a reef fauna qualitatively similar to that of the Florida Middle Grounds.* These areas of hard bottom have long supported a valuable fishery based on red snapper, and form the mainstay of the northern Gulf party boat fishery.

De Soto Canyon cuts in from relatively deep water to approach the Florida Gulf Coast between Pensacola and Ft. Walton. It is an area of transient eddy current and associated phenomenon caused by the Loop Current during certain seasons of the year. It is a major area of pronounced upwelling, which enhances the development and support of a productive sport fishery, especially billfish and tuna. The waters over the outer shelf and slope also constitute a primary spawning ground for mackerel, dolphin, cobias, and other important species.

Like Zones XXV and XXVI, this essentially is an offshore zone with regard to its marine mammal fauna. However, past records have shown that there is considerable influence from more inshore zones, especially in the more northern or inshore parts of it. Species such as the common dolphin, the bottlenosed dolphin, and the spotted dolphin have been reported rather further offshore in this zone than in others in the eastern Gulf – probably due in part to the faster bottom-depth drop-offs in this area than off Florida, and thus the ecological boundaries as far as dolphin are concerned are not as strict. The more offshore species of Zone XXVI would also be expected here, including some "endangered" species of large whales. *As with zones elsewhere, marine mammals here should be capable of swimming out of man-influenced environmental disturbances.*

J. ZONE XXIV

Climatic data from Summary Area C (Figure C-2) can be considered representative of zone XXIV; for specific baseline data and details the reader is referred to Section I.

The *West Florida Shelf* between the 20-fathom and 100-fathom contour consists of several zones of calcareous sediments (Figure C-4). These sediments are in part relic. Three distinctive zones occur from an inner shell and quartz sand, to shell sand, to algae and oolitic sand and mud. The sediments are thin and discontinuous over limestone. Hermatypic corals occur in patches on the rock outcrops as far north as the Florida Middle Ground.

In the nearshore area off western Florida, there is a general northward, counter-clockwise current drift prevailing most of the year which is driven by the Loop Current and modified by the wind. At the shelf edge off the southern half of western Florida, upwelling generally occurs along the outer margin of the Loop Current bringing cooler, nutrient-rich waters to the surface. When sufficient data are available, mathematical models of the Loop Current and circulation on the continental shelf will be feasible. One such model has been developed for the indented section of the coast of western Florida from Cape San Blas to Tarpon Springs. It accounts for the existing circulation pattern in a well-mixed body of water under the influence of surface winds and current flowing by the open western side. Upwelling generated by the Loop Current appears to be responsible for the maximum on the southwest Florida shelf while the Mississippi and other river discharge along with cool meteorological conditions may be primarily responsible for winter peaks on the northern Gulf shelf.

In depths from about 30 to 200 meters, the benthic fauna of the Gulf of Mexico is generally West Indian in composition. This poorly known area is particularly well characterized by hard-bottom sponge communities. The distribution of decapod crustaceans is poorly known and bathymetrically very wide. *It is not* unlikely that other groups are also widely distributed and might occur at all depths in the southern Gulf. Most shelf areas of the eastern Gulf bear limestone ridges and outcroppings supporting a rich sessile biota and a benthic ichthyofauna clearly of tropical affinity. One of the best known and most heavily exploited examples of this biotope is the Florida Middle Grounds (in Zone XXIV) characterized by Moe (1963) as an area of high relief where hills and cliffs of up to seven fathoms have been recorded.

The most conspicuous fin-fish of such areas include the commercially important groupers of the genera *Epinephelus* and *Mycteroperca* and snappers of the genus *Lutjanus*. Collectively, these species make up one of the most valuable fin-fisheries of the eastern Gulf. The recent discovery of the sport fishing potential of the Gulf Loop Current, some 80 miles offshore in the Gulf of Mexico west of Tampa should stimulate offshore sport fishing in the central Gulf Coast area. Sizeable numbers of billfish have been found as well as concentrations of large snapper and grouper associated with the eastern end of the Gulf Loop Current (Old Salt, 1972).

This zone includes both the offshore marine mammals that might be expected primarily in Zones XXV and XXVI, and inshore species of cetaceans that might be expected in Zones XIV – XIX. *While any of the "endangered" species of cetaceans might be expected here, man's activities would be unlikely to disturb them to any significant degree, and as in the more offshore zones, the animals should be able to swim out of short-term disturbances.*

K. ZONE XXV

The Yucatan Channel and the Straits of Florida consist of the sills between Cuba and the Greater Antillian Island archipelago and the carbonate peninsulas of Yucatan and Florida. The sills are related to the volcanic, orogenic origin of Cuba and the upgrading and outgrading of carbonate deposits from Yucatan and Florida. Depths of over 12,000 feet occur in the Yucatan Channel. *As the Loop Current waters enter the Gulf of Mexico through the Yucatan Channel, the core of the current attains a velocity of more than 200 cm/sec (approximately 4 knots) in summer and diminishes to 50 cm/sec (approximately 1 knot) in October or November.*

Geostrophic-flow computations, based on data taken in May, 1970 (EGMEX I), show that the major flow of water is to the north through the Yucatan Straits flowing at 144 cm/sec along the western side. However, along the eastern side of the Yucatan Channel there was small southerly flow of water at 19-22 cm/sec. As the main body of water progresses northward into the Gulf, the velocity decreases abruptly to 60-67 cm/sec after passing the confines of the Campeche Banks. Within the Gulf the current on each side of the loop is largely contained in a band 90 to 150 km in width. The data from EGMEX I show that the Loop Current velocity increases to 159 cm/sec as it flows southward along the western Florida coast in the "upwelling" area in Zone XXIV. In the Straits of Florida, the velocity remains the same (150 cm/sec). The above mentioned geostrophic velocities agree with the current velocities of the EGMEX III survey which were measured directly with drogues drifting in the Loop Current at 150-200 meters depth (22° isotherm). The directly measured current velocities were 175-200 cm/sec in the Yucatan Straits; the velocity decreased to 50 cm/sec where the Loop Current turns east and increased again to 175 cm/sec as the waters moved south and flowed out in the Straits of Florida.

Above 25 to 30 million cubic meters of water per second flow into the Gulf through the Yucatan Straits, and approximately an equal rate and volume of water flows out through the Straits of Florida. By comparison, the amount of water discharged into the Gulf by the Mississippi River and numerous streams is small, being less than 25,000 cubic meters per second. The amount lost by evaporation is not known.

The deep water benthic fauna of the eastern Gulf contains both Atlantic and Caribbean species. *Though this fauna is imperfectly known, it seems certain that no faunal boundary exists between Zones XXV and XXVI;* thus these two basically West Indian areas have been combined. It is probable that fairly narrow bathymetric faunal zones are associated with sediment types and concentrations of organic nutrients on the deep slope. The number of individuals per species decreases rapidly below a depth of 130 meters and is depauperate compared to the deep Atlantic fauna. For example, of 220 brachyuran species reported from the Gulf, only one (an Oxystome) was found to occur below a depth of 1,000 meters. It is likely that other macroinvertebrate ephiphinal groups are similarly scarce in deep water.

The royal red shrimp (Hymenopenaeus robustus) is the fourth most important commercial species and occurs only in deep water (250-550 meters) over soft bottom from North Carolina to the Guianas. This shrimp prefers cold water between 8 and 12°C, and exhibits an offshore summer migration and inshore movement in winter. Spawning occurs all year, with a peak from January through May. Royal reds do not mature until then and live to at least five years of age (Anderson and Linder, 1971; Roe, 1969). Sea bob *(xiphopeneus kroyeri)* and the rock shrimp *(sicyonia brevirostris)* are additional shrimp now fished commercially in the Gulf of Mexico. Both species complete their life cycles outside estuaries or in waters where the salinity is at least 20°/oo. The sea bob resource is now fully utilized, but the fishery for rock shrimp is only a few years old, and its potential is still unknown. *In terms of importance to the fisheries of the eastern Gulf, this area is the primary avenue of transport for planktonic organisms of Caribbean origin as well as for certain large migratory fishes* (tuna, billfish, etc.) exploited seasonally along the shelf edge.

Zone XXV also includes the eastern portion of the Yucatan Shelf, a broad region of calcareous substrate supporting a benthic ichthyofauna similar to that of the Florida Shelf. In general, the zone would be similar to XXVI, but since a portion of the Yucatan Continental Shelf is included, some influence might be had from a more inshore population of cetaceans such as might be found in Zones XIV through XXIV. *Inasmuch as Zone XXV lies to the south of any potential human activity within the Gulf, and hence is "upcurrent," it seems unlikely that any disturbances (including oil spills) would affect the marine mammals found there.*

L. ZONE XXVI

Climatic data from Summary Area D (Figure C-2) can be considered representative of Zone XXVI for specific baseline data and details. The reader is referred to the discussion on climate presented in Section I.

The Eastern Gulf of Mexico Floor in the area of the Mississippi Fan and the adjoining portions of the De Soto and West Florida Slope and Escarpment is presently covered by two to three feet of foraminiferal clay, 11,000 years and younger. Late Pleistocene clastic sediments underlie these sediments in the area of the Mississippi Fan and the De Soto Slope whereas cretaceous and younger limestone occur and outcrop on the West Florida Escarpment and Slope. Salt domes are known to occur as far eastward as De Soto Canyon.

This deep water area of the eastern Gulf supports a varied pelagic fish fauna, including species of sport and commercial interest. According to Bright (1968) the Gulf of Mexico deep-sea bottom-fishes are primarily benthopelagic. This fauna is primarily an extension of the Caribbean ichthyofauna, with a small element derived from the Atlantic Ocean north of the Gulf with no significant amount of endemism. Species diversity and abundance is greatest in depths less than 1500 meters. Judging from Bright's collections at stations within area XXVI, dominant bottom fishes include the familes *Brotulidae, Macrouridae* and *Stephanoberycidae*. Of the 219 species of bottom fishes known from the Gulf of Mexico below 350 meters, 64 have ranges extending below 1000 meters. Collections of mesopelagic fishes from within and outside the Loop Current were reported by Zahuranec *et al.* (1970). Sixty-eight species of 23 families were collected, the most abundant belonging to the families *Myctophidae* (lanternfishes) and *Gonostomatidae* (bristlemouths).

The eastern border of Area XXVI supports seasonal populations of tuna and billfish. These have been of interest to both domestic and foreign long-living enterprises (Wise and Davis, in press), *and are receiving considerable attention from sportsmen.* This is almost completely an offshore zone, although a corner of it touches the Yucatan Shelf and hence some influence in the southwest part of it might be felt from the shelf fauna. As an offshore zone, the marine mammals to be expected there are all cetaceans and include primarily the large whales. In addition, one might expect to encounter the rough-toothed dolphin and the common dolphin; the long-snouted dolphin, and possibly the pygmy and dwarf sperm whales; the pygmy killer whale; and the beaked whales. *Some of the larger whales are listed as "endangered," but all of these, as well as the smaller whales and dolphins would be capable of swimming out of any sort of environmental disturbance caused by human activities.*

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The State University System of Florida Institute of Oceanography (SUSIO), contained within the State Universities' governing body, the Board of Regents, is a coordinating agency for inter-institutional oceanographic matters. The permanent professional staff is small. As such, for contracts with organizations outside of the State University System, SUSIO acts as the contracting and coordinating body by further subcontracting with selected individuals to assure the most highly qualified people for the scope of the contract. To this end, professional and technical people from government, private universities, and industry as well as from the state universities are utilized. Considerable success has been enjoyed in this approach of addressing interdisciplinary programs – both to advance scientific knowledge and to apply it.

On October 25, 1972 the majority of the participating authors assembled for a work seminar hosted by SUSIO in St. Petersburg, Florida. Representatives of Arthur D. Little, Inc., participated. Each author was first requested to divide the area in question into dissimilar regions based upon their respective disciplines and mark the boundaries on overlays for C&GS Chart #1007. Each individual presented and discussed regional boundaries as determined by his discipline. *Remarkable interdisciplinary agreement of dissimilar regional boundaries was apparent* before half of the presentations were completed. The remaining presentations reinforced this fact. Based on a composite of the respective overlays, the team jointly determined, by mutual agreement, boundaries of the major hydro-biological zones. The resulting chart, which represented the first requirement of this contract, was integrated with the efforts of the other two subcontracts to produce a consistent chart of the Gulf of Mexico and the U.S. coastal zone (shown as Figure C-1).

This report was prepared to characterize and document the hydrobiological zones that were collectively determined. Within each section of this report the editors have consolidated the individually addressed disciplines for the hydrobiological regions and zones from the reports of the participating authors. In an attempt to conform to the requested length limitation of this report, no attempt has been made to extensively cite, or present, scientific documentation of the characterization of the regions and zones. The boundaries are based on the professional judgment of the participating authors and editors, and the primary effort of this report is to depict dominant similarities within the regions and zones and dissimilarities between them. Where dissimilarities do not exist, we have defined what is contained in each region with respect to the disciplines.

Because of similarity in purpose to this report, a specific report developed by SUSIO is singled out for reference. (A copy has been provided to the prime contractor.) The report, *A Summary of Knowledge of the Eastern Gulf of Mexico, 1972,* was funded by and prepared in response to a request by the American Petroleum Institute (API).

The API report represents a compilation and evaluation of selected studies of the significant natural and artificial environmental characteristics of the eastern Gulf of Mexico. It was prepared by a group of qualified scientists collectively conversant with the major environmental aspects of the subject area.

The purpose of the report was to provide an overview of the current status of knowledge and information on continuing studies which are significant for a more complete understanding of the environment and ecology of the subject area. Selected investigations have been utilized by the respective authors and there has been no attempt to list or discuss all studies within the area.

While the referenced report does not specifically address the dissimilar hydrobiological areas determined for deep water port studies, it does contain, or reference, probably the most extensive compilation of information available for the eastern Gulf of Mexico. The additional details contained therein are directly applicable to the U.S. Corps of Engineers' contract. Since division of the Gulf is based on natural boundaries as determined by different disciplines, many of the included discussions in the API report do reference the same or similar hydrobiological areas as determined for A.D. Little. In such cases, sections or partial sections of the API report have been used directly in this report for A.D. Little.

Factors that might be affected by the construction and operation of a deep water port have been emphasized in this report; but the possible effects have not been discussed per se. All factors, whether vulnerable or not, certainly cannot be considered to be covered.

The documentation presented herein is based on currently available data; but not all of the data have been published.

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This document constitutes an abridged version of the report on dissimilar hydrobiological zones of the eastern Gulf of Mexico prepared earlier under the same Agreement No. A-10209 and submitted to Arthur D. Little, Inc., by SUSIO on 28 December, 1972.