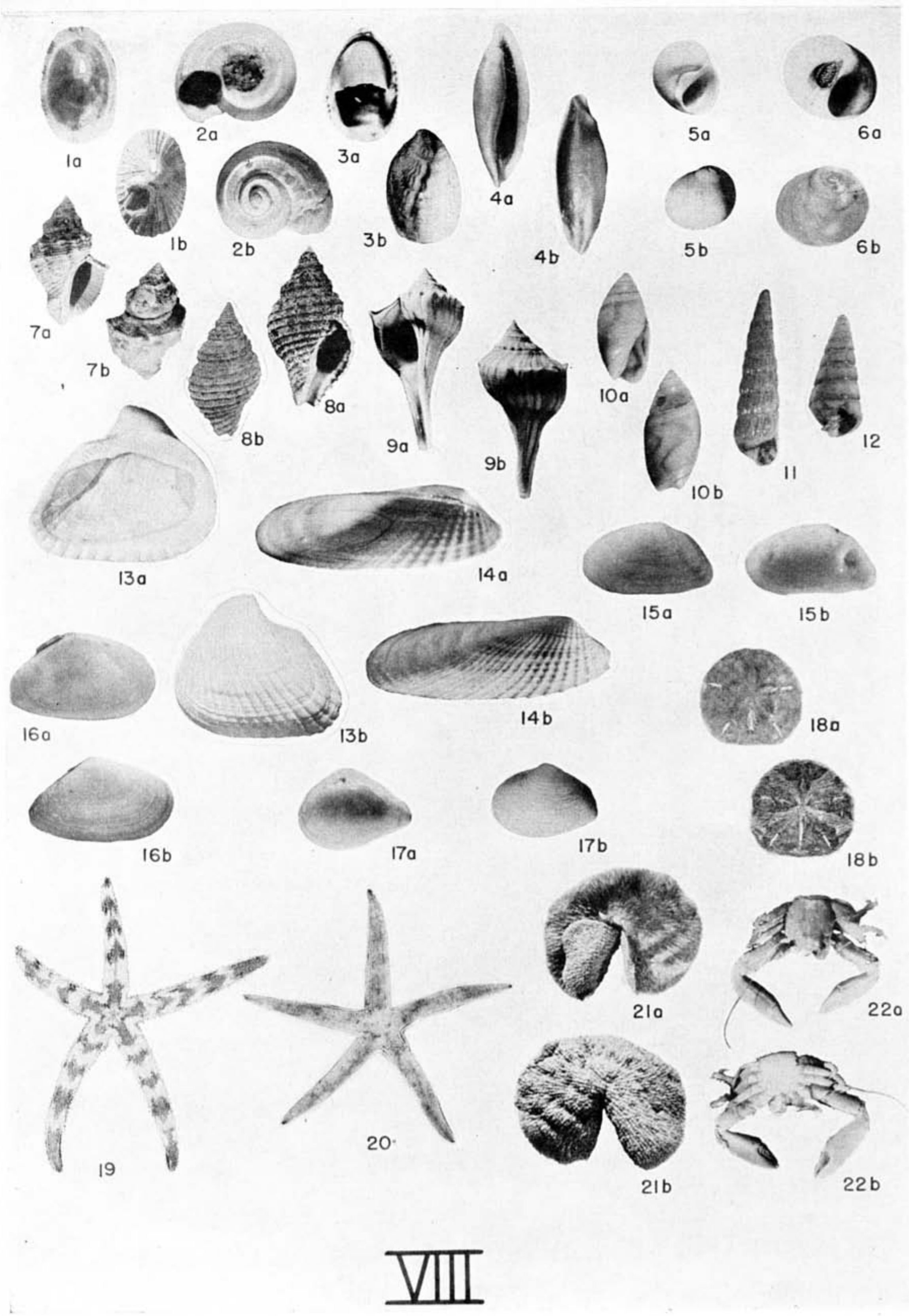
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VIII

PLATE IV

from the inlets in the form of tidal deltas. The physical characteristics of this environment in the Rockport region are tabulated in Table I. The hypersaline conditions are also typical of most of the Laguna Madre, but its isolation from a constant source of Gulf water results in only a few species living there, compared with the many species found in such areas as Redfish Bay.

The abundant rooted grasses and benthic algae associated with this environment support a large population of gastropods which either feed on or live upon the plants, as well as the many species which feed on decomposed plant material. These gastropods are excellent indicator species for this environment, because they are comparatively rare in most of the other depositional environments studied. Figure 20 shows the areal extent of the hypersaline shallow-bay environment in the Rockport region as illustrated by the distribution of the gastropod *Cerithium variabile.* This species is extremely abundant in the hypersaline shallow bays, although they occur intermittently in the other bays, in very shallow water close to shore, where salinities are usually much higher than in the rest of the bay (because of excess evaporation), and most of the bottom vegetation occurs. All of the species of invertebrates taken in this environment are listed in the Appendix, and the most abundant and characteristic species are listed here and illustrated on Plates V and VI.

GASTROPODS

Bittium varium (Pfeiffer, 1840)
Bulla striata Bruguière, 1792
Caecum nitidum Stimpson, 1851
Caecum pulchellum Stimpson, 1851
Cerithidea pliculosa (Menke, 1829)
Cerithium variable (C. B. Adams, 1848)
Crepidula glauca convexa Say, 1822
Haminoea succinea (Conrad, 1846)
Littorina irrorata (Say, 1822)
Melampus bidentatus Say, 1822
Modulus modulus (Linné, 1758)
Neritina virginea (Linné, 1758)
Niso interrupta Sowerby, 1834
Rissoina chesneli (Michaud, 1832)
Tegula fasciata (Born, 1780)
Truncatella pulchella Pfeiffer, 1839
Vermicularia fargoi Olsson, 1951

PLATE IV

VIII. INLET INFLUENCE (NON-RESTRICTIVE)

1. *Diodora cayenensis*, size—12×7 mm., a. interior, b. exterior.
2. *Cyclostremiscus trilix*, size—2 mm. diameter, a. aperture, b. top.
3. *Crepidula fornicata*, size—23×14 mm., a. interior, b. exterior.
4. *Neosimnia uniplicata*, size—6×3 mm., a. aperture, b. back.
5. *Natica pusilla*, size, 3×4 mm., a. aperture, b. back.
6. *Polinices duplicatus*, size—41×39 mm., a. aperture, b. back.
7. *Thais haemastoma haysae*, size—59×33 mm., a. aperture, b. back.
8. *Cantharus cancellarius*, size—30×17 mm., a. aperture, b. back.
9. *Busycon contrarium*, size—80×39 mm., a. aperture, b. back.
10. *Olivella mutica*, size—8×2 mm., a. aperture, b. back.
11. *Turbonilla incisa*, size—5×1 mm., aperture.
12. *Pyramidella crenulata*, size—5×2 mm., aperture.
13. *Eontia ponderosa*, size—32×28 mm., a. interior, b. exterior.
14. *Petricola pholadiformis*, size—23×8 mm., a. interior, b. exterior.
15. *Tellina versicolor*, size—12×6 mm., a. exterior, b. interior.
16. *Tellina alternata*, size—52×29 mm., a. interior, b. exterior.
17. *Corbula swiftiana*, size—6×4 mm., a. interior, b. exterior.
18. *Mellita quinquiesperforata*—size—53×46 mm., a. dorsal, b. ventral.
19. *Luidia alternata*, size—130×120 mm., dorsal.
20. *Luidia clathrata*, size—95 mm., dorsal.
21. *Renilla mülleri*, size—75×58 mm., a. ventral, b. dorsal.
22. *Petrolisthes armatus*, size—12×10 mm., a. dorsal, b. ventral.

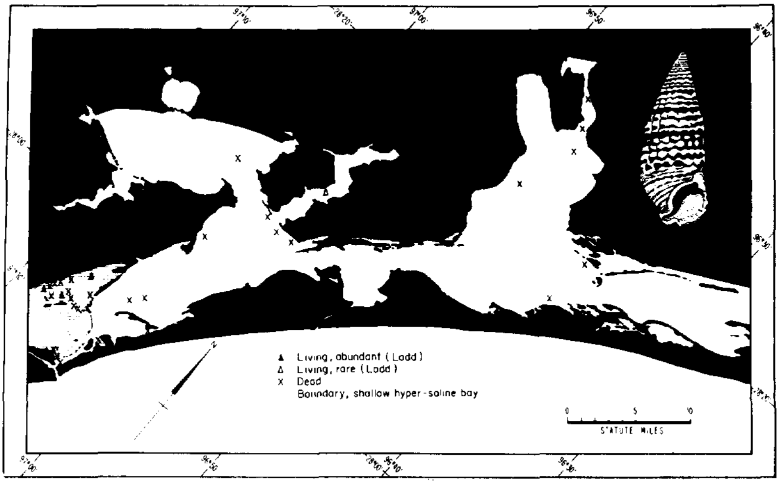


FIG. 20.—Distribution of gastropod, *Cerithium variabile*, indicative of shallow high-salinity and hypersaline bays and bay margins wherever benthic vegetation is abundant.

PELECYPODS

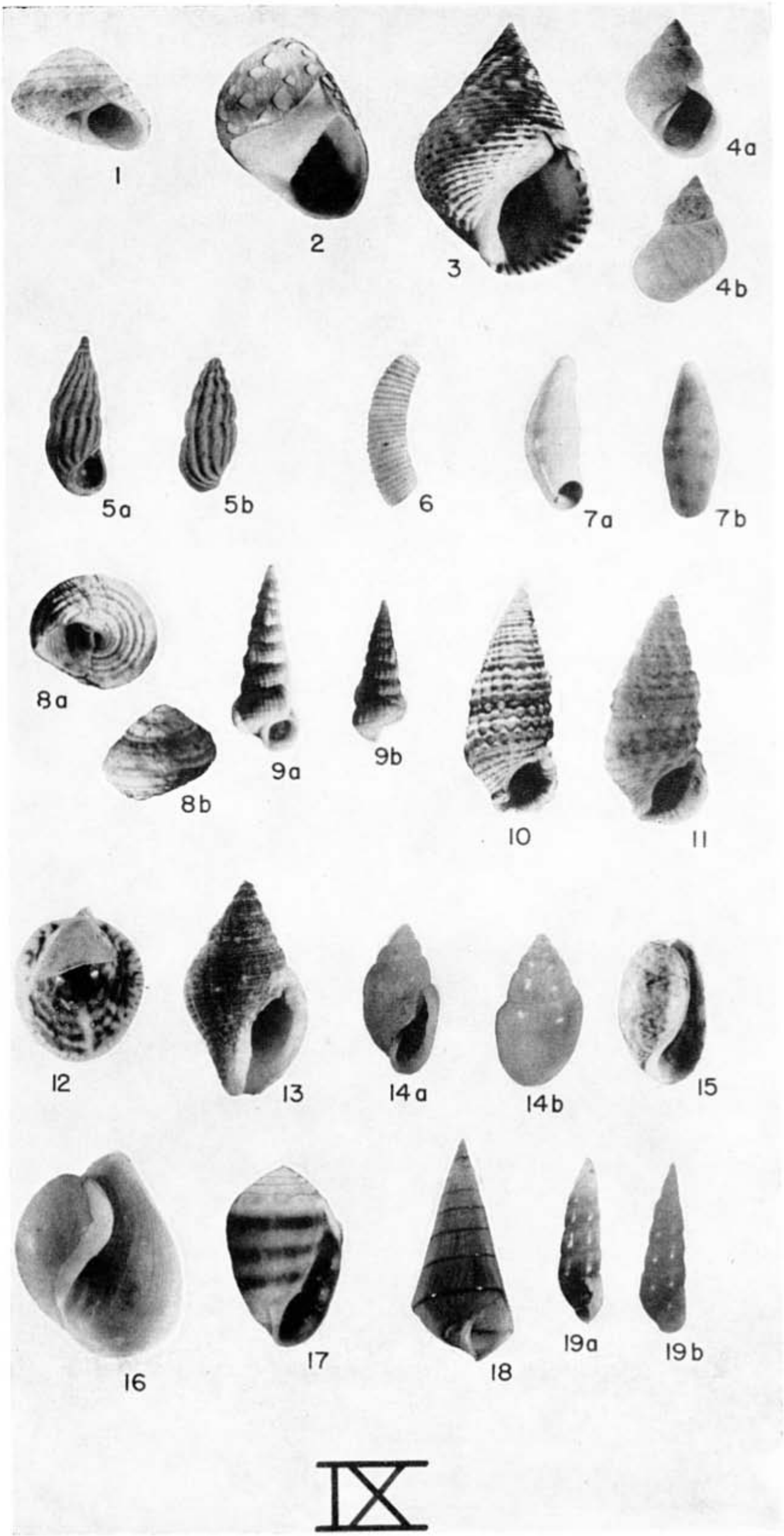
Amygdalum papyria (Conrad, 1846)
Anodontia alba Link, 1807
Anomalocardia cuneimeris (Conrad, 1846)
Brachidontes citrinus (Röding, 1798)
Cardita floridana (Conrad, 1838)
Laevicardium mortoni (Conrad, 1831)
Phacoides pectinatus (Gmelin, 1790)
Pseudocyrena floridana (Conrad, 1846)
Semele purpurescens (Gmelin, 1790)

The hypersaline bays have a larger standing crop (living populations at any one time) than any of the other bay environments, and at times the bottom is completely covered with living mollusks. The reasons for this high benthic productivity are not entirely evident, but they are surely related to abundance of marine

PLATE V

IX. SHALLOW, GRASSY, HYPERSALINE BAY AND LAGUNA MADRE
GASTROPODS

1. *Tegula fasciata*, size—11×8 mm., aperture.
2. *Neritina virginea*, size—11×10 mm., aperture.
3. *Littorina irrorata*, size—19×14 mm., aperture.
4. *Littorina nebulosa*, size—14×9 mm., a. aperture, b. back.
5. *Rissoina chesneli*, size—4×1 mm., a. aperture, b. back.
6. *Caecum pulchellum*, size—3×1 mm., side view.
7. *Caecum nitidum*, size—3×1 mm., a. aperture, b. back.
8. *Modulus modulus*, size—9×10 mm., a. aperture, b. back.
9. *Cerithidea pliculosa*, size—32×11 mm., a. aperture, b. back.
10. *Cerithium variabile*, size—12×5 mm., aperture.
11. *Cerithium*, species (juvenile), size—5×2 mm., aperture.
12. *Crepidula glauca convexa*, size—17×10 mm., aperture.
13. *Cantharus tinctus*, size—21×14 mm., aperture.
14. *Acteon punctostriatus*, size—5×2 mm., a. aperture, b. back.
15. *Bulla striata*, size—15×8 mm., aperture.
16. *Haminoea succinea*, size—12×9 mm., aperture.
17. *Melampus bidentatus*, size—11×7 mm., aperture.
18. *Niso interrupta*, size—5×2 mm., aperture.
19. *Odostomia bisuturalis*, size—5×1 mm., a. half aperture, b. aperture.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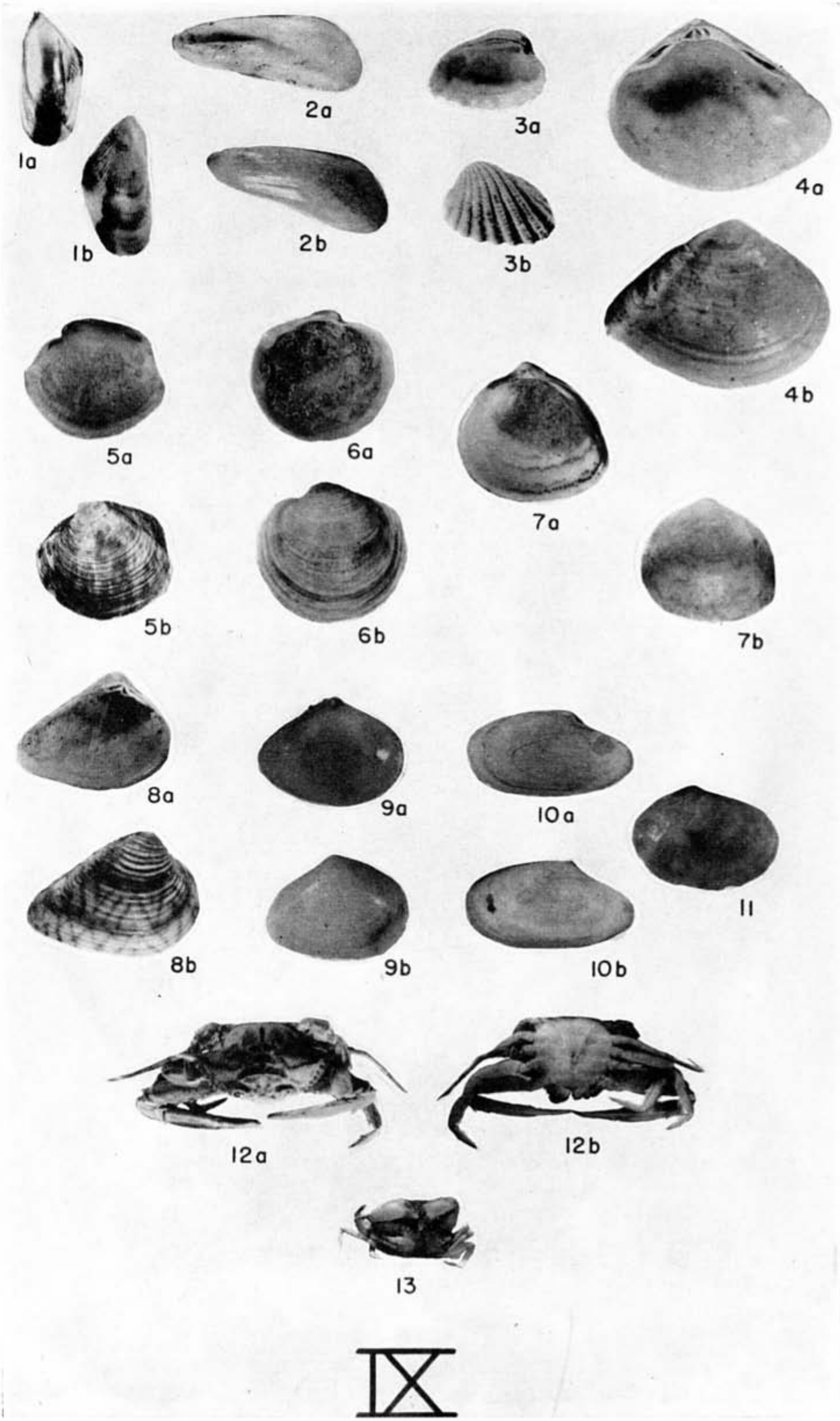
IX

Plate V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IX

Plate VI

vegetation. It is suspected that the warmer, shallow, and more transparent (because they are more protected and calmer) saline waters are nearly ideal for the photosynthetic production of plant material. This material provides food for algae feeders, a place of attachment for many sessile gastropods and pelecypods (*Crepidula*, *Brachidontes*, and *Amygdalum*), and a source of organic material on the bottom for the detritus feeders. With this increase in available organic material, there appears to be a corresponding increase in zooplankton which furnishes an abundant food source for the filter feeders.

ASSEMBLAGES OF LAGUNA MADRE

The Laguna Madre is a region with environmental characteristics similar to those of the shallow hypersaline lagoon and bays of the Rockport region previously discussed. This long narrow lagoon stituated between Corpus Christi and the Mexican Border (Figs. 21a and 21b and Fig. 1) is separated from the Gulf of Mexico along all of its 130-mile length by Padre Island, a barrier mostly less than a mile wide with no inlets to the Gulf of Mexico except at the extreme southern end, the Brazos Santiago Pass. The Laguna Madre is characterized by predominantly sand and shell sediments, extreme shallowness (from tidal flats to 10 feet), and by year-round hypersalinities. Before the construction of the Intracoastal Waterway, monthly averages of salinity ranged from 50°/₀₀ to more than 100°/₀₀ (Collier and Hedgpeth, 1950, p. 162). Recently, slightly lower salinities, with a high of 80°/₀₀ were reported by Simmons (1957, p. 167). Although salinity values higher than that of normal sea water (35°/₀₀) have been recorded in other Texas bays for extended periods, hypersalinities are generally considered abnormal elsewhere along the northern Gulf coast. Detailed discussions of the variations in salinity and temperature in the Laguna Madre can be found in Hedgpeth (1947), Collier and Hedgpeth (1950), Breuer (1957), and Simmons (1957). A more detailed description of the hydrography and geology of the entire Laguna Madre can be found in Rusnak (in press).

The very high salinities and high summer water temperatures (30°–35°C.),

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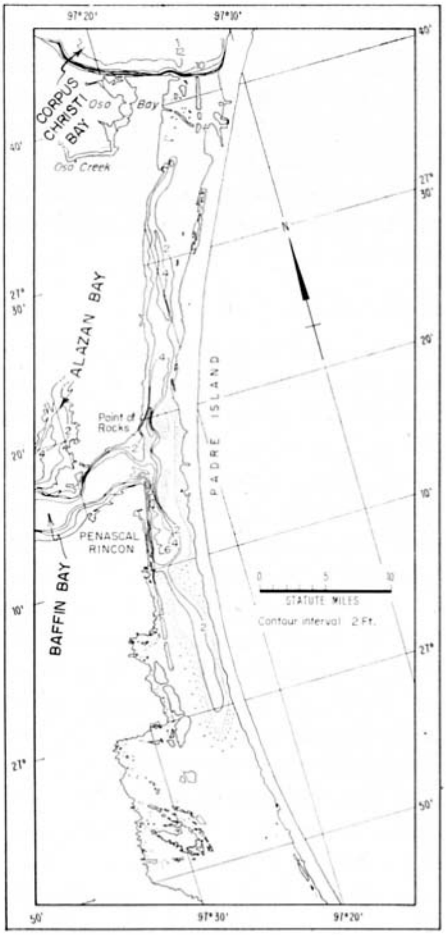
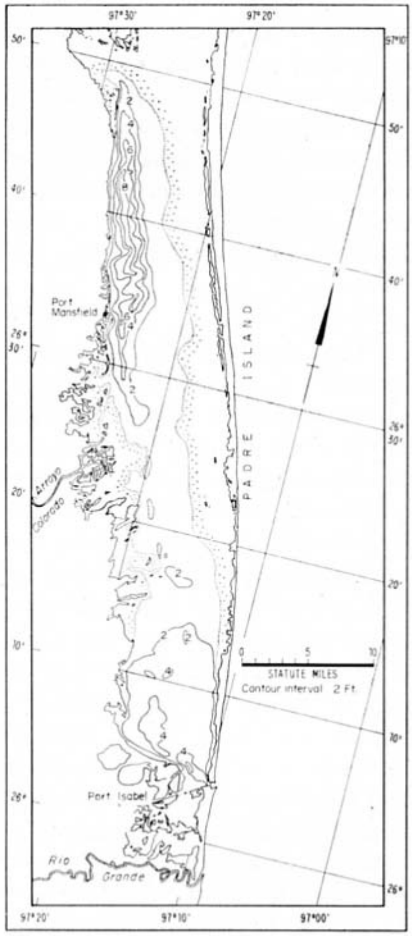
PLATE VI

IX. SHALLOW, GRASSY, HYPERSALINE BAY AND LAGUNA MADRE
PELECYPODS AND CRUSTACEANS

1. *Brachidontes citrinus*, size—18×9 mm., a. interior, b. exterior.
2. *Amygdalum papyria*, size—23×9 mm., a. interior, b. exterior.
3. *Cardita floridana*, size—15×10 mm., a. interior, b. exterior.
4. *Pseudocyrena floridana*, size—18×13 mm., a. interior, b. exterior.
5. *Phacoides pectinatus*, size—30×27 mm., a. interior, b. exterior.
6. *Anodontia alba*, size—65×60 mm., a. interior, b. exterior.
7. *Laevicardium mortoni*, size—15×14 mm., a. interior, b. exterior.
8. *Anomalocardia cuneimeris*, size—11×7 mm., a. interior, b. exterior.
9. *Tellina tampaensis*, size—10×5 mm., a. interior, b. exterior.
10. *Macoma tenta*, size—10×9 mm., a. interior, b. exterior.
11. *Semele purpurescens*, size 19×13 mm., interior.
12. *Portunus gibbesi*, size—49×22 mm., a. dorsal, b. ventral.
13. *Neopenope texana sayi*, size 8×7 mm., side or ventral view.



21a



21b

FIG. 21a.—Bathymetry and locality names of northern Laguna Madre (after Rusnak, in press, preliminary map).

FIG. 21b.—Bathymetry and locality names of southern Laguna Madre (after Rusnak, in press, preliminary map).

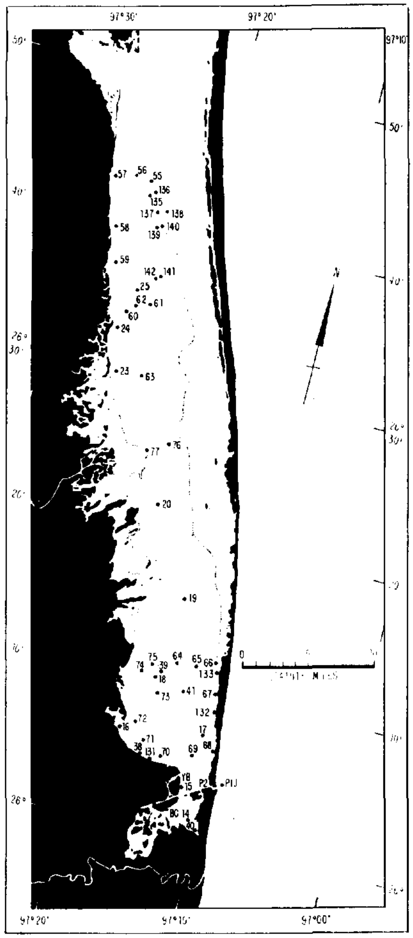
and the absence of exchange of water between the Laguna Madre and either the Gulf of Mexico or Corpus Christi Bay create a physiographic and biological environment distinct from those in other Texas bays (except for Redfish Bay). The range of physical variables for the various parts of the Laguna Madre can be found in Table I.

The Laguna Madre is of special interest, since it appears to be one of the most biologically productive areas in the world (Hedgpeth, 1947, 1958, pp. 716–17; and Simmons, 1957). Although the production of fish is two to three times greater in the Laguna Madre than the entire production of all other Texas bays, vertebrates are not the only organisms which are extremely abundant. Counts of 1,400–2,000 specimens per square foot of living individuals of the pelecypod, *Anomalocardia cuneimeris*, were made in the northern Laguna (Simmons, 1957, pp. 180, 192). The amount of attached bottom vegetation in some parts of the Laguna is also many times greater than that found in other Gulf coastal bays. Phytoplankton productivity may be very high, although only one productivity measurement has been made (by Simmons and W. H. Thomas for A.P.I. Project 51). A value of 908 micrograms of carbon fixed/liter/day was obtained in the northern Laguna, as compared with 350 micrograms of carbon fixed/liter/day for Breton Sound in the Mississippi Delta region, and 2–6 micrograms of carbon fixed/liter/day in the open Gulf of Mexico (Simmons and Thomas, personal communication). Populations of zooplankton (primarily copepods) are extremely high throughout the year. Simmons (1957, p. 177) reports counts of the copepod, *Acartia tonsa* Dana, of more than 7,000,000 individuals per liter. As in Redfish Bay at the north, the high productivity of planktonic organisms and benthic vegetation apparently contributes the organic matter needed to support the large population of mollusks which feed on detrital deposits.

From the analyses of the 121 biological stations (Figs. 22a and 22b) in the Laguna Madre, and from notes and specimens furnished by Mrs. Jeanne Frisbey of Port Isabel, Texas, it was possible to characterize five areas or environments (Fig. 23) based on the occurrences of 89 species of invertebrates. These five environments not only have distinct sediment and salinity characteristics, but also have distinctive faunal assemblages as well. Although the majority of invertebrate species taken in the Laguna Madre are also taken in smaller numbers in some of the other Texas bays and on the nearshore shelf of the Gulf of Mexico, a few species are apparently restricted to the Laguna. The assemblages characterizing four of these environments do not have exact counterparts elsewhere on the Gulf of Mexico coast, except possibly the Laguna Madre of Mexico (Hildebrand, 1958).

I. *Inlet-influenced, hypersaline lagoon.*—The extreme southern end of the Laguna Madre (Fig. 21b) may be described as an inlet-influenced, hypersaline environment, because it is strongly influenced by the flow of Gulf of Mexico water through the Brazos Santiago Pass. The presence of the inlet in this region permits an immigration of a considerable number of Gulf species into the Laguna, and in this respect the area closely resembles the inlets and shallow hypersaline bays near inlets farther north along the Texas coast. The distribution maps of two of the characteristic mollusks of the Laguna inlet-influenced environment (Figs. 24a and 24b), the gastropod, *Anachis avara semiplicata*, and the pelecypod, *Chinone cancellata*, demonstrate the boundaries of this assemblage. Although *Chione* is indicative of the inlet areas in the Laguna, and also of the margins of open high-salinity bays and sounds at the north, both regions have similar salinity and bottom sediment characteristics. Dead shell of *Chione* was taken in

22a



22b

FIG. 22a.—Biological station locations, northern Laguna Madre (mostly taken with minidredge).
FIG. 22b.—Biological station locations, southern Laguna Madre (mostly taken with minidredge).

the more hypersaline parts of the Laguna, but they have apparently been reworked from older deposits. Sixty-nine species of invertebrates were taken in this environment: 37 alive and 32 as dead shells, The more characteristic species are listed here, and the physical characteristics are given in Table I.

GASTROPODS

Anachis avara semiplicata (Stearns, 1873)
Bulla striata Bruguière, 1792
Crepidula glauca convexa Say, 1822
Littorina nebulosa (Lamarck, 1822)
Nassarius vibex (Say, 1822)
Neritina virginea (Linné, 1758)
Turbonilla interrupta Totten, 1835

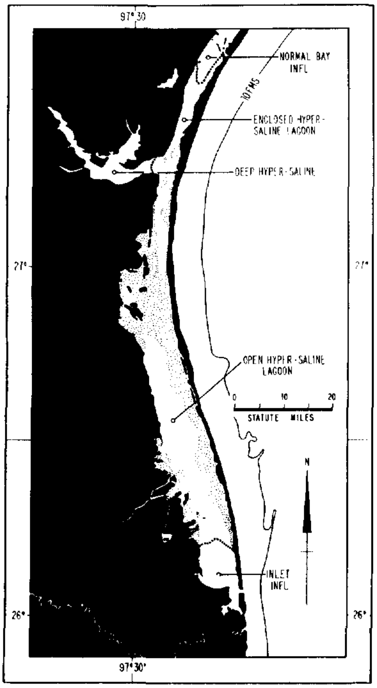


FIG. 23.—Areal distribution of macro-invertebrate assemblages in Laguna Madre.

PELECYPODS

Abra aequalis (Say, 1822)
Aequipecten irradians amplicostatus (Dall, 1898)
Anadara transversa (Say, 1822)
Anomia simplex d'Orbigny, 1842
Atrina seminuda (Lamarck, 1819)
Chione cancellata (Linné, 1767)
Cyrtopleura costata (Linné, 1758)
Macoma tenta (Say, 1834)
Nuculana acuta (Conrad, 1834)
Ostrea equestris (Say, 1834)

ECHINODERMS

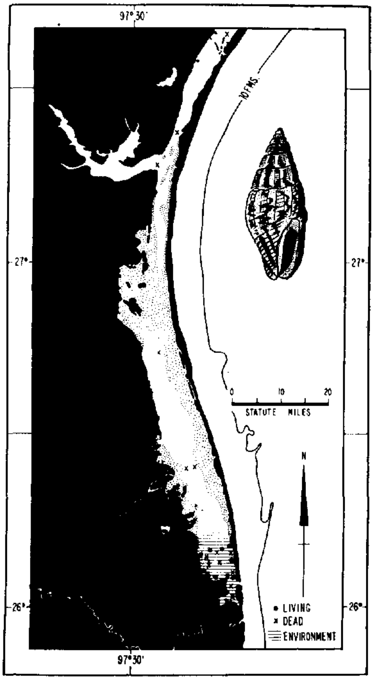
Lytechinus variegatus (Lamarck, 1816)
Ophiothrix angulatus (Say, 1825)

CRUSTACEANS

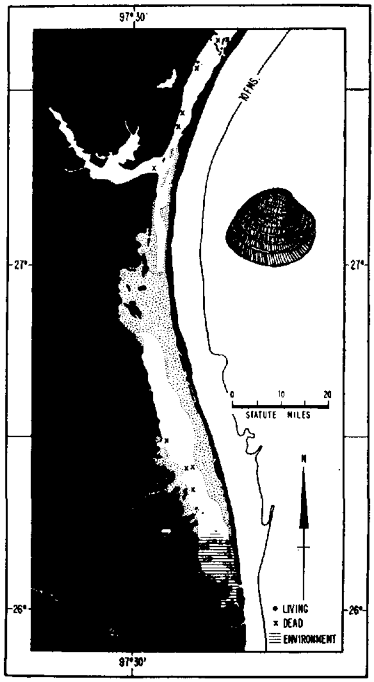
Crangon heterochelis (Say)
Neopenope texana sayi (Stimpson)
Portunus gibbesi (Stimpson)

This part of the lagoon, with normal marine conditions and comparatively stable physical conditions has by far the greatest diversity of species of invertebrates, although the observed number of individuals of each species is small. All of the species collected in this environment are given in Table II in the Appendix.

II. *Open shallow hypersaline lagoon.*—This environment (Fig. 23), adjacent to the inlet region and extending to the tidal flat and sand-dune region separating the southern and northern Laguna Madre, comprises the largest open-water area in the Laguna. The open hypersaline lagoon, like the shallow hypersaline lagoon near inlets, contains an abundance of marine vegetation, and this is one of the major factors influencing the composition of the assemblages. The ranges



24a



24b

FIG. 24a.—Distribution of gastropod, *Anachis avara semiplicata*, indicative of inlet-influenced hypersaline part of southern Laguna Madre.

FIG. 24b.—Distribution of pelecypod, *Chione cancellata*, indicative of inlet-influenced part of southern Laguna Madre and open bays on north.

of other physical factors characteristic of this environment are given in Table I. The distributions of two of the characteristic pelecypods, *Amygdalum papyria* and *Laevicardium mortoni*, are illustrated (Figs. 25a and 25b). The fact that *Amygdalum* occupies the western shore and *Laevicardium* lives primarily on the eastern shore can be partly explained by the abundance of vegetation on the western shore, utilized by *Amygdalum* for attachment, and the specific sediment types (Fig. 26) preferred by *Laevicardium* on the eastern side. The characteristic mollusks of this assemblage are here listed.

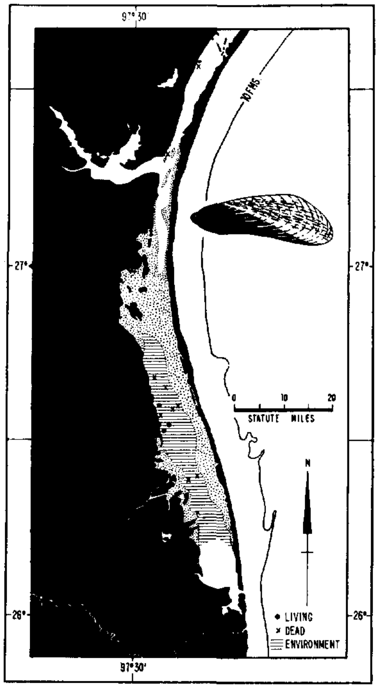
GASTROPODS

Bittium varium (Pfeiffer, 1840)
Haminoea succinea (Conrad, 1846)
Mitrella lunata (Say, 1826)
Truncatella pulchella Pfeiffer, 1839

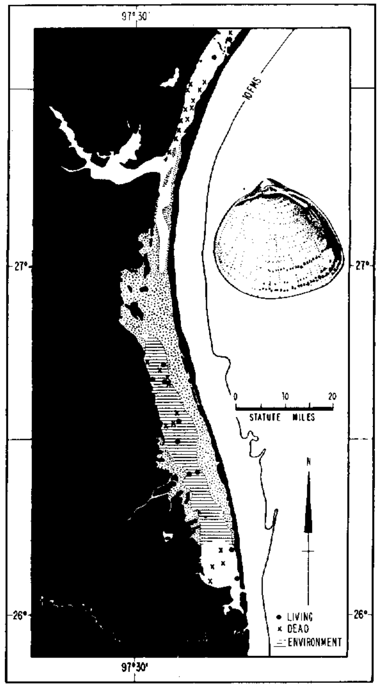
PELECYPODS

Amygdalum papyria (Conrad, 1846)
Brachidontes citrinus (Röding, 1798)
Laevicardium mortoni (Conrad, 1830)
Macoma brevifrons (Say, 1834)
Mactra fragilis Gmelin, 1790
Pseudocyrena floridana (Conrad, 1846)
Tagelus divisus (Spengler, 1794)
Tellina tampaensis Conrad, 1866

In all, 33 species were collected in the open hypersaline environment: 13 alive and 20 as dead shells. All of the species collected in this region are given in



25a



25b

FIG. 25a.—Distribution of pelecypod, *Amygdalum papyria*, indicative of vegetation-covered, open hypersaline part of southern Laguna Madre.

FIG. 25b.—Distribution of pelecypod, *Laevicardium mortoni*, indicative of shallow sandy part of open hypersaline environment in Laguna Madre.

the Appendix. Although the open lagoon region is characterized by relatively stable conditions, these conditions are at the upper limit of tolerance for most of the species of marine invertebrates. The number of living species is therefore sharply reduced from the adjacent slightly variable but more favorable inlet-influenced environment. Although there were fewer species, the number of living individuals of each species was high.

III. *Enclosed hypersaline lagoon.*—As can be observed in Figure 21a, the shallow central part of the northern Laguna Madre is hydrographically and geographically separated from the rest of the Laguna by a land area on the south and a sill of slightly submerged rocks across Baffin Bay. A series of islands separates this region from Corpus Christi Bay. Physical data indicate that this environment is characterized by excessively high summer water temperatures and more or less stable hypersalinity, ranging from 40 to 79‰.

The species living in the enclosed lagoon are found in other bays on the Gulf coast, but not in such large numbers or in the association peculiar to this area. The distributions of two of the characteristic pelecypods, *Anomalocardia cunei-*

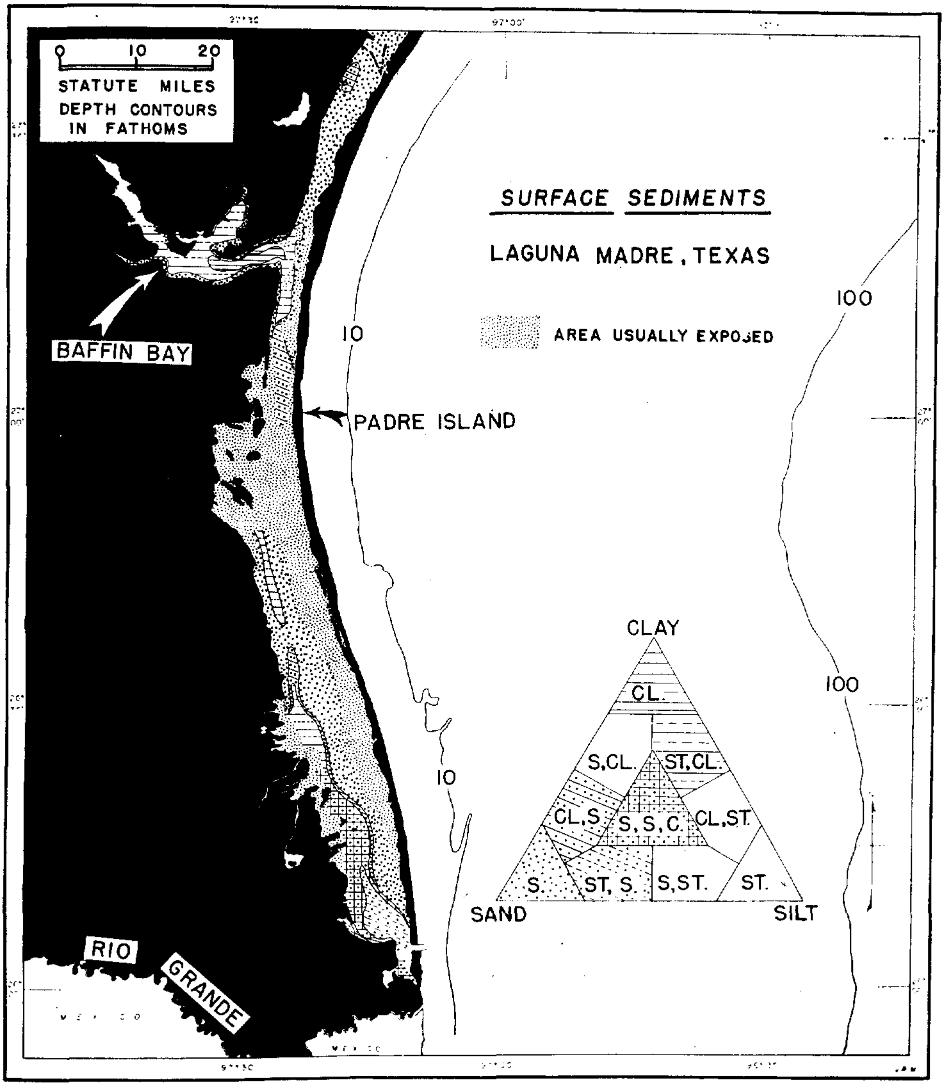
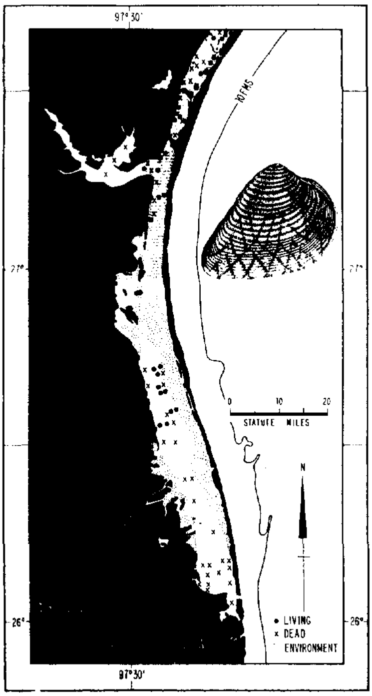


FIG. 26.—Distribution of surface sediments of Laguna Madre, based on percentages of sand-silt-clay (after Shepard and Rusnak, 1957).

meris and *Tellina tampaensis*, are shown in Figures 27a and 27b. The other two common mollusks are the gastropod, *Cerithium variabile*, and the pelecypod, *Mulinia lateralis*. All of the mollusks taken in the environment are given in the Appendix. Thirty-eight species of mollusks were collected in the enclosed lagoon, but only four were taken alive. The shells of the other species appear to be mostly reworked material from the dredge spoils of the Intracoastal Waterway and the



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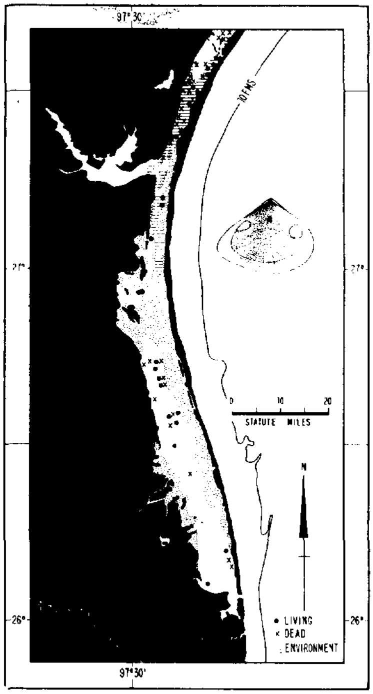

27b

FIG. 27a.—Distribution of pelecypod, *Anomalocardia cuneimeris*, characteristic of enclosed hypersaline environment in Laguna Madre.

FIG. 27b.—Distribution of pelecypod, *Tellina tampaensis*, characteristic of very shallow portions of enclosed hypersaline environment, Laguna Madre.

Pleistocene-Recent deposits on the western shore (Rusnak, in press).

Virtually the same molluscan assemblage is reported from the Laguna Madre de Tamaulipas of Mexico by Hildebrand (1958). Hildebrand lists *Laevicardium mortoni*, *Anomalocardia cuneimeris*, and *Mulinia lateralis* as living in areas with a salinity range of from 38 to 49°/₀₀.

Although only four species of shelled invertebrates were taken alive in this environment, the living individuals of these species per sample outnumbered all of the other individuals in the rest of the Laguna Madre. This population (at certain times of the year) constitutes the largest assemblage of living mollusks, except for the oyster reefs, along the northern Gulf coast, despite the fact that this is an area of very adverse physical conditions in terms of high salinities and temperatures, as well as extreme shallowness. Although adverse, the physical conditions are more stable in salinity range (always hypersaline) than the other parts of the Laguna Madre, resulting in high populations of a very few species.

IV. *Deep hypersaline bay, clayey substrate.*—Baffin and Alazan bays (Figs. 21a and 23) form the boundaries of the relatively deep hypersaline bay area of the

Laguna Madre. The physical characteristics of these bays are discussed by Breuer (1957) and Rusnak (in press), and are listed in Table I. The outstanding characteristics of Baffin Bay are sediments composed of more than 75 per cent clay, extremely variable salinities, ranging from less than $2°/_{oo}$ during periods of high runoff to well over $80°/_{oo}$ during droughts; and depths considerably greater than the adjacent parts of the Laguna Madre.

Of the total of 90 invertebrate species found in the Laguna Madre, only 8 species were taken in the Baffin-Alazan region, and of these eight, only one was taken alive during this study, *Mulinia lateralis*. This species has been taken alive in every other environment on the Gulf coast except the outer continental shelf. Six species of pelecypods were taken as dead shells, and *Anomalocardia cuneimeris* has been found living in Baffin Bay, and at times has suffered mass mortalities during freezes and extremely high salinities (Breuer, 1957). Most of the pelecypods were found as shell associated with plant debris along the shore, and may have drifted in from the central part of the Laguna Madre. Some dead specimens of the gastropod, *Acteon punctostriatus*, were collected in adjacent waters during the present study, and this species was reported as living in Baffin Bay by Hedgpeth (1958, p. 716). Since this environment is the most variable and adverse for marine life, it was not surprising to find the smallest number of species, as well as the least number of individuals in the Laguna Madre.

Although this environment would be difficult to detect in ancient sediments on the basis of macrofauna alone, a definite clue would be suggested by the presence of *Mulinia lateralis*, or small mactrid-like pelecypods, in a very fine-grained shale. *Mulinia* is an excellent indicator of environmental adversity, thriving best in very low or very high salinities, where most marine invertebrates have difficulty surviving. It can also withstand rapid and extreme hydrographic changes in a very short time. This species ranges from the New England coast in the north to South America (Abbott, 1954), and occurs in the fossil record as far back as the late Miocene (Maury, 1920).

V. *Hypersaline lagoon, influenced by adjacent lower-salinity bay.*—The extreme northern end of the Laguna Madre adjacent to Corpus Christi Bay constitutes the area designated as the hypersaline lagoon modified by enclosed, low-salinity bay waters (Fig. 23). The range of physical factors in this region is intermediate between that of the enclosed hypersaline lagoon and that of a "normal," enclosed estuary or bay, exemplified by Corpus Christi Bay. The range of physical factors is given in Table I. Like the enclosed lagoon, the sediments are predominantly sand and shelly sand (Fig. 26), and the water depths are between 2 and 4 feet (Fig. 21a). The primary difference between this and the adjacent enclosed lagoon is the periodic influence of lower-salinity waters entering from Corpus Christi Bay, permitting intermittent invasion by normal bay fauna.

The fauna of this environment is a mixture of species found in greater abundance in the enclosed lagoon, and species usually associated with intermediate to high-salinity bays. The proximity of a former inlet, Corpus Christi Pass (Fig.

21a) is indicated by the presence of old echinoid fragments and shells of *Crassinella lunulata*, *Lucina amiantus*, and *Dentalium texasianum*, typical of the inlet assemblage. None of the species of living invertebrates taken is abundant and distinctive enough to characterize this environment, although the composition of the assemblage may be diagnostic in indicating a mixture of environments. Fifty-four species of invertebrates were collected in this region: of these only 11 species were taken alive. The large number of invertebrate species and small number of living individuals per species suggest a favorable environment for marine organisms, but one which is not quite as stable as the inlet areas. The abundant and more or less characteristic species forming this assemblage are here listed, and all of the species collected are given in Table II in the Appendix.

GASTROPODS
Nassarius vibex (Say, 1822)
Odostomia bisuturalis (Say, 1821)

PELECYPODS
Crassostrea virginica (Gmelin, 1791)
Ensis minor Dall, 1899
Mactra fragilis Gmelin, 1790
Phacoides pectinatus (Gmelin, 1790)
Tellina tampaensis Conrad, 1866

CRUSTACEANS
Callinectes sapidus Rathbun

Those few species taken in the Laguna Madre, and not shown in the Rockport faunal plates, are included on Plates V and VI.

Generalizations concerning Laguna Madre.—In summary, the study of faunal assemblages in the Laguna Madre, where there is a wide range of values of physical factors, and varying degrees of stability of these factors, has supported the contention that the variability and adversity of the environments are two very important factors which influence the composition of biological assemblages. This thesis has been stated in part in "Liebig's Law of Minimum," restated by Taylor (1934, p. 378) as: "The growth and functioning of an organism is dependent upon the amount of essential environmental factor presented to it in minimal quantity during the most critical year or years of the climatic cycle." With this thesis in mind, observations in the Laguna Madre support the following series of criteria which may be useful in stratigraphic interpretation.

1. Under conditions involving variable and extreme salinities and temperatures, only a few species of marine invertebrates and individuals of each species may survive.

2. When hydrographic conditions are stable, but salinities and temperatures are in the extreme range, a few tolerant species may become extremely abundant.

3. When physical conditions are stable and within the normal range for marine environments, there will be many species but fewer individuals per species.

The same situation was found in the Mississippi Delta region. As a rule, the farther one moves away from the Delta, where there are lowered salinities and high turbidity, the more species and fewer individuals of each species are found in any one sample (Parker, 1956, pp. 368–69).

INTERPRETATION OF POST-PLEISTOCENE DEPOSITIONAL HISTORY OF A TEXAS BAY

In the course of earlier geologic studies carried out by A.P.I. Project 51 in the Rockport area, deep borings were made in the Guadalupe River Delta, San Antonio Bay, and Matagorda Island. Some of these borings were re-examined in the light of macrofaunal interpretations alone. Except for one boring in the Delta and another in Matagorda Island, in which a Porter soil sampler was used, all of the borings used here were taken with a light rotary drilling rig having a 3-inch-diameter core barrel. Details of these operations and lithologic interpretations of the cores can be found in Shepard and Moore (1955) and Shepard (1956).

FIG. 28.—Location of core holes, used to interpret post-Pleistocene history of deposition in San Antonio and Mesquite bays.

Shortly after these borings had been obtained, all levels of the cores with macrofaunal remains were studied and the faunas listed as to species and comparative abundance. This information was incorporated with evidence supplied by the foraminiferal assemblages and analyses of sediment coarse fractions. Some of the shell and wood material from various levels in these borings was age-dated by the Carbon-14 method by Magnolia Petroleum Company's Field Research Laboratory. All of this information was then used to construct a possible late Pleistocene and Recent history of deposition in the Rockport bays, and the formation of the barrier islands.

In order to demonstrate the application of data obtained from macrofaunal analyses to the interpretation of older environment of deposition, the drillings from one traverse extending from the Guadalupe Delta to the Gulf and another parallel with the barrier islands and perpendicular to the previous traverse (Fig. 28) were re-examined. A cross section to a maximum depth of 90 feet was constructed, and the macrofaunal assemblages listed for each depth sampled

(Fig. 29). A new cross section was then made giving the probable gross environments of deposition (Fig. 30). Since the picture of environmental or morphological changes differed slightly from that published by Shepard and Moore (1955) for San Antonio Bay, a check of the original environmental interpretations by the Foraminifera Laboratory at Scripps Institution was made by Miss Frances L. Parker. This check revealed that both the microfauna and macrofauna were in good agreement as to environments of deposition in the present cross sections. The interpretations gained from the study of the perpendicular section across lower San Antonio Bay (Figs. 31a and 31b) also agreed with that obtained from the Guadalupe River to Gulf section.

If one examines the interpretations in the major cross section (Fig. 30), it can be seen that the estuarine deposits lie just above the Pleistocene (?) unconformity, and appear to be contained behind a topographic high at approximately the same position as the present barrier island. Since sea-level was about 70–120 feet lower, the Gulf shoreline would have been a considerable distance seaward of its present position, and San Antonio Bay could have been an embayed part of the upper part of a long estuary, similar to the present Calcasieu and Sabine lakes. There could also have been sufficient tidal influence to keep salinities high enough for oyster-reef growth. As sea-level rose, the shoreline moved in toward its present position, the narrow estuarine part was inundated, and for a brief period open sound with a strong nearshore Gulf influence existed in what is now lower San Antonio Bay. With the slowing of the sea-level rise to its present level, continuous barriers were eventually formed, closing the embayment again, producing the present enclosed-bay condition. The strong marine or open Gulf influence apparently extended up into the bay area as far as boring location XS 386 (Fig. 28). One Carbon-14 date indicates that this marine influence occurred about 6,000 years ago. There is also a strong indication that some of these borings may have been made in a rather narrow channel characterized by strong currents, since the deposits at about 45 feet in depth at stations XS 382 to 386 contain a great many remains of organisms adapted to and dependent on high current velocities. These remains are especially noticeable in the borings located in San Antonio Bay between the pre-Recent sand ridges, known as Live Oak Ridge (Price, 1933). This suggests that Live Oak Ridge has always been dissected by the Guadalupe River. As sea-level rose to the base of the ridge, inlet conditions would have prevailed until the channel was filled with clayey deposits. A new lagoon was then formed back of the newly formed barrier that is now Matagorda Island. With the formation of Matagorda Island (or perhaps first a series of small islands and spits creating open-bay or sound conditions) an enclosed-bay condition developed. The present barrier appears to have been formed between 2,000 and 4,000 years ago.

It is far more difficult to trace the history of depositional changes in the barrier island from the macrofauna alone, because the same fauna that lives in depths of 20–30 feet seaward of the barrier would also become incorporated in

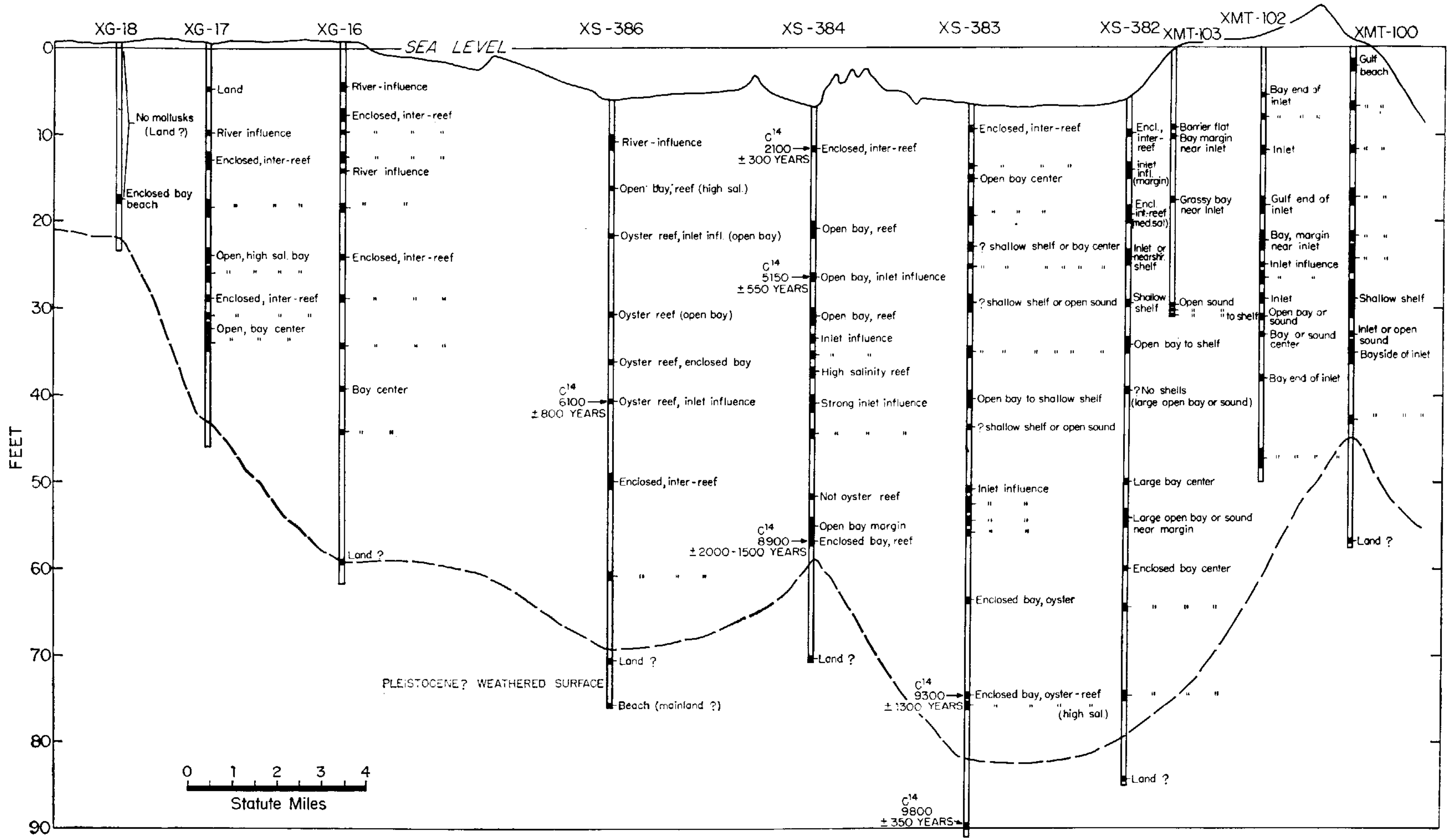

FIG. 29.—Macrofaunal assemblage interpretations for each depth sampled (plus a few cuttings) in drillings taken from Guadalupe River Delta to Matagorda Island Gulf beach.

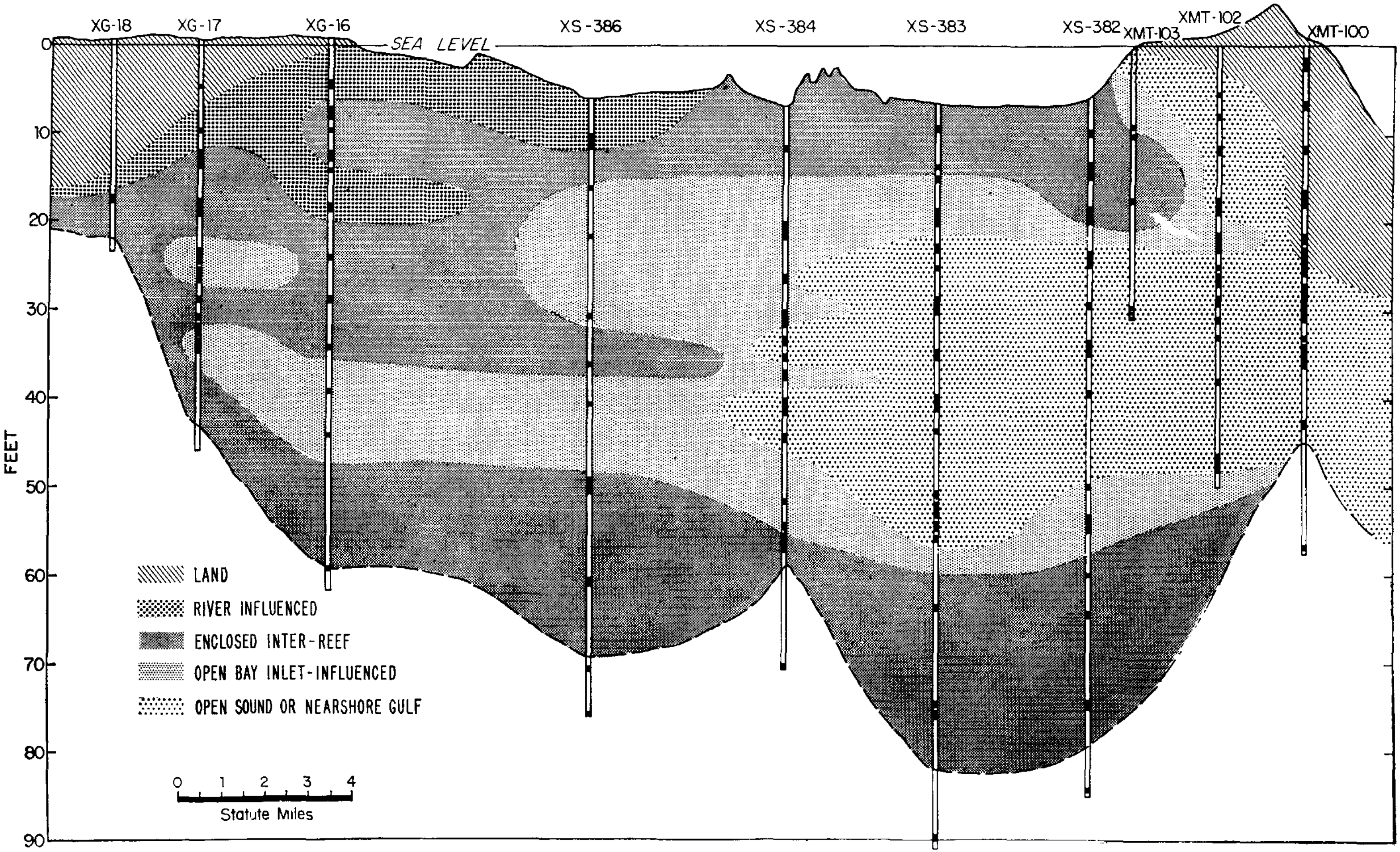

FIG. 30.—Generalized interpretation of cross section from Guadalupe River Delta to Gulf of Mexico, based on macrofaunal evidence.

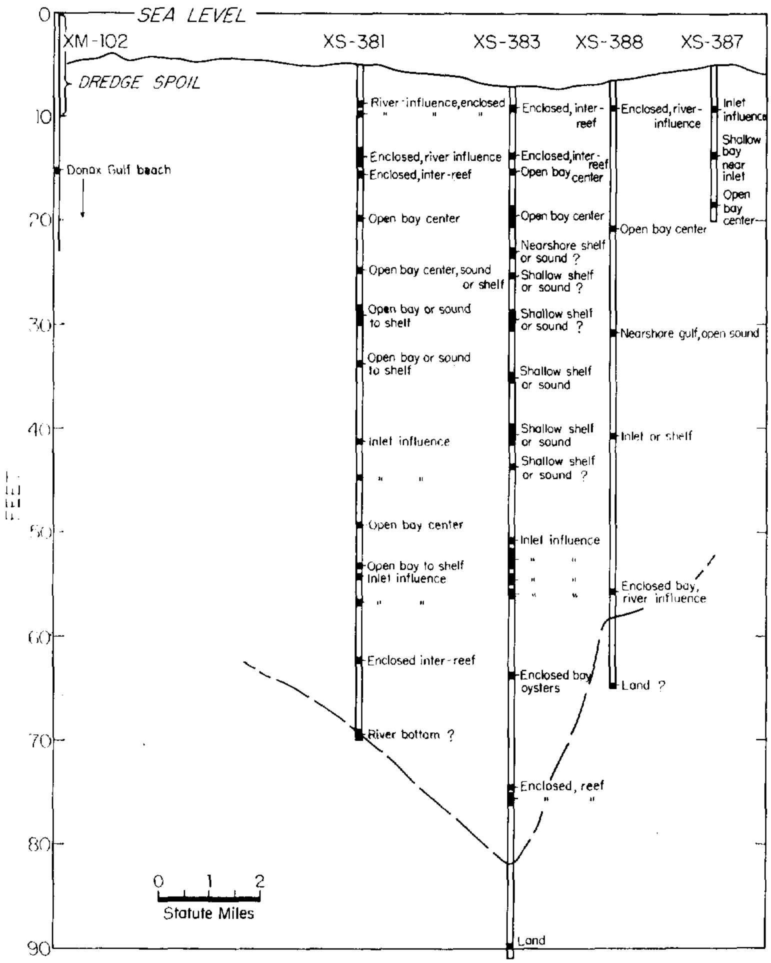

FIG. 31a.—Macrofaunal assemblage interpretation for each depth sampled (plus a few cuttings) in drillings taken in Mesquite Bay and lower San Antonio Bay.

the beach deposits. In general, the presence and comparative abundance of the pelecypod, *Donax*, which lives entirely in or just outside the surf zone is a good indication of Gulf beach deposits. About 27 feet below the land surface, in the boring XMT 100, deposits containing relatively few *Donax* and an abundance of shells more indicative of a marine environment well outside the surf zone and depths of 20–50 feet were identified. This evidence suggests that the present barrier did not form at this location simultaneously with the arrival of sea-level to that location, and that a wide inlet or very open sound preceded the formation of the barrier island (Shepard and Moore, 1955, p. 1567).

Implications of this study to interpretations of Tertiary sediments.—Most of

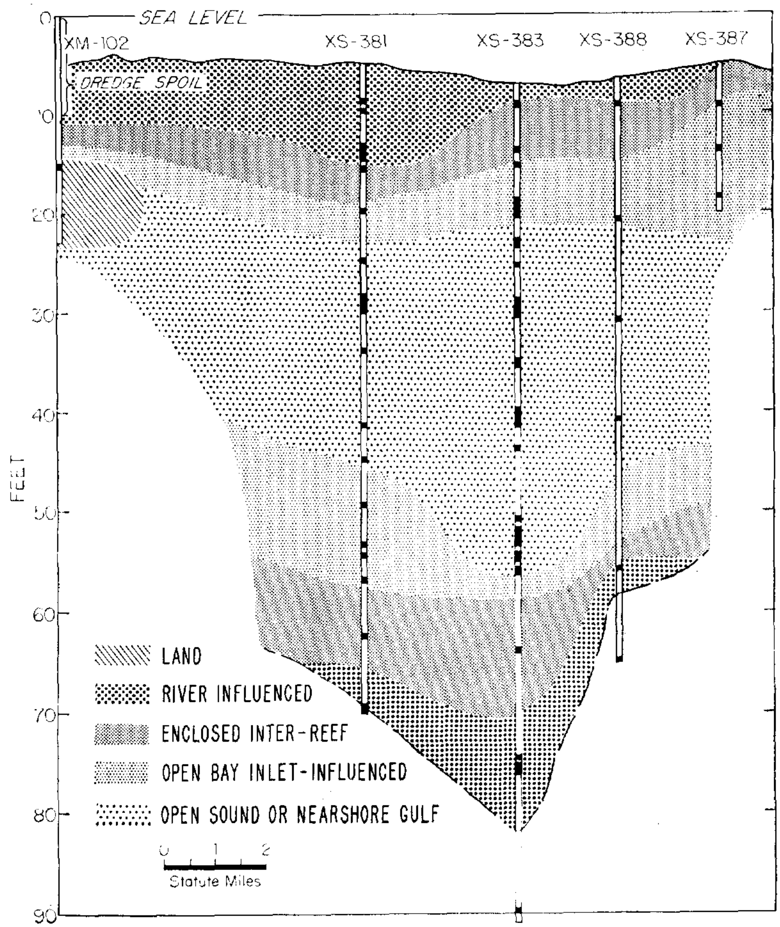

FIG. 31b.—Generalized interpretation of depositional history of Mesquite Bay and lower San Antonio Bay, based on macrofaunal evidence.

the important or characteristic species found in the sedimentary environments of the northern Gulf coast have also been found in the Pleistocene and Pliocene sediments of the Gulf and Atlantic coasts (Olsson and Harbison, 1953; Maury, 1920 and 1922; Parker, 1956, pp. 369–71). Some paleontologists and malacologists also consider many of the Miocene representatives of these species as the same as those living today, although this is a matter of personal opinion. What is more important, is that at least the Miocene and many of the Eocene and Paleocene forms are so similar in appearance to the Recent indicator forms, that only a well trained specialist can tell them apart. It was also observed from the literature that the same species were associated during the Tertiary as they are now. These observations suggest that evolution has been slow in many of the indicator mollusks; and the environments in which they lived during the Tertiary should have been similar. If the environments of the Tertiary were radically different, natural selection and environmental pressures would have brought about more morphologic changes and the same species or related species would not be found associated. There is always the possibility that the soft parts of these animals may have undergone considerable modification and adaptation that were not manifested in shell morphological changes. With these ideas in mind, some hope is offered in using the assemblages outlined in this paper to interpret Tertiary deposits.

Summary

The following criteria for the recognition of depositional environments have been formulated from assessing the relationships between the distribution of benthic invertebrates and the present-day environments in which they live. These criteria should be useful in recognizing older bay and estuarine environments of deposition. These environments and invertebrates typical of them on the northern coast of the Gulf of Mexico are illustrated diagrammatically in Figure 32.

1. River-influenced, low-salinity bays are characterized by two basic forms of shelled organisms: massive-hinged, chalky pelecypods of the genus *Rangia*, and small, rather high-spired gastropods belonging primarily to the family Amnicolidae. Both appear to be inhabitants of clayey sediments brought down by rivers, and are generally distributed in open bays in agreement with the distribution of river water.

2. Enclosed bays of low to variable salinity are characterized by an increased number of species of invertebrates, and the occurrence of mollusk reefs (on the Gulf coast, *Crassostrea virginica*). These reefs act as natural barriers to the circulation, serving to separate this environment from the high-salinity and river-influenced parts of the bays. The reefs themselves constitute a specific assemblage of filter-feeding attached forms, while the "inter-reef" assemblage consists of rather small, thin-shelled pelecypods, adapted for deposit-feeding in the finer sediments which settle out between the reefs. The enclosed-bay deposits may also show periodic fluctuations of low- and high-salinity faunas in regions where there are long-period fluctuations of rainfall. On the Texas coast, the oyster reefs near inlets also respond to alternate droughts and floods with the alternation of species of oysters: *Ostrea equestris* during high salinities and *Crassostrea virginica* during low-salinity periods.

3. Open high-salinity bays have a distinctive fauna which can be subdivided into two assemblages: that of the bay margin and the assemblage of the bay center. Although salinity appears to be the controlling factor for the gross high-salinity bay fauna, substrate and circulation seem to be responsible for the separation of this fauna into two assemblages. The bay margins are predominantly sandy as a result of wave and current action; therefore, the characteristic filter-feeding faunas are those adapted for life in the relatively well sorted sandy sedi-

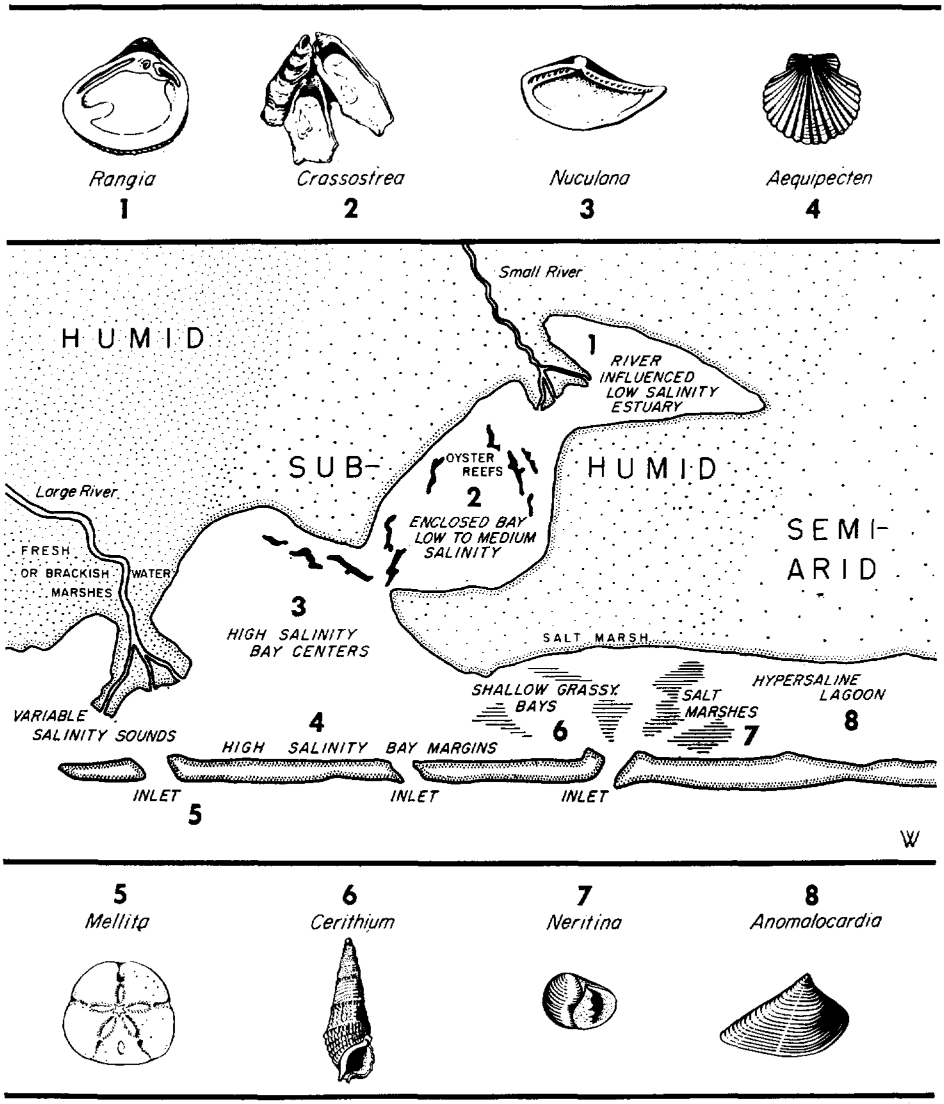

FIG. 32.—Diagrammatic representation of bay and lagoonal macro-invertebrate environments in relation to general climatic provinces. Figured species is not everywhere found in the Texas region, but represents genus found in these environments throughout North America. *Rangia* (1) also found at Delta shores and distributaries of large rivers. *Nuculana* (3) also common in variable salinity sounds and pro-delta slopes. *Mellita* (5) migrates through inlets into bays. Certain species of *Neritina* (7) also found in fresh- or brackish-water marshes near large river mouths.

ments. On the Texas coast, the predominant organisms in this environment are scallops (*Aequipecten*), clams (*Mercenaria* and *Chione*), razor clams (*Tagelus*), and certain gastropods. On the other hand, the sediments of the bay centers are predominantly clayey, and the assemblage characteristic of high-salinity bay centers includes small pelecypods and gastropods capable of remaining at the surface of these soupy sediments. This assemblage is more dependent on the organic detritus contained in these sediments for food than the bay margin assemblage. It is also significant that the fine clayey sediments often completely lack a fauna producing hard parts (except for shell swept in from neighboring environments). This may be a partial explanation for the apparent lack of fossils in many marine shales.

4. Inlet areas on the Texas coast are characterized by the largest number of species of invertebrates, as the strong tidal currents typical of inlets bring in both shallow nearshore shelf faunas and bay faunas. As a result of stable, normal oceanic salinities and greater depths in the inlets, most marine invertebrates are more apt to survive there. It is also significant that many of the inlet indicator forms are adapted for attaching to the bottom or to objects on the bottom, a necessity in these areas of strong currents and hard sand bottom. Inlets should be recognized in older sediments on a faunal basis by the presence of large amounts of sand and shell material, echinoderm fragments, and a mixture of bay, Gulf, and indigenous species.

5. Hypersaline bays and lagoons are inhabited by many of the same species occurring in normal-salinity bays and lagoons, but the composition of the assemblages is quite distinct. Both in hypersaline and very low-salinity regions, the variability and adversity of the environment determine the species composition and comparative abundance of each species. In extremely variable hypersaline areas, the number of species is very low, and the number of living individuals is small also. In stable hypersaline areas (and stable, very low-salinity waters), the number of species is still small, but the number of living individuals is extremely large. As the salinity decreases or increases to normal values (along with relative stability), the number of species increases and the number of individuals per species decreases.

6. Several assemblages are recognized in hypersaline waters which are distinct enough to be useful in determining ancient environments of deposition. These are: (1) *shallow hypersaline bays or lagoons near inlets*, characterized by large numbers of gastropods and certain pelecypods which migrate between gulf and bay; (2) *open shallow hypersaline bay or lagoon*, characterized by abundant pelecypods, usually attached to the prevalent bottom vegetation; (3) *enclosed hypersaline lagoon*, identified by only a few species of closely related pelecypods, occurring in tremendous numbers; (4) *deep hypersaline bay with clayey substrate and variable salinity*, containing very few species of invertebrates and only scattered living individuals of each; and (5) *hypersaline bay with lower-salinity bay influence*, characterized by dominant hypersaline species, mixed with normal bay fauna.

7. It was demonstrated with a series of shallow borings that the depositional history of a small area can be deduced from the analysis of the macrofaunal remains, if they are present, although the study of the sediments and lithology should not be neglected.

8. Most of the invertebrate species used as indicators in this paper have existed since late Tertiary time, and closely related forms, identical in appearance, and living in the same association have existed throughout the Tertiary. This suggests similar environments of deposition have also existed throughout the Tertiary and that present-day faunal interpretations should be useful in solving the history of an area.

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APPENDIX

TABLE II. **CHECK LIST OF INVERTEBRATES, BY ENVIRONMENTS, IN THE ROCKPORT, TEXAS REGION AND LAGUNA MADRE**

Species Rockport Region	River Infl.	Enclos. Bays	Low Sal. Reef	High Sal. Reef	Open Bay Center	Open Bay Margin	Inlet Infl.	Shallow Hypersal.
Littoridina sphinctostoma Abbott & Ladd, 1951 G	xxxxx	-----						
Macoma mitchelli Dall, 1895 P	xxxxx	xxxxx			-----	---		
Rangia cuneata (Gray, 1831) P	xxxxx	--x--				--		
Mulinia lateralis (Say, 1822) P	--x--	xxxxx			xxxxx	xxxxx	-----	-----
Tagelus plebeius (Solander, 1786) P	-xxx-				---	---		
Amphiodia limbata (Grube) E		xxxxx			xxxxx	xxx		
Anachis obesa (C. B. Adams, 1845) G		xxxxx		xxxxx	-----	-xxx-	xxxxx	--
Crassostrea virginica (Gmelin, 1791) P	-----	xxxxx	xxxxx	-xxx-	-----	-----	-----	---
Brachidontes recurvus (Rafinesque, 1820) P			xxxxx	--x--		---	---	
Bittium varium (Pfeiffer, 1840) G			-x-	xxxxx	-	---	-xx--	xxxxx
Crepidula plana Say, 1822 G		---	-x-	xxxxx	-xx--	xxxxx	xxxxx	-----
Mitrella lunata (Say, 1826) G			-xx-	xxxxx			xxxxx	-----
Anachis avara semiplicata (Stearns, 1873) G		--		xxxxx	-----	xxxxx	-xxx-	--
Anomia simplex d'Orbigny, 1842 P		---		xxxxx	-xx--	xxxxx	xxxxx	--
Astrangia astreiformis Milne-Edwards and Haime, 1849 Co				xxxxx		--	xxxxx	
Brachidontes exustus (Linné, 1758) P		---		xxxxx	xxxxx	xxxxx	xxxxx	xx
Bugula neritina (Linné, 1758) Br				xxxxx	xxxxx	xxxxx	xxxxx	xx
Crangon heterochelis (Say) Cr				xxxxx			xxxxx	
Diplothyra smithi (Tryon, 1862) P				xxxxx				
Ischnochiton papillosus (C. B. Adams, 1845) Chiton				xxxxx			xxxxx	
Menippe mercenaria (Say) Cr				xxx				
Neopenope texana sayi (Stimpson) Cr				xxxxx			xxx	
Odostomia impressa (Say, 1821) G		xx-		xxxxx		-xxx-	---	-----
Ostrea equestris Say, 1834 P				xxxxx			xxxxx	--x--
Petrolisthes armatus (Gibbes) Cr				xxxxx				
Seila adamsi (H. C. Lea, 1846) G				--x--			-----	
Thais haemastoma floridana (Conrad, 1837) G				xxxxx		-	xxxxx	x
Thais haemastoma haysae Clench, 1927 G			---	-x-			-x-	
Triphora perversa nigrocinta (C. B. Adams, 1839) G				----				
Anadara transversa (Say, 1822) P		---		xxxxx	xxx	--x--	xxxxx	--
Abra aequalis (Say, 1822) P	-	-----			--x--		xxxxx	------
Chione cancellata (Linné, 1767) P		---			xxxxx	-xxx-	xxxxx	-----
Diplodonta punctata (Say, 1822) P					-xx--	-x-		
Diplodonta semiaspera Philippi, 1836 P					-x-	-	-xx-	-
Ensis minor Dall, 1899 P		-xx--			xxxxx	xxxxx	---	
Loliguncula brevis (de Blainville, 1823) Ceph.					xxxxx		xxxxx	
Nassarius acutus (Say, 1822) G		---			-xxx-	---	-xx--	
Nuculana acuta (Conrad, 1834) P	--	-----			xxxxx	-xxxx	xxxxx	--
Nuculana concentrica (Say, 1824) P	-	-x-			xxxxx	---	---	
Pandora trilineata (Say, 1822) P					xxxxx	xxxxx	-xxx-	
Periploma fragile (Totten, 1835) P					-xxx-			
Retusa canaliculata (Say, 1827) G		-----			-xxx-	---	-----	------
Semele proficua (Pulteney, 1799) P		--			--x--		-xx--	-

Table II (cont.) - 2 -

Species	River Infl.	Enclos. Bays	Low Sal. Reef	High Sal. Reef	Open Bay Center	Open Bay Margin	Inlet Infl.	Shallow Hypersal.
Truncatella pulchella Pfeiffer, 1839 G					--			
Trachycardium muricatum (Linné, 1758) P					-xx--	xx-xx	xxxxx	
Anadara campechiensis (Gmelin, 1790) P		---			--x--	xxx	xxxxx	--
Tagelus divisus (Spengler, 1794) P					-----	xxxxx	-xx-	
Aequipecten irradians amplicostatus (Dall, 1898) P					---	xxxxx	xxxxx	x-
Astarte nana E. A. Smith, 1881 P						--x--	---	
Cerithiopsis greenei (C. B. Adams, 1839) G						--		
Cerithium variabile (C. B. Adams, 1848) G						--x--		xxxxx
Cyclinella tenuis (Récluz, 1852) P						-xxx-	-xxx-	
Cyrtopleura costata (Linné, 1758) P					--	----	----	
Dinocardium robustum (Solander, 1786) P						---	---	
Ervillia concentrica (Gould, 1862) P		---				xxxxx		
Laevicardium mortoni (Conrad, 1830) P		-				xxxxx	--x-	xxxxx
Littorina ziczac (Gmelin, 1790) G						-xxx-	xxxxx	
Lucina crenella (Dall, 1901) P		--			--	-----	-----	--
Lyonsia floridana hyalina (Conrad, 1846) P						xxxxx	-xx-	
Macoma constricta (Bruguiere, 1792) P					-----	-xx	-	----
Macoma brevifrons (Say, 1834) P						xxxxx	--	
Macoma limula Dall, 1895 P						x		
Mactra fragilis Gmelin, 1790 P						--x--		
Melampus bidentatus Say, 1822 G						-xx-		xxxxx
Mercenaria m. campechiensis (Dall, 1902) P					--	--xx-	xxxxx	
Mysella planulata (Stimpson, 1857) P		-----			-----	--x--	-xxx-	
Nassarius vibex (Say, 1822) G					-----	xxxxx	---	-xxx-
Neritina virginea (Linné, 1758) G						----		-----
Odostomia bisuturalis (Say, 1821) G						--		
Palaemonetes, sp. Cr.						xxxxx	xxxxx	
Periploma inequale (C. B. Adams, 1842) P						-xx--	-----	
Petricola pholadiformis Lamarck, 1818 P						---	---	
Polinices duplicatus (Say, 1822) G					-----	-xxx-	xxxxx	
Phacoides pectinatus (Gmelin, 1790) P						-----		--x--
Pseudocyrena floridana (Conrad, 1846) P						--x--		-----
Tellina alternata Say, 1822 P						x-	-x-	
Thyone mexicana Deichmann, 1946 E						xx		
Turbonilla incisa Bush, 1899 G					---	-----	-xxx-	
Vermicularia fargoi Olsson, 1951 G						-----	-----	-----
Bulla occidentalis A. A. Adams, 1850 G						--	--	-----
Cerithidea pliculosa (Menke, 1829) G						-----	-----	--x--
Macoma tenta (Say, 1834) P						x-	xx-xx	
Anadara brasiliana (Lamarck, 1819) P						--	-----	
Anachis avara similis (Ravenel, 1861) G							xx	
Arbacia punctulata (Lamarck, 1816) E							xxx	

Table II (cont.) —3—

Species	River Infl.	Enclosed Bays	Low Sal. Reef	High Sal. Reef	Open Bay Center	Open Bay Margin	Inlet Infl.	Shallow Hypersal.
Atrina seminuda (Lamarck, 1819) P							-xx—	
Busycon contrarium (Conrad, 1840) G							xxxxx	
Busycon spiratum (Lamarck, 1816) G							--	
Cantharus cancellarius (Conrad, 1846) G							xxxxx	--xx-
Cantharus tinctus (Conrad, 1846) G							xxxxx	
Cardita floridana (Conrad, 1838) P							-----	-----
Chaetopleura apiculata Say, 1839 Chiton							x	
Chione clenchi Pulley, 1952 P							-x	
Corbula contracta Say, 1822 P						---	xxxxx	
Corbula swiftiana C. B. Adams, 1852 P							-----	
Crassinella lunulata (Conrad, 1834) P					---	-x-	xxxxx	
Crepidula fornicata (Linné, 1758) G							-xxx-	-----
Crepidula glauca convexa Say, 1822 G						--x--	-xx--	xxxxx
Cyclichna bidentata (d'Orbigny, 1841) G							--	
Cyclostremiscus trilix (Bush, 1885) G							---	
Dentalium texasianum Philippi, 1849 Scaph		--			-----	---	-xxxx	
Diodora cayenensis (Lamarck, 1822) G						--	-xxx-	-
Donax variabilis texana Philippi, 1847 P						--	---	
Dosinia discus (Reeve, 1850) P					-----	-----	--x--	
Eontia ponderosa (Say, 1822) P							-xxx-	
Epitonium angulatum (Say, 1831) G							-x	-
Epitonium rupicolum (Kurtz, 1860) G							-x-	
Epitonium tollini Bartsch, 1938 G							--	
Hemipholas elongata (Say, 1825) B							xxxxx	
Heterocrypta granulata (Gibbes, 1849) Cr							xxxxx	
Kurtziella perryae Bartsch and Rehder, 1939 G							x-	
Labiosa plicatella (Lamarck, 1818) P							--	
Leptogorgia setacea (Pallas, 1766) Co							xxxxx	
Libinia emarginata Leach Cr				xx			xxxxx	
Littorina irrorata (Say, 1822) G						----	xxxxx	xxxxx
Lucina amiantus (Dall, 1901) P							-xxx-	
Luidia alternata (Say, 1825) E							x	
Luidia clathrata (Say, 1825) E							xxxxx	
Lytechinus variegatus (Lamarck, 1816) E							x	
Mellita quinquiesperforata (Leske) E							xxxxx	
Modulus modulus (Linné, 1758) G						----	--x--	--x--
Natica pusilla Say, 1822 G							-xxx-	-
Neosimnia uniplicata (Sowerby, 1848) G							xx	
Oliva sayana Ravenel, 1834 G							--	-
Olivella mutica (Say, 1822) G							--	
Ophiolepis elegans Lütken, 1859 E							xxxxx	
Ophiothrix angulata (Say, 1825) E							x	
Ovalipes guadalupensis (Saussure) Cr							xxxx	

Table II (Cont.) - 4 -

Species	River Infl.	Enclosed Bays	Low Sal. Reef	High Sal. Reef	Open Bay Center	Open Bay Margin	Inlet Infl.	Shallow Hypersal.
Pteria colymbus (Bolten Röding, 1798) P							-	-
Pyramidella crenulata Holmes, 1859 G							---	--
Quadrans lintea Conrad, 1837 P							--	
Renilla mülleri Kölliker Co							xxxxx	
Sinum perspectivum (Say, 1831) G							xxx	
Tellidora cristata (Récluz, 1842) P							-xxxx	
Tellina tayloriana Sowerby, 1867 P							--x--	
Tellina versicolor De Kay, 1834 P							--x--	
Terebra dislocata (Say, 1822) G							x	
Turbonilla hemphilli Bush, 1899 G							-----	-
Turbonilla interrupta Totten, 1835 G							--x--	
Vitrinella, sp. G							-x	
Amygdalum papyria (Conrad, 1846) P								-xx-
Anodontia alba Link, 1807 P						---	---	xxxxx
Anomalocardia cuneimeris (Conrad, 1846) P						--x--	-----	xxxxx
Brachidontes citrinus (Röding, 1798) P								xx
Caecum nitidum Stimpson, 1851 G								-----
Caecum pulchellum Stimpson, 1851 G								-----
Fasciolaria hunteria (Perry, 1811) G								---
Haminoea elegans (Gray, 1825) G						--	-	-----
Laevicardium laevigatum (Linné, 1758) P						--		---
Melanella conoidea (Kurtz and Stimpson, 1854) G								--
Niso interrupta Sowerby, 1834 G								----
Prunum apicinum (Menke, 1828) G								--
Rissoina chesneli (Michaud, 1832) G								---
Semele purpurescens (Gmelin, 1790) P							-	--
Tegula fasciata (Born, 1780) G								-----

Laguna Madre Region	Inlet-Hypersal.	Open Hypersal.	Enclos. Hypersal.	Deep Hypersal.	Low Sal. Bay Infl.	Hypersal.
Aequipecten irradians amplicostatus (Dall, 1898) P	xxxxx				-	
Anachis avara semiplicata (Stearns, 1873) G	xxxxx	--	-		-	
Anachis obesa (C. B. Adams, 1845) G	-x					
Anadara brasiliana (Lamarck, 1819) P	--					
Anadara transversa (Say, 1822) P	--x--	-			--	
Anomia simplex d'Orbigny, 1842 P	--x--		--		---	
Atrina seminuda (Lamarck, 1819) P	--					
Cantharus cancellarius (Conrad, 1846) G	-xx-					
Cantharus tinctus (Conrad, 1846) G	xxxxx					
Chione cancellata (Linné, 1767) P	xxxxx	--	--		--	
Crangon heterochelis (Say) Cr	xx					
Crepidula glauca convexa Say, 1822 G	xxxxx	-x	--		--	

Table II (Cont.) - 5 -

Species	Inlet Hypersal.	Open Hypersal.	Enclos. Hypersal.	Deep Hypersal.	Low Sal. Bay Infl	Hypersal.
Crepidula fornicata (Linné, 1758) G	-					
Crepidula plana Say, 1822 G	--x--				-	
Cyclinella tenuis (Récluz, 1852) P	-					
Cyrtopleura costata (Linné, 1758) P	xx					
Diplodonta semiaspera Philippi, 1847 P	--				-	
Epitonium multistriatum (Say, 1826) G	--		-			
Iscnochiton papillosus (C. B. Adams, 1845) Chit.	-x					
Littorina angulifera (Lamarck, 1822) G	xxx					
Littorina nebulosa (Lamarck, 1822) G	xxx					
Littorina ziczac (Gmelin, 1790) G	xxxxx					
Lytechinus variegatus (Lamarck, 1816) E	x					
Macoma tenta (Say, 1834) P	---					
Mellita quinquiesperforata (Leske) E	--					
Natica pusilla Say, 1822 G	-					
Neopenope texana sayi (Stimpson) Cr	xxxxx					
Neritina virginea (Linné, 1758) G	-xxx-		----			
Nuculana acuta (Conrad, 1834) P	-xx--				-	
Odostomia impressa (Say, 1821) G	--					
Ophiothrix angulata (Say, 1825) E	xx					
Ostrea equestris Say, 1834 P	--x--	-			--	
Polinices duplicatus (Say, 1822) G	-x-		-			
Portunus gibbesi (Stimpson, 1859) Cr.	x					
Pyramidella crenulata Holmes, 1859 G	-					
Pyramidella fusca (C. B. Adams, 1839) G	--				-	
Hiatella arctica (Linné, 1767) P ?	-					
Tegula fasciata (Born, 1780) G	----					
Tellidora cristata (Récluz, 1842) P	-					
Tellina versicolor De Kay, 1843 P	-x					
Thais haemastoma floridana (Conrad, 1837) G	xxx					
Trachycardium muricatum (Linné, 1758) P	--					
Turbonilla interrupta Totten, 1835 G	-x-	-	--		-	
Vermicularia fargoi Olsson, 1951 G	-x					
Vitrinella, sp. G	-					
Abra aequalis (Say, 1822) P	--x--	-	-		---	
Brachidontes citrinus (Röding, 1798) P	-xx-	-xx--	--x--	--	-----	
Brachidontes exustus (Linné, 1758) P	--	-	-			
Brachidontes recurvus (Rafinesque, 1820) P	--	-			-	
Bulla occidentalis A. A. Adams, 1850 G	----		-		----	
Cerithidea pliculosa (Menke, 1829) G	---	---	---		---	
Cerithium variabile (C. B. Adams, 1848) G	--x--	--	--x--		-----	
Corbula contracta Say, 1822 P	-				-	
Donax tumida Philippi, 1848 P	-	-	-		-	

Table II (Cont.) - 6 -

Species	Inlet Hypersal.	Open Hypersal.	Enclos. Hypersal.	Deep Hypersal.	Low Sal. Bay Infl.	Hypersal.
<u>Kurtziella perryae</u> Bartsch and Rehder, 1939 G	-		-			
<u>Macoma constricta</u> (Bruguiere, 1792) P	---	-	--			
<u>Modulus modulus</u> (Linné, 1758) G	--	-	--			
<u>Nassarius vibex</u> (Say, 1822) G	-xxx-	xx	-----		-x-	
<u>Retusa canaliculata</u> (Say, 1827) G	-----	--	----		---	
<u>Amygdalum papyria</u> (Conrad, 1846) P		xxxxx	-		-	
<u>Bittium varium</u> (Pfeiffer, 1840) G	x	xxxxx	-----		-----	
<u>Haminoea elegans</u> (Gray, 1825) G		---				
<u>Laevicardium mortoni</u> (Conrad, 1830) P	--x--	xxxxx	-----		-xx	
<u>Macoma brevifrons</u> (Say, 1834) P	-xx--	xxxxx	----	-	-----	
<u>Mactra fragilis</u> Gmelin, 1790 P	----	--x--	--		x	
<u>Mitrella lunata</u> (Say, 1826) G	-	-x-				
<u>Pseudocyrena floridana</u> (Conrad, 1846) P		xxxxx	-----		---	
<u>Tagelus divisus</u> (Spengler, 1794) P	--	-----			--	
<u>Truncatella pulchella</u> Pfeiffer, 1839 G		-				
<u>Anomalocardia cuneimeris</u> (Conrad, 1846) P	-----	xxxxx	xxxxx	-----	xxxxx	
<u>Mulinia lateralis</u> (Say, 1822) P	-xx--	xxxxx	xxxxx	--xx-	xxxxx	
<u>Tellina tampaensis</u> Conrad, 1866 P	--	-xxxx	xxxxx		--x--	
<u>Caecum nitidum</u> Stimpson, 1851 G			--	-		
<u>Cardita floridana</u> (Conrad, 1838) P	-	-	--			
<u>Lucina crenella</u> (Dall, 1901) P	-		---	-	-	
<u>Melampus bidentatus</u> Say, 1822 G			--		-	
<u>Odostomia bisuturalis</u> (Say, 1821) G		--	-xx-		-x	
<u>Olivella mutica</u> (Say, 1822) G			--			
<u>Acteon punctostriatus</u> (C. B. Adams, 1840) G	-	---	--	-xx	--	
<u>Astarte nana</u> E. A. Smith, 1881 P					-	
<u>Callinectes sapidus</u> Rathbun Cr		x	-		xxxxx	
<u>Crassinella lunulata</u> (Conrad, 1834) P					-	
<u>Crassostrea virginica</u> (Gmelin, 1791) P	----		----		--x--	
<u>Dentalium texasianum</u> Philippi, 1849 Scaph.					-	
<u>Ensis minor</u> Dall, 1899 P					-x-	
<u>Lucina amiantus</u> (Dall, 1901) P					--	
<u>Lyonsia floridana hyalina</u> (Conrad, 1846) P	-				x	
<u>Phacoides pectinatus</u> (Gmelin, 1790) P	-x	--	----	-	-xx--	
<u>Tagelus plebeius</u> (Solander, 1786) P		--			---	

x = Living Frequency of x's and -'s indicate relative abundance.
- = Dead Shell

P - Pelecypods Ceph - Cephalopods
G - Gastropods Scaph - Scaphopods
E - Echinoderms
Cr - Crustaceans
Co - Coelenterates
Br - Bryozoa