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Robert P. Waldron

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A SEASONAL ECOLOGICAL STUDY OF FORAMINIFERA FROM TIMBALIER BAY, LOUISIANA

by

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"Fieldwork was supported by the Coastal Studies Institute, in part with financial support of the Geography Branch of the Office of Naval Research,
"Field work was supported by the Coastal Studies Institute, in part with

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INTRODUCTION

This study concerns the ecological habits of living Foraminifera from a shallow Louisiana coastal bay during a period of ten months. It is a part of an extensive study undertaken by the Coastal Studies Institute of Louisiana State University to determine the effect of chemical and physical properties of water upon marine life in a large, open bay over an extended period of time. Samples were collected monthly from established locations for the chemical, biological and foraminiferal determinations. Results of the chemical and biological studies will be published by the respective investigators in subsequent papers.

The period of time covered by this portion of the study extended from January 1957 to October 1957. Unfortunately, the chemical and biological studies of the bay ended July 1957. Various chemical determinations which were considered pertinent to the study were continued by the investigator throughout the remaining time.

Physical influences, such as geomorphology, hydrography and climate, are presented in this paper to help determine exactly what effects each had upon the living Foraminifera of the bay. The chemical data of the bottom waters, presented in Tables 20 to 29, are principally the results of the concurrent chemical study of the bay.

GEOMORPHOLOGY

General. Timbalier Bay (figure 1) is one of a series of large, shallow bays along the Louisiana coast. It lies almost entirely within Lafourche Parish, except for a minor portion which extends into Terrebonne Parish. The bay area is between longitudes 90° 13′ and 90° 29′ N and latitudes 29° 03′ and 29° 19′ W. Grand Pass Timbalier, which connects the bay with the Gulf of Mexico, is approximately 54 miles west of the mouth of the Mississippi River.

The bay opens into another large bay to the west, Terrebonne Bay. Less than one hundred years ago, the two bays were separated by the natural levee ridge of a major north-south trending stream, located just off the western border of the map (figure 1). When the area was surveyed in 1891, (U. S. G. S., Timbalier Sheet, Louisiana, edition of 1894), there were numerous breaks in these natural levees. Since then, most of the remaining levees have been destroyed by wave action leaving only a few small islands (U. S. G. S., Jacko Bay and Timbalier Island quadrangles, editions of 1935).

In outline, Timbalier Bay is generally triangular. The length is 17 miles from north to south, and the maximum width is about 14.5 miles. Its surface area is approximately 140 square miles.

Geologic History. The eastern two-thirds of coastal Louisiana is an area of deltaic sedimentation. Periodically, the Mississippi River has moved its delta from one area to another. This produced a series of overlapping lenses of deltaic sediments.

Prior to the development of the present delta, the Mississippi River emptied into the Gulf of Mexico in the vicinity of Timbalier Bay. Two periods of delta formation are recognized within the area — the Early and Late Lafourche subdeltas.[1]

Approximately 40 miles northwest of Timbalier Bay, the principal channel of the Early Lafourche subdelta divided into a number of distributaries before emptying into the Gulf of Mexico. Bayou Pointe au Chien, shown along the

[1]Morgan, J. P. and Larimore, P. B., (1957), p. 308.

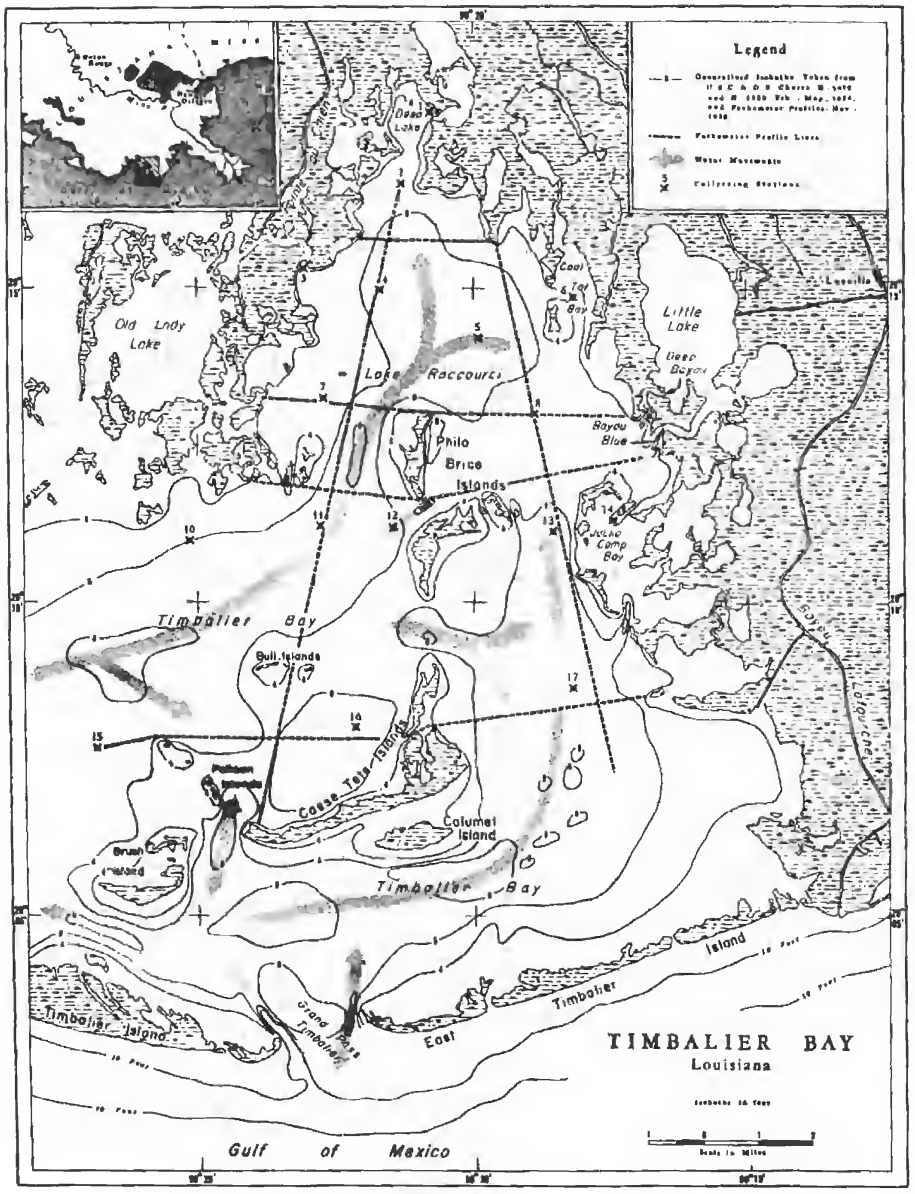

Legend
Dead Lake
Old Lady Lake
Lake Raccourci
Little Lake
Deep Bayou
Bayou Blue
Philo Brice Islands
Timbalier Bay
Bull Islands
Coose Tete Islands
Columet Island
Brush Island
Timbalier Bay
Timbalier Island
Grand Pass Timbalier
East
Timbalier Island
TIMBALIER BAY
Louisiana
Gulf of Mexico

Figure 1

northwest portion of the map (figure 1), is the most easterly of these distributaries.

It is the opinion of W. G. McIntire and J. P. Morgan (personal communication) that Bayou Pointe au Chien and other eastern streams are older than those farther west. The easternmost distributaries gradually deteriorated in favor of the younger western distributaries, and their seaward extensions became subjected to coastal erosion. Barrier or beach islands formed, and persisted to the present.

The Mississippi River then moved into the channel now occupied by Bayou Lafourche, forming the Late Lafourche subdelta. This subdelta failed to become as large as the Early Lafourche subdelta for the reason that the channel of the Mississippi was diverted to its present course. The exposed remains of the Late Lafourche subdelta are now being wasted away rapidly by wave action of the gulf.[2]

Land Areas. The limits of the drainage basin surrounding Timbalier Bay are defined by the natural levees of two former distributaries of the Mississippi River, Bayou Lafourche and Bayou Pointe au Chien. These natural levees are composed of oxidized silty clays, and stand several feet above the surrounding marsh. Numerous smaller and lower natural levees cross the area, but they are not easily recognizable because of an overlapping marsh cover.

Since abandonment of the Lafourche distributary system by the Mississippi River, the process of subsidence has been dominant. With sediment compaction and subsidence, lakes and bays have increased in size and importance. Larger water bodies allow more effective wave erosion, resulting in destruction of levees and levee-flank marshy areas.

Most of the islands within the bay are remnants of natural levees. The largest of these are Pelican, Bull, Philo Brice and the northern Casse Tete island. Along the southern portion of the bay, there are islands which are, or have been, barrier or beach islands. Brush, Calumet and the southern Casse Tete islands are remnants of a former shoreline of the gulf. Timbalier and East Timbalier islands have rapidly migrated toward the west and formed a new barrier beach trend sheltering the older barrier islands from wave erosion.

Water Bodies. Timbalier Bay averages approximately six feet in depth, the southern half being about one foot deeper than the northern half. It is divided into an upper bay area called Lake Raccourci, and the southern part known as Timbalier Bay. Lake Raccourci is connected by several restricted passes around Philo Brice Island into the more extensive lower bay area. A less important division is evident in Timbaler Bay proper. The islands of Casse Tete and southern Philo Brice divide this lower area into eastern and western portions.

There is no drainage of fresh water into the bay other than rain which falls into the catchment basin area. Lunar tides, usually never greater than a foot, create considerable water movement within the bay. Winds, however, affect the character and height of the normal tides. A south wind, aided by a high tide, will force enough water into the bay to flood the low standing marsh.

The directions of water movement within the bay are indicated on the hydrographic chart (figure 1). Only a minor amount of water that enters and leaves Timbalier Bay passes through Grand Pass Timbalier. The main water movement into Timbalier Bay is through adjacent Terrebonne Bay, which has a larger and deeper pass into the Gulf of Mexico. This larger pass to the west permits a general northeast-southwest movement of the water, instead of the north-south path it followed when the two bays were not open into each other. Migration of Timbalier and East Timbalier islands toward the west has tended to

[2]Ibid., p. 308.

reduce the size of Grand Pass Timbalier. This has resulted in enlargment of the opening between Timbalier and Terrebonne bays and forcing most of the water to pass through the larger western outlet. This change in direction of drainage has taken place gradually over the last sixty years.

Several fathometer profiles were run across the bay before the main part of the study began. Water level at the time was approximately one foot above the mean low tide level. In order to construct the hydrographic chart (figure 1), additional data taken from the Coast and Geodetic Survey charts were adjusted to this datum.

CLIMATIC HISTORY FOR THE YEAR

A summary of the climatic conditions which occurred during the year 1957 was obtained from published data of the U. S. Weather Bureau.[3] Whenever possible, data from the Golden Meadow station were used since Golden Meadow is just north of Timbalier Bay and is in the basin area which drains into the bay. During several months when the data from this station were unavailable, it was necessary to refer to data taken at Grand Isle, which is just to the east of Timbalier Bay, and within another drainage area. The notes on tidal changes were from personal observations, because no other data were available.

December. Abnormally warm weather prevailed over the area with below normal rainfall, 5.02 inches. The average temperature was about 64.0° (Fahrenheit) with the warmest reading, 83° and the coldest, 41°.

January. Quite changeable temperatures and only a minor amount of precipitation characterized weather conditions of the area. Although the average temperature was 58.4°, extremes ranged from 24° in the middle of the month to 83° on the last day. Only 1.04 inches of rain fell.

February. Exceptionally warm weather persisted in the area, especially during the first half of the month when daytime temperatures were mostly in the 80's. The average temperature for the month was 64.1° with the extremes being 84° and 38°. Only 1.76 inches of rainfall was recorded.

March. Fairly cool temperatures prevailed, the average being 60.3°, with the warmest daytime temperature nearly 80° and the coldest, 35°. On the twenty-first of the month 2 inches of rain was recorded. Total rainfall for the month was 4.44 inches.

April. Warmer temperatures and heavier rainfall characterized April weather. The average temperature was 69.4° with the extremes ranging from 40° to 87°. The heaviest single rainfall was 2.16 inches on the first of the month, with a total of 6.09 inches for the entire month. During the night of the third, very rough water resulted from severe thunderstorms which moved over the area.

May. This month was mostly mild and moderately dry. Average temperature for the period was 76.2° with a low of 51° on the sixth of the month and a high of 89° on the eighteenth. Just 2.66 inches of precipitation was recorded for the period with 1.35 inches of that amount having fallen on the second day of May.

June. Extremely abnormal conditions characterized weather conditions for thin month. Temperatures averaged 80.9° with extremes in the middle 60's and middle 90's. Precipitation was very heavy, with rain being recorded on over 15 days of the month. Total amount for the month was 9.96 inches with a single rainfall of 5.58 inches on the third. On the morning of June 27, strong winds, high water and heavy rains of Hurricane "Audrey" lashed the coast of Louisi-

[3]Weather Bureau, 1956-57, vol. 61, no. 12 and vol. 62, nos. 1-9.

ana, leaving over 500 persons dead and millions of dollars of property damage in the western portion of the state. The center of the storm passed inland approximately 260 miles west of Timbalier Bay. This area received only .25 inch of rain, but the tides rose from 3 to 4 feet above normal.

July. Hot, dry weather prevailed during the first two and a half weeks, and the temperatures averaged only slightly cooler during the rest of the month. Average temperature for July was 81.8° with a single reading of 96° on the sixth of the month. Approximately 6.78 inches of rain fell, being concentrated mostly in the latter half of the month.

August. Temperatures over the area averaged close to normal for the month with the daytime maximums remaining in the lower 90's. Average for the period was 82.9° with rainfall totaling approximately 7.38 inches. Tropical storm "Bertha", on the ninth of August, which crossed into the mainland in the southwestern portion of the state, produced 2.5 inches of rain. Tides in the area rose about 2 feet.

September. Cool, rainy weather prevailed over the area for the month of September. Warmest weather occurred during the first few days of the month with a high of 92° being recorded on the first. A low of 62° was recorded on the twenty-ninth. This month had 9.61 inches of rain, with 8.60 inches of that amount occurring after the fifteenth. Tropical storm "Esher" entered the mainland at approximately the location of Timbalier Bay on the seventeenth, causing 6.00 inches of rainfall over a three day period. Tides rose 2 to 3 feet in advance of the storm.

PHYSICAL AND CHEMICAL PROPERTIES OF THE WATER

The chemical data for the months of January to July were obtained by F. A. Ekker and E. L. Haden, chemists for the Coastal Studies Institute. The results of their study will be published in another paper. From August to October, pertinent chemical determinations were continued along with the foraminiferal study.

The chemical analyses, plus temperatures, of the waters of the bay are listed in the appendix (tables 20 to 29) so that their applications to the foraminiferal assemblages can be better shown. Most of the determinations are of bottom waters since this study was concerned with bottom-dwelling organisms. A brief description of the method used for each determination is given in the following paragraphs, plus observations as to trends shown during the year.

Temperature. The temperatures of the bottom waters are expressed in degrees Centigrade and were determined at the time of collection. The temperature readings generally increased after March until July, when they were at their maximum. Temperatures at shallower stations usually were a little higher than at others.

Hydrogen Ion Concentration. A Beckman Model N2 pH meter was used for determining the hydrogen ion concentration (pH). The readings for March are slightly lower than normal, but otherwise no definite trends were noted.

Redox Potential. To obtain redox potential (eH) a Beckman Model N2 pH meter was used, and the readings were obtained from platinum versus calomile electrodes. These readings were converted to millivolts by using the formula:

(7-pH scale reading) 60.0 = mv

The readings during April were considerably higher than the other months, followed by a trend toward lower readings during the summer months.

Chlorinity. Chlorinity was determined in the laboratory following Knudsen's Titration Method (Oxner, 1946). The readings are expressed as parts per thousand by weight.

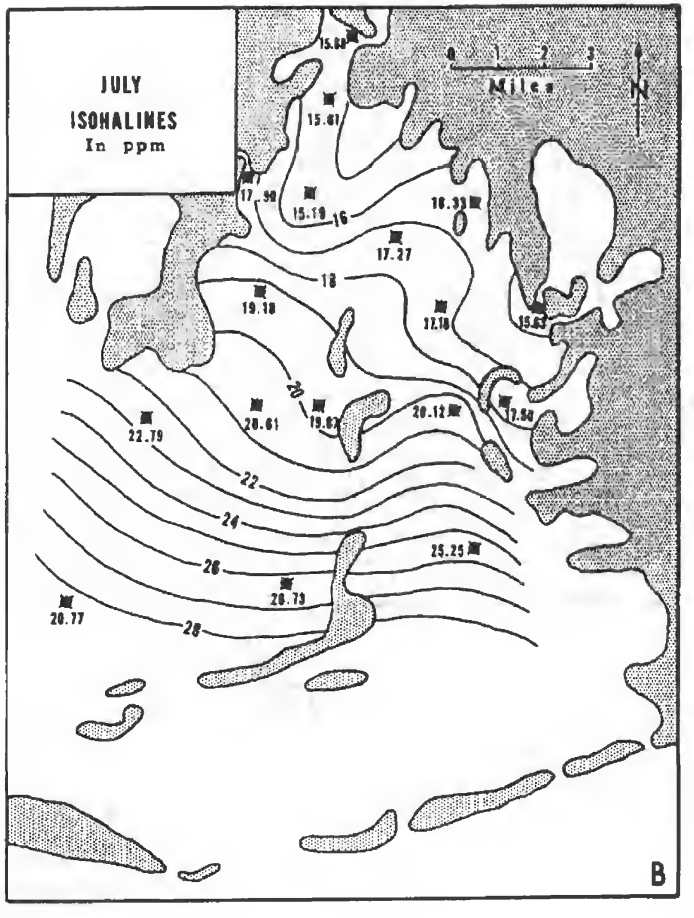


Figure 2b

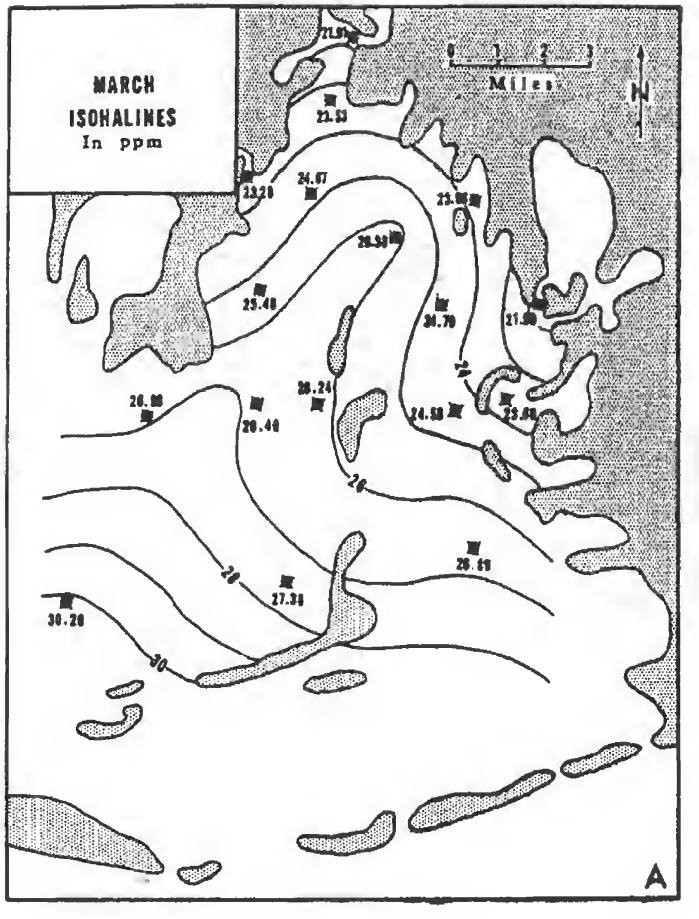


Figure 2a

Salinity. Hydrographical Tables of Knudsen were used to convert chlorinity to salinity by the following equation:

$$S = 0.030 + 1.8050\ Cl$$

where values are in parts per thousand. The overall data show that the highest salinities occur during the late winter months followed by lower salinities during the summer. Isohalines for March and July are shown on Figure 2.

Alkalinity. Alkalinity was determined in the laboratory by using a Beckman Model N2 pH meter. A known volume of sample was mixed with a set volume of standard hydrochloric acid and the change in pH caused by the acid noted. Readings are expressed in milliequivalents of acid per liter. The readings are fairly constant except for the months of April and May when they were slightly below normal.

Phosphate Phosphorus. An estimate of the inorganic phosphate phosphorus was made by the molybdenum blue method. The readings are expressed in microgram atoms per liter. No definite trends in occurrence are noted.

Nitrate-Nitrite Nitrogen. This determination was made spectrophotometrically using strichnidine as the colorimetric reagent. The readings here are also expressed in microgram atoms per liter. Again no definite trends are noted.

Carbohydrate. Carbohydrate was determined spectrophotometrically using anthrone as the colorimetric reagent. The results are expressed as milligrams per liter of sucrose equivalent. The figures show a constant upward trend during the four months recorded, with June showing the highest.

Sulfate. Determination for the months of January and February were made by the turbidimetric method with the remaining determinations being obtained by the barium chloranilate method. The readings are expressed in parts per thousand by weight. January displays the highest figures while June has the lowest.

The above chemical analyses were made at each station. The effects of chemistry upon the living Foraminifera will be discussed in the sections on Species and Populations.

DESCRIPTION OF THE STATIONS

Location. The seventeen stations (figure 1), from which the monthly collections of materials were made, present an adequate representation of the several physical environments which exist within the bay. Five locations (stations 2, 4, 5, 7 and 8) were chosen in the upper bay or Lake Raccourci area. Three stations (numbers 1, 3 and 9) were located in mouths of bayous and two (numbers 6 and 14) in smaller bays opening into the main body of water. Stations 11, 12 and 13 were in passes. The remaining four stations (numbers 10, 15, 16 and 17) were established in the lower bay or Timbalier Bay proper. Limited collection time, however, prevented the addition of other stations in equally desirable locations. The seventeen stations sampled periodically are described below:

Station 1. In the mouth of Chinois Pass in the northeastern end of Deep Lake.
Depth: 7 feet
N 29° 17′ 40″ Lat., W 90° 21′ 45″ Long.

Station 2. At the northern end of Lake Raccourci, 0.5 mile south of Deep Lake.
Depth: 6 feet
N 29° 16′ 33″ Lat., W 90° 21′ 22″ Long.

Station 3. Center of mouth of Grand Bayou Felicity.
Depth: 6 feet
N 29° 15′ 12″ Lat., W 90° 23′ 08″ Long.

Station 4. Lake Raccourci, 1.4 miles east-southeast of mouth of Grand Bayou Felicity.
Depth: 6.5 feet
N 29° 14′ 55″ Lat., W 90° 21′ 42″ Long.

Station 5. Lake Raccourci, 1.5 miles west of southern opening to Coal Tar Bay.
Depth: 6.5 feet
N 29° 14′ 15″ Lat., W 90° 19′ 55″ Long.

Station 6. Center of Coal Tar Bay.
Depth: 5 feet
N 29° 14′ 50″ Lat., W 90° 18′ 16″ Long.

Station 7. Lake Raccourci, 1.95 miles west of northern tip of Philo Brice Islands.
Depth: 5.5 feet
N 29° 13′ 14″ Lat., W 90° 22′ 45″ Long.

Station 8. Lake Raccourci, 1.85 miles east of northern tip of Philo Brice Islands.
Depth: 6 feet
N 29° 13′ 03″ Lat., W 90° 18′ 56″ Long.

Station 9. Near southern bank of Deep Bayou mouth.
Depth: 4 feet
N 29° 12′ 57″ Lat., W 90° 16′ 53″ Long.

Station 10. Approximately 1 mile south of the western portion of Fornation Islands.
Depth: 6.5 feet
N 29° 11′ 02″ Lat., W 90° 23′ 03″ Long.

Station 11. 0.9 mile south of the eastern-most island of Fornation Islands.
Depth: 8 feet
N 29° 11′ 10″ Lat., W 90° 23′ 03″ Long.

Station 12. 0.6 mile southwest of pass between Philo Brice Islands.
Depth: 7 feet
N 29° 11′ 06″ Lat., W 90° 21′ 30″ Long.

Station 13. About midway between eastern tip of Philo Brice Islands and islands flanking Jacko Camp Bay.
Depth: 6 feet
N 29° 11′ 8″ Lat., W 90° 18′ 48″ Long.

Station 14. North-central Jacko Camp Bay.
Depth: 4.5 feet
N 29° 11′ 18″ Lat., W 90° 17′ 32″ Long.

Station 15. 1.25 miles west of northernmost island of Pelican Islands.
Depth: 7.5 feet
N 29° 07′ 48″ Lat., W 90° 26′ 46″ Long.

Station 16. 0.9 mile west-southwest of bayou crossing Casse Tete Islands.
Depth: 6.5 feet
N 29° 07′ 52″ Lat., W 90° 22′ 09″ Long.

Station 17. About midway between northern tip of Casse Tete Island and and Devils Island which extends out past mainland.
Depth: 7.5 feet
N 29° 08′ 33″ Lat., W 90° 18′ 16″ Long.

Sedimentology. The character of the bottom sediments at each station

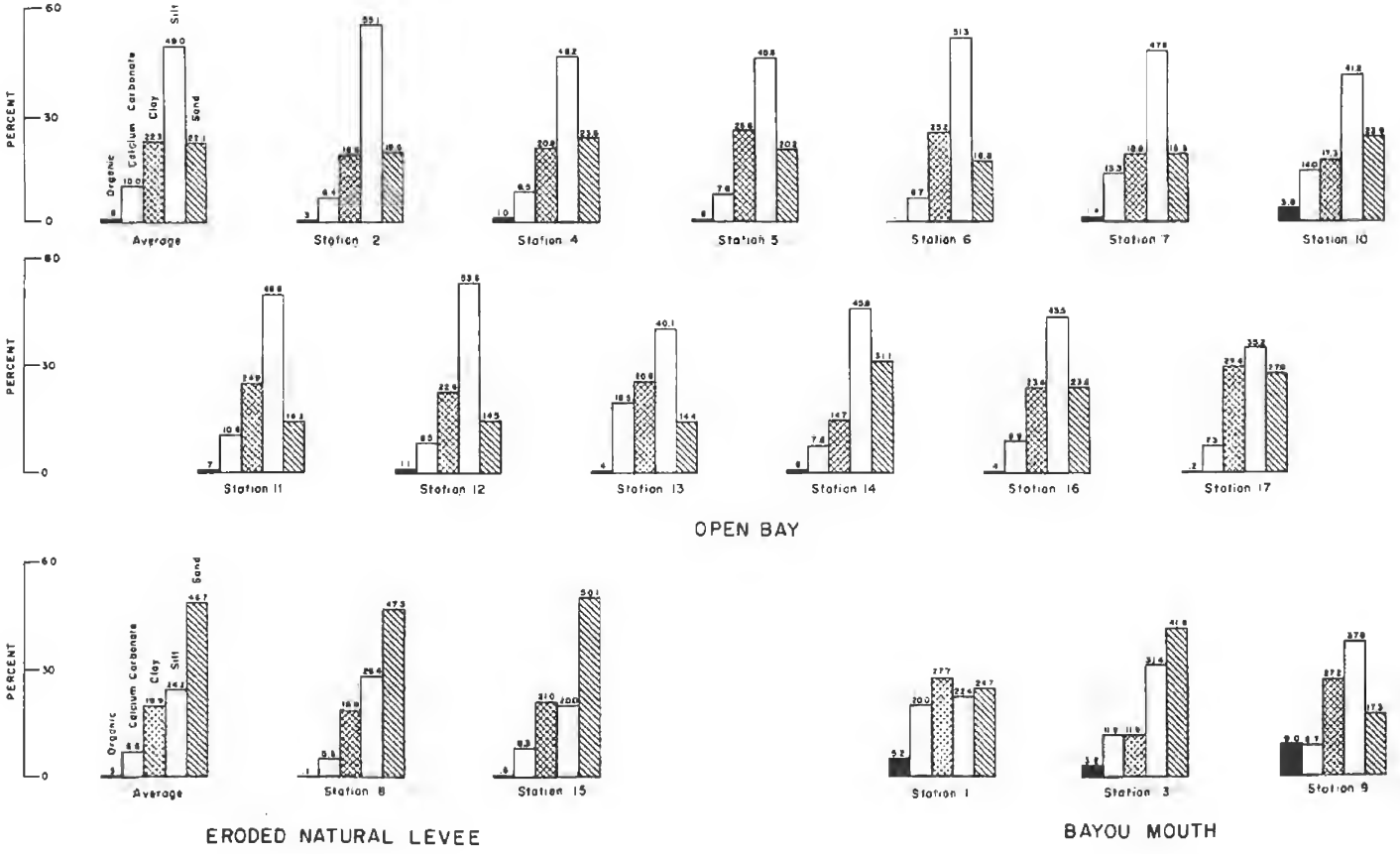

PERCENT
Organic
Calcium Carbonate
Clay
Silt
Sand
Average
Station 2
Station 4
Station 5
Station 6
Station 7
Station 10
Station 11
Station 12
Station 13
Station 14
Station 16
Station 17
OPEN BAY
Station 8
Station 15
ERODED NATURAL LEVEE
Station 1
Station 3
Station 9
BAYOU MOUTH

Figure 3

is presented by histograms in Figure 3. The extreme top inch and a half of material was used for these determinations.

Percentages of the solubles were obtained by dissolving out each with known chemicals — hydrogen peroxide for the organics and hydrochloric acid for the calcium carbonate — and noting the weight losses. Clay and silt percentages were obtained by use of the hydrometer technique. The size scale for the clastics (Wentworth, 1922) is as follows:

Clay	less than 0.0039 mm.
Silt	between 0.062 and 0.0039 mm.
Sand	between 0.125 and 0.062 mm.

Two distinctive bottom types were noted within the bay. The principal type contained much silt with approximately equal amounts of clay and sand. The other had a high percentage of sand. Examination of old maps indicates that the areas with high sand-content (stations 8 and 15) were on or near former natural levees. Sediment from other areas resulted from the wasting away of marsh deposits. Bottom sediments from stations in bayou mouths are grouped together, because they are a result of constant mixing by the tidal movements of the water.

The high calcium carbonate contents recorded for a few stations are due to admixture of shell fragments of oysters (*Crassostrea virginica*) and mussels (*Mytilus recurvus*) from beds scattered throughout the area. Stations 1 and 13 are located on oyster reefs.

METHODS OF STUDY

Collection of Samples. Ten monthly collections of sample material were made during the period from January 9, 1957 to October 6, 1957. Two of these collections, January and August, are incomplete because of rough water and boat failure. The dates of the collections are as follows, along with the month to which they will be referred in the population analyses:

January	January 9-10, 1957	June	June 19-20, 1957
February	January 29-30, 1957	July	July 15-17, 1957
March	March 13-14, 1957	August	August 13, 1957
April	May 8-9, 1957	September	September 7-8, 1957
May	May 30-31, 1957	October	October 5-6, 1957

Bottom mud samples were taken with a Hanna bottom sampler (Hanna, 1954), using a 2-3/4 inch diameter plastic tube, 2 feet in length. A ball check valve was used at the top to create a vacuum and prevent core loss. The top half-inch of sediment of these cores was shaved off and preserved in formalin (40% formaldehyde), neutralized with sodium bicarbonate.

Treatment of Samples. All samples were washed and processed in the laboratory within three days after they were collected, to prevent the acid action of the formalin from dissolving calcareous foraminiferal tests. The samples were washed over a screen having average openings of 0.074 mm., and the organic debris was removed by decanting.[4] The washed residues were then stained with rose Bengal dye,[5] in order to make it possible to distinguish living Foraminifera from abandoned tests. Lastly, the samples were air dried.

Material from each sample above 0.149 mm. in diameter was examined thoroughly for its foraminiferal content. The finer material contained only a

[5]Walton, W. R., (1952), pp. 56-60.

[4]Warren, A. D., (1957), p. 31.

meager amount of Foraminifera, and specific identifications became extremely difficult. Total population counts were made from the January samples, except for stations 13, 14 and 17 which were not collected during this month. For these stations it was necessary to use the February samples. Slides of the live Foraminifera from all samples were made so that they could be identified and measured. The following size scale was used in the measurements:

Small ..... less than 0.177 mm.
Medium ..... between 0.177 and 0.25 mm.
Large ..... greater than 0.25 mm.

The sizes shown in Tables 1-17 are averages of species in each sample.

MORPHOLOGY

Twenty-three species of Foraminifera are considered to be common in the waters of Timbalier Bay. The other species that occur are rare in the samples collected and have very little effect upon the population counts (tables 1 to 17).

It was found that several species were restricted to definite environmental conditions. Similar restrictions of the same species were noted from an area near the mouth of the Mississippi River by A. D. Warren (unpublished thesis, 1954).

Although total population counts were made (table 19), no conclusions are drawn from them.

Illustrations of the species are not given, but adequate illustrations are available in the papers of Andersen (1953), Parker *et al.* (1953), Phleger and Parker (1951), and Warren (1957). The species are listed in alphabetical rather than taxonomic sequence.

AMMOASTUTA SALSA Cushman and Bronnimann

Ammoastuta salsa Cushman and Bronnimann, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 1, p. 17, pl. 3, figs. 14-16.

Occurs in most areas of the bay, but never becomes too important.

AMMOBACULITES CRASSUS Warren

Ammobaculites crassus Warren, 1957, Contr. Cushman Found. Foram. Res., vol. 8, pt. 1, 32, pl. 3, figs. 5-7.

Restricted to the Lake Raccourci area, and becomes most prominent in the extreme northern portions of the bay.

AMMOBACULITES SUBCATENULATUS Warren

Ammobaculites subcatenulatus Warren, 1957, Contr. Cushman Found. Res. vol. 8, pt. 1, pt. 1, p. 32, pl. 3, figs. 11-13.

Favors the extreme northern portion of the bay as is shown by its greatest numbers and sizes, but also occurs in more southerly area.

AMMOTIUM DILATATUM (Cushman and Bronnimann)

Ammobaculites dilatatus Cushman and Bronnimann, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 2, p. 39, pl. 7, figs. 10, 11.

Present throughout the bay in relatively large numbers. Average sizes show very little variation.

AMMOTIUM FRAGILE Warren

Ammotium fragile Warren, 1957, Contr. Cushman Found. Foram. Res., vol 8, pt. 1, p. 32, 3, figs. 14, 15.

Common in the central portion of Lake Raccourci; sizes become smaller from north to south.

AMMOTIUM SALSUM (Cushman and Bronnimann)

Ammobaculites salus Cushman and Bronnimann, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 1, p. 16, pl. 3, figs. 7-9.

Extremely large populations of this species occur in Lake Raccourci, averaging medium-sized individuals.

ARENOPARELLA MEXICANA (Kornfeld)

Trochammina inflata Montaug var. *mexicana* Kornfeld, 1931, Contr. Dept. Geol. Stanford Univ., vol. 1, p. 86, pl. 13, figs. 5a - c.

This species appears to favor areas of moving water, such as passes and mouths of bayous.

BOLIVINA STRIATULA Cushman

Bolivina striatula Cushman, 1922, Publ. 311, Carnegie Inst. Washington, p. 27, pl. 3, fig. 10.

Favors areas where salinities are nearly marine, although a single specimen was noted from station 8 in the August sample, indicating it also favors sandy bottoms.

ELPHIDIUM GUNTERI Cole

Elphidium gunteri Cole, 1931, Fla. State Geol. Surv., Bull. 6, p. 34, pl. 4, figs. 9, 10.

Present over the entire bay, except for Jacko Camp Bay. It constitutes the second most abundant species in the bay.

ELPHIDIUM LIMOSUM (Cushman and Bronnimann)

Cribroelphidium limosus Cushman and Bronnimann, 1948, Contr. Cushman Lab. Form. Res., vol. 24, pt. 1, p. 19, pl 4, figs. 7a, b.

Common in the Lake Raccourci portion of the bay, but shows its highest populations fringing the land areas.

ELPHIDIUM MATAGORDANUM (Kornfeld)

Nonion depressula (Walker and Jacob) var. *matagordana* Kornfeld, 1939, Contr. Dept. Geol. Stanford Univ. vol. 1, no. 3, p. 87, pl. 13, figs. 2a, b.

Common in all areas of the bay, but most abundant along eastern shorelines.

ELPHIDIUM POEYANUM (d'Orbigny)

Polystomella poeyana d'Orbigny, 1839, in De la Sargra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 55, pl. 6, figs. 25, 26.

Present over most of the bay, but shows preference for the areas of highest salinities.

GAUDRYINA EXILIS Cushman and Bronnimann

Gaudryina exilis Cushman and Bronnimann, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 2, p. 40, pl. 7, figs. 15, 16.

This species was found only at station 15, suggesting that it is normally marine.

HAPLOPHRAGMOIDES MANILAENSIS Andersen

Haplophragmoides manilaensis Andersen, 1953, Contr. Cushman Found. Foram. Res., vl. 4, pt. 1, p. 22, pl. 4, fig. 8.

Noted only from Lake Raccourci stations 2 and 7.

HAPLOPHRAGMOIDES WILBERTI Andersen

Haplophragmoides wilberti Andersen, 1953, Contr. Cushman Found. Foram. Res., vol. 4, pt. 1, p. 21, pl. 4 fig. 7.

Present in bayous and passes having low to moderate salinities.

MILIAMMINA FUSCA (H. B. Brady)

Quinqueloculina fusca H. B. Brady, 1870, Ann. Mag. Nat. Hist., ser. 4, vol. 6, p. 47 (286), pl 11, figs. 2a - c, 3.

Occurs over the entire bay, but has greatest populations in northern and eastern Lake Raccourci area.

QUINQUELOCULINA cf. Q. LAMARCKIANA d'Orbigny

Quinqueloculina lamarckiana d'Orbigny, 1839, in De la Sargra, Hist. Phy. Pol. Nat. Cuba, "Foraminiferes," p. 189, pl. 11, figs. 14, 15.

Found only in the southwestern portion of the bay, since it requires high salinities. Individuals are smaller and not as broad as the typical *Q. lamarckiana* of the Gulf of Mexico.

QUINQUELOCULINA RHODIENSIS Parker

Quinqueloculina rhodiensis Parker, 1953, Cushman Found. Foram. Res., Spec. Publ, no. 2, p. 12, pl. 2, figs. 15-17.

Noted from all areas of the bay, but its populations never become too large. Individuals appear to be smooth in youth, becoming more costate in later stages.

STREBLUS PARKINSONIANA (d'Orbigny)

Rosalina parkinsoniana d'Orbigny, 1839, in De la Sagra, Hist. Phys. Nat. Cuba, "Foraminifères", p. 99, pl. 4, figs. 25-27.

This species occurs throughout the bay and exhibits the greatest populations found in the area.

STREBLUS TEPIDA (Cushman)

Rotalia beccarii (Linne') var. *tepida* Cushman, 1926, Publ. 331, Carnegie Inst. Washngton, p. 79, pl. 1.

Present over the entire bay and is only slightly less common than *Elphidium gunteri*.

TROCHAMMINA COMPRIMATA Cushman and Bronnimann

Trochammina comprimata Cushman and Bronnimann, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 2, p. 41, pl. 8, figs. 1-3.

Occurs in most sections of the bay, but seems to favor areas of fast moving water.

TROCHAMMINA INFLATA (Montagu)

Nautilus inflatus Montagu, 1808, Test. Brit., p. 81, pl. 18, fig. 3.

Individuals of this species are present mainly in the western half of the bay.

TROCHAMMINA MACRESCENS H. B. Brady

Trochammina inflata (Montagu) var. *macrescens* H. B. Brady, 1870, Ann. Mag. Nat. Hist., ser. 4, vol 6, p. 51, pl 11, figs. 5a - c.

Found in areas of moving water and low to moderate salinities.

BIOFACIES

Timbalier Bay is polyhaline with a salinity and fauna similar to those found in polyhaline bays of Texas by Ladd (1951). The average salinity of the bay ranges between 17.5 and 27.0 o/oo. Most of the foraminiferal species noted in the bay have a wide area of distribution. The following species occur throughout the bay and are generally major species in every population.

Ammotium dilatatum
Elphidium gunteri
Elphidium matagordanum
Streblus parkinsoniana
Streblus tepida

A foraminiferal faunal division occurs within the bay, between the northern and southern areas. The Lake Raccourci portion of the bay (upper bay) contains a fauna quite different from that of the southern half of the bay (lower bay). Lake Raccourci is characterized by a high ratio of arenaceous species, while the lower bay contains species which are normally marine or near-marine. Although the lower half of the bay is physiographically divided, the faunal assemblages are essentially the same.

Upper Bay Facies. This facies zone occupies the area which contains stations 1 through 9 and 14. The average salinity ranges between 17.5 and 21.0 o/oo. The area contains three major water inlets which at times have great effects upon the salinity of the area. This facies zone is characterized by the following species:

Ammobaculites crassus
Ammobaculites subcatenulatus
Ammotium fragile
Ammotium salsum
Elphidium limosum
Miliammina fusca

Arenoparella mexicana and *Haplophragmoides wilberti* show minor importance at individual stations.

Lower Bay Facies. Stations 10 through 13 and 15 through 17 are contained within this zone. The average salinity ranges between 22.0 and 27.0 o/oo. No major freshwater inlets empty directly into this portion of the bay, so the salinity remains quite high throughout the year. Species characterizing this zone are:

Elphidium poeyanum
Quinqueloculina rhodiensis

Trochammina comprimata and *Trochammina inflata* show some importance at stations 10 and 11. Station 15, which has the highest salinity, yields *Bolivina striatula*, *Gaudryina exilis* and *Quinqueloculina* cf. *Q. lamarackiana* which are found only occasionally at other stations.

SPECIES

Numerous observations have been made concerning the habits of individual species of living Foraminifera in the bay. Figures 4 to 8 were designed to show the changes which took place at different stations over a period of 10 months. The stations were chosen to represent the five different environmental areas which are found in the bay.

Figures 9 and 10 are north-south profiles along each side of the bay showing the characteristics of species within the bay during March and July when salinities and temperatures are at extremes.

Two species of *Ammotium* are found to be restricted almost entirely to the upper bay, whereas the third species, *Ammotium dilatatum*, is fairly common throughout the bay. It had two to three reproductive periods in ten months at two — or three — month intervals. *Ammotium fragile* appeared to have only two increases, one between January and March, the other between May and September. This species prefers the eastern half of the upper bay. The remaining speces, *Ammotium salsum*, had three reproductive periods from April to September.

Elphidium gunteri had four periods of reprduction during the ten months of observation. Figures 9 and 10 show the large population present in the lower part of the bay in March. Another species, *Elphidium limosum*, is limited to the extreme northeast portion of the bay and had only two periods of increase, one in March and another from June to August. *Elphidium matagordanum* also prefers the eastern side of the bay but had three or four increases at intervals of two or three months. The most nearly marine species of the four, *Elphidium poeyanum*, showed three reproductive phases.

Miliammina fusca prefers the northeastern portion of the bay and had about three periods of reproduction.

The two species of *Streblus* constitute a major percentage of the Foraminifera in the bay. *Streblus parkinsoniana* favors true bay conditions where the largest populations occur. The species underwent three periods of reproduction during the ten months and became most numerous in September. *Streblus tepida* also experienced three periods of reproduction during the ten months,

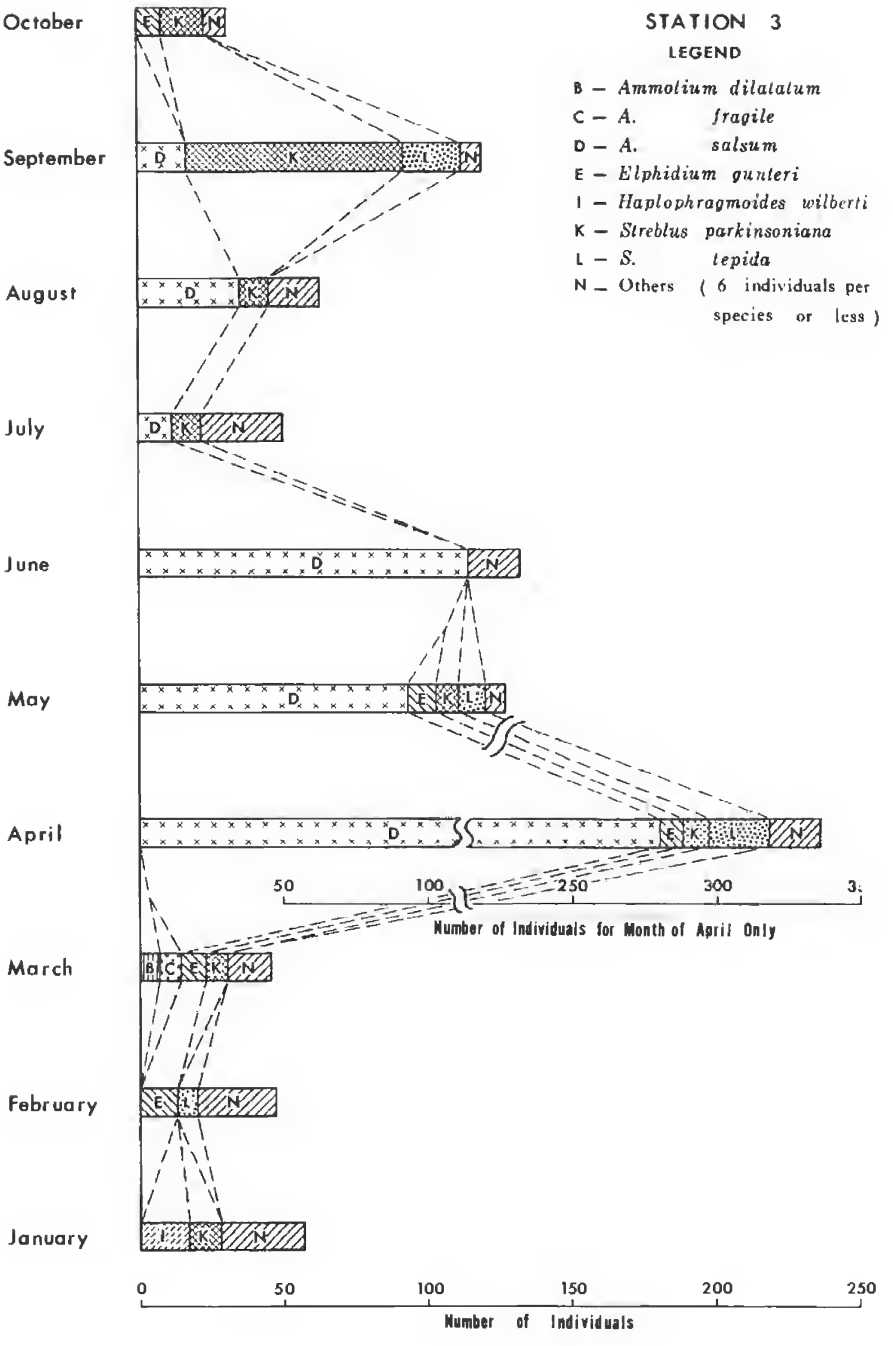

STATION 3
LEGEND
B — Ammolium dilatatum
C — A. fragile
D — A. salsum
E — Elphidium gunteri
I — Haplophragmoides wilberti
K — Streblus parkinsoniana
L — S. tepida
N — Others (6 individuals per species or less)
October
September
August
July
June
May
April
March
February
January
50
100
250
300
Number of Individuals for Month of April Only
0
50
100
150
200
250
Number of Individuals

Figure 4

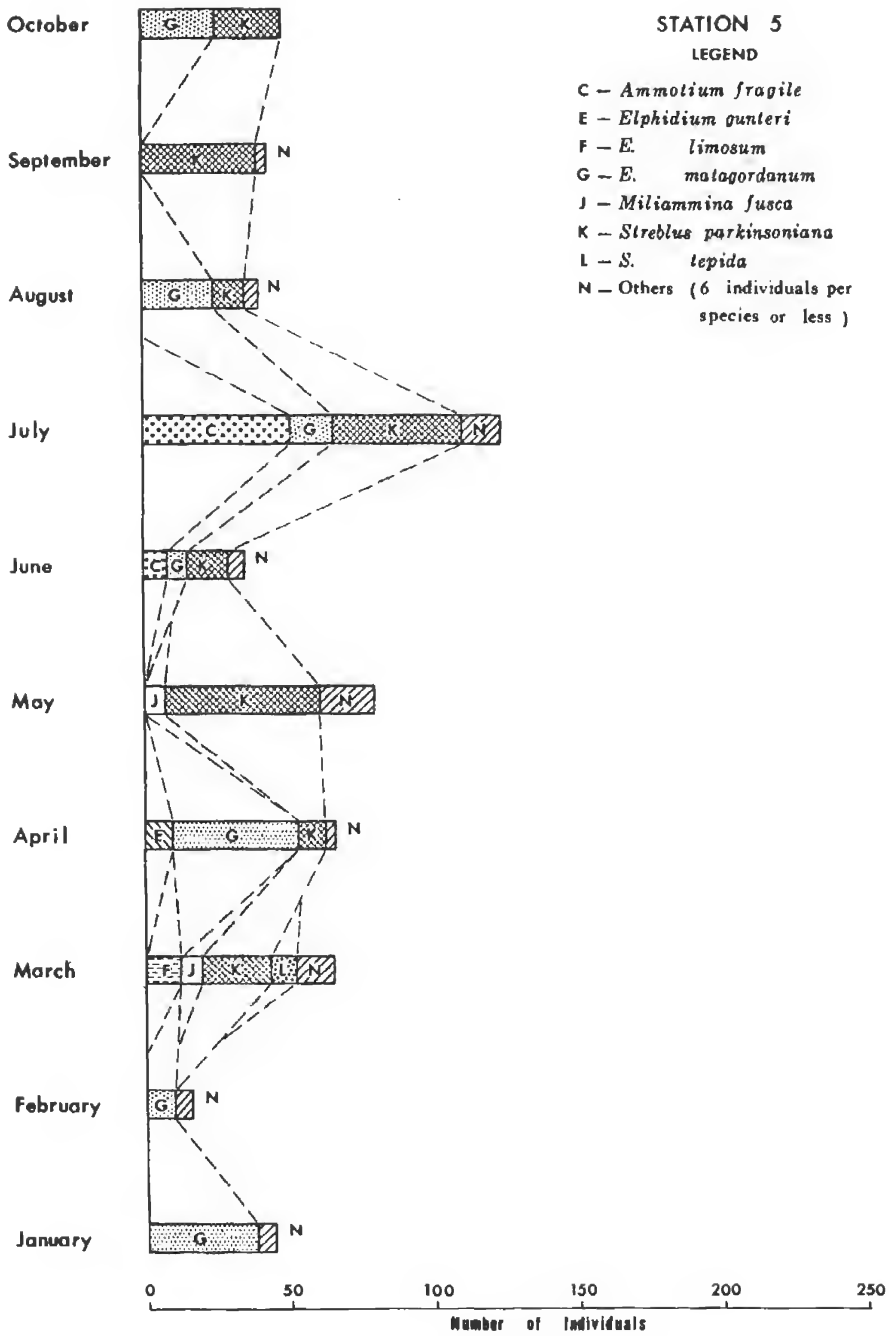

STATION 5
LEGEND
C — Ammotium fragile
E — Elphidium gunteri
F — E. limosum
G — E. matagordanum
J — Miliammina fusca
K — Streblus parkinsoniana
L — S. tepida
N — Others (6 individuals per species or less)
October
September
August
July
June
May
April
March
February
January
0
50
100
150
200
250
Number of Individuals

Figure 5

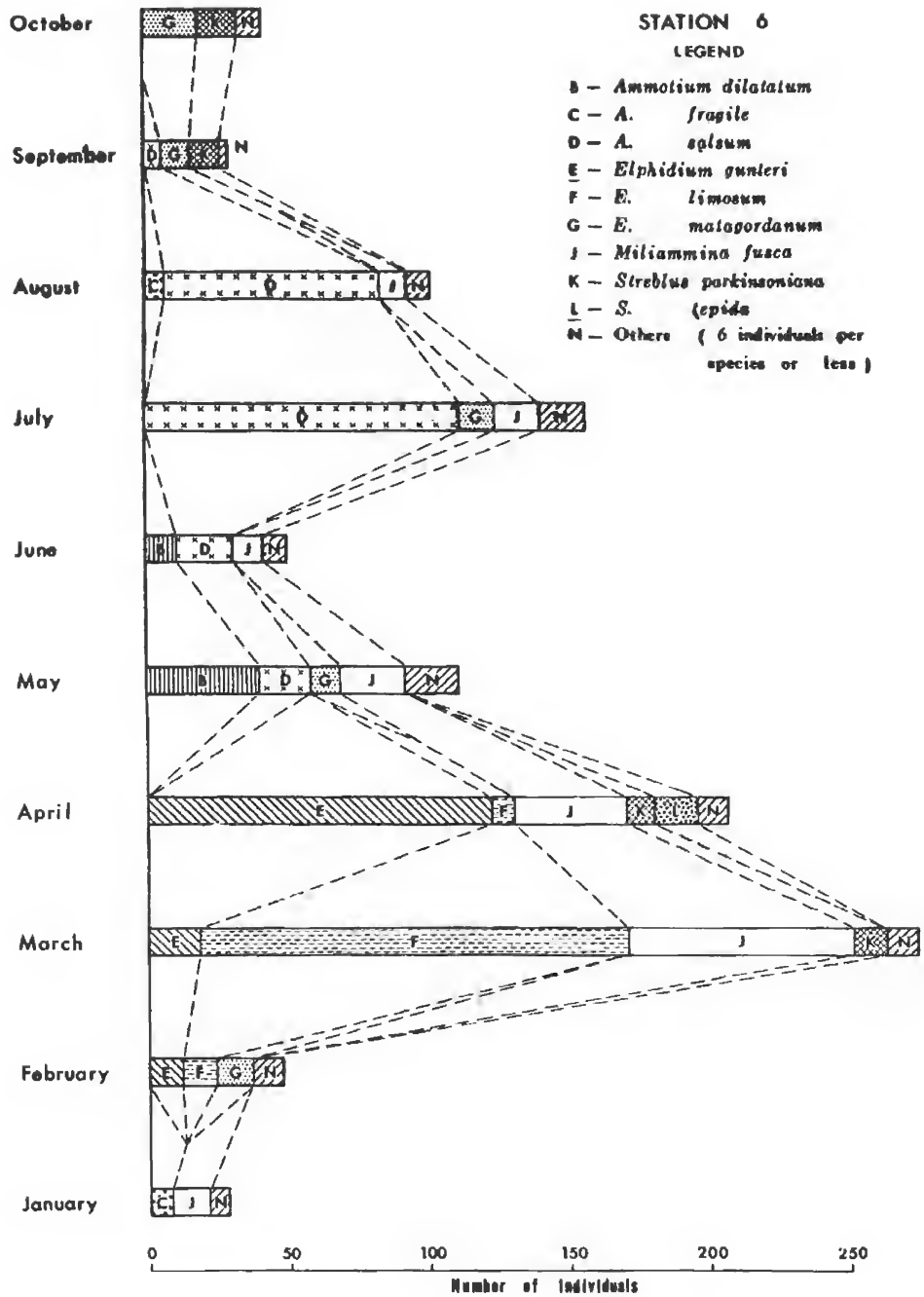

STATION 6
LEGEND
B — Ammotium dilatatum
C — A. fragile
D — A. salsum
E — Elphidium gunteri
F — E. limosum
G — E. matagordanum
J — Miliammina fusca
K — Streblus parkinsoniana
L — S. lepida
N — Others (6 individuals per species or less)
October
September
August
July
June
May
April
March
February
January
0
50
100
150
200
250
Number of Individuals

Figure 6

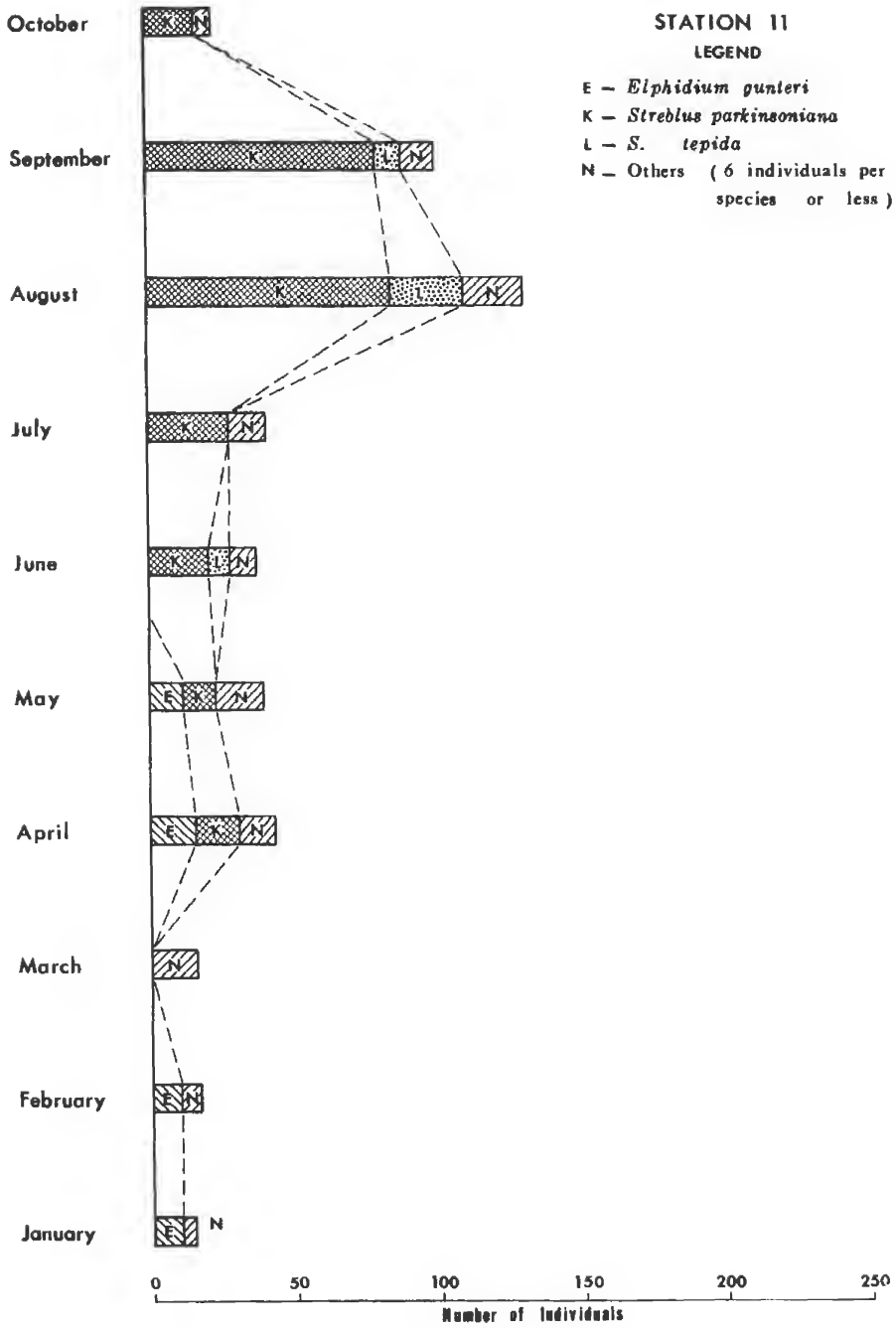
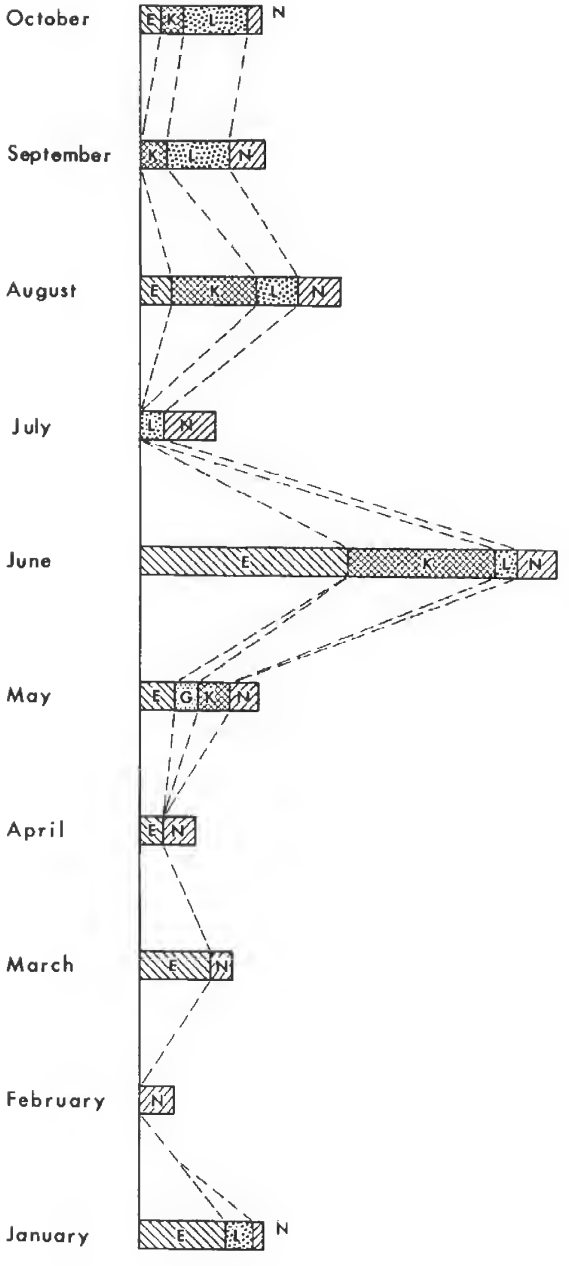

STATION 11
LEGEND
E — Elphidium gunteri
K — Streblus parkinsoniana
L — S. tepida
N — Others (6 individuals per species or less)
October
September
August
July
June
May
April
March
February
January
0
50
100
150
200
250
Number of Individuals

Figure 7



STATION 15

LEGEND

E — *Elphidium gunteri*

G — *E. matagordanum*

K — *Streblus parkinsoniana*

L — *S. tepida*

N — Others (8 individuals per species or less)

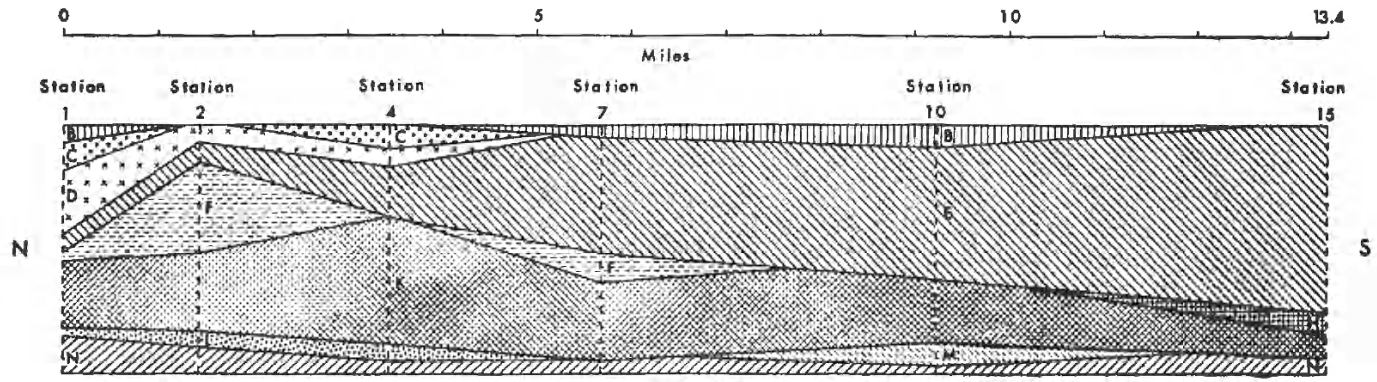


Figure 9a

MARCH – Species Distribution Profile

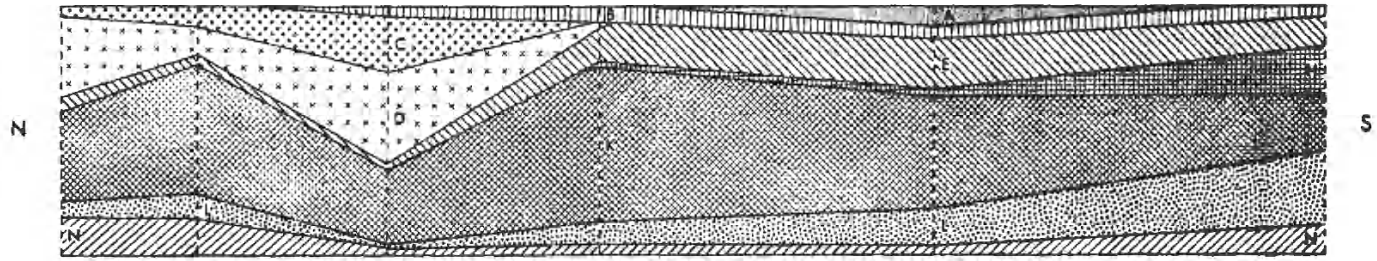
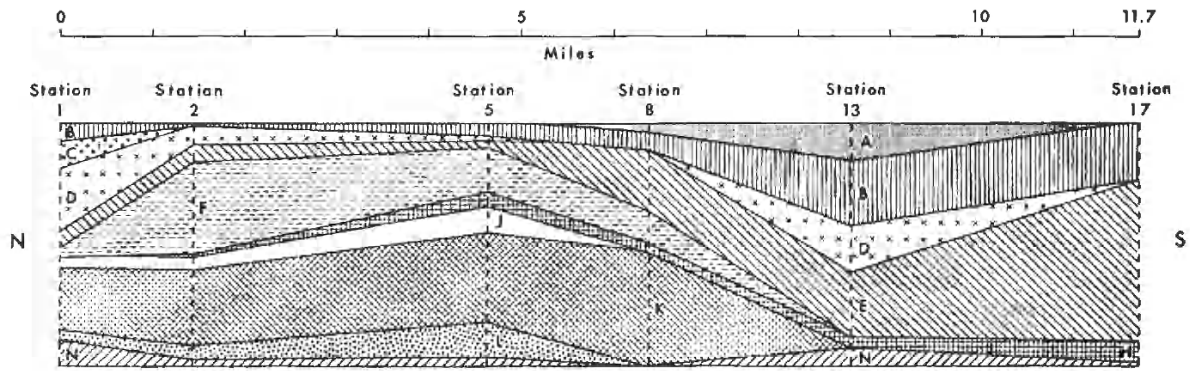


Figure 9b

JULY – Species Distribution Profile

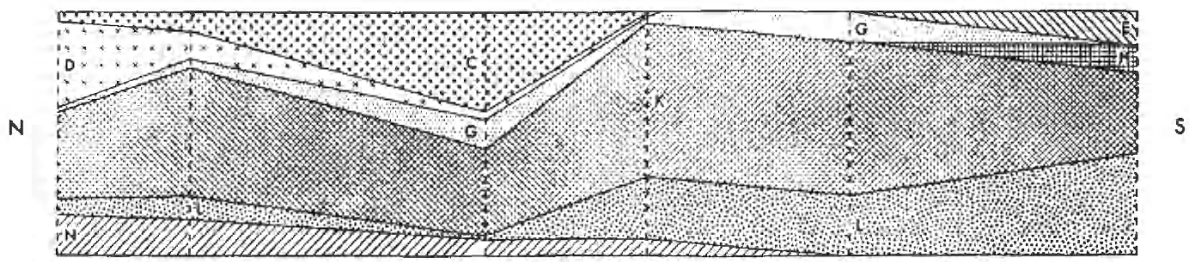
A – *Ammobaculites subcatenulatum*
B – *Ammotium dilatatum*
C – *A. fragile*
D – *A. salsum*
E – *Elphidium gunteri*
F – *E. limosum*
H – *E. poeyanum*
K – *Streblus parkinsoniana*
L – *Streblus lepida*
M – *Trochammina comprimata*
N – Others (8 individuals per species or less)

Figure 10a



MARCH – Species Distribution Profile

Figure 10b



JULY – Species Distribution Profile

A – *Ammobaculites subcatenulatum*
B – *Ammotium dilatatum*
C – *A. fragile*
D – *A. salsum*
E – *Elphidium gunteri*
F – *E. limosum*
G – *E. matagordanum*
H – *E. poeyanum*
J – *Miliammina fusca*
K – *Streblus parkinsoniana*
L – *S. tepida*
N – Others (8 individuals per species or less)

but, unlike *Streblus parkinsoniana*, this species increases in abundance seaward. The two — or three — month period between reproductions of the species does not agree fully with the findings of Bradshaw (1957), but is must be remembered that the laboratory cultures lacked the competition of other species found normally in nature.

Myers[6] attributes the reproductive peaks of Foraminifera to an abundance of food in conjuncton with favorable temperatures. Bradshaw's experiments and the present study indicate that reproduction is dependent upon salinity and temperature.

Chemical data relating to pH, redox potential, alkalinity, and phosphate, nitrate, carbohydrate and sulfate contents of the water appear to show no correlation with the reproductive cycles of the Foraminifera studied (see PHYSICAL AND CHEMICAL PROPERTIES OF THE WATER).

POPULATIONS

Study of the populations of living Foraminifera from each station (tables 1 to 17) suggests that a definite pattern is discernible in the total population increases of the Foraminifera within the bay. In most cases, there were sudden increases in the number of individuals at a station from one month to the next. The figures from Table 18 (total populations of living Foraminifera) are plotted diagrammatically (figure 11) so that they can be visualized more easily. The months showing the peaks of the increases were not always selected as the most diagnostic, as is shown in Figure 11. Instead, the months which showed the first evidence of a sudden increase in populations were chosen.

During January and February, the total living populations from each station were low. In March, a sudden increase in populations was noted at stations 1, 2, 4, 5, 6, 9 and 14 (Figure 12). In April, there was a sudden increase at stations 3, 8, 11, 12, 13 and 17, and in May, a population increase was noted at station 16. As though to complete a cycle, the stations on the western side of the bay (numbers 2, 4, 7, 10 and 15) had population increases in June.

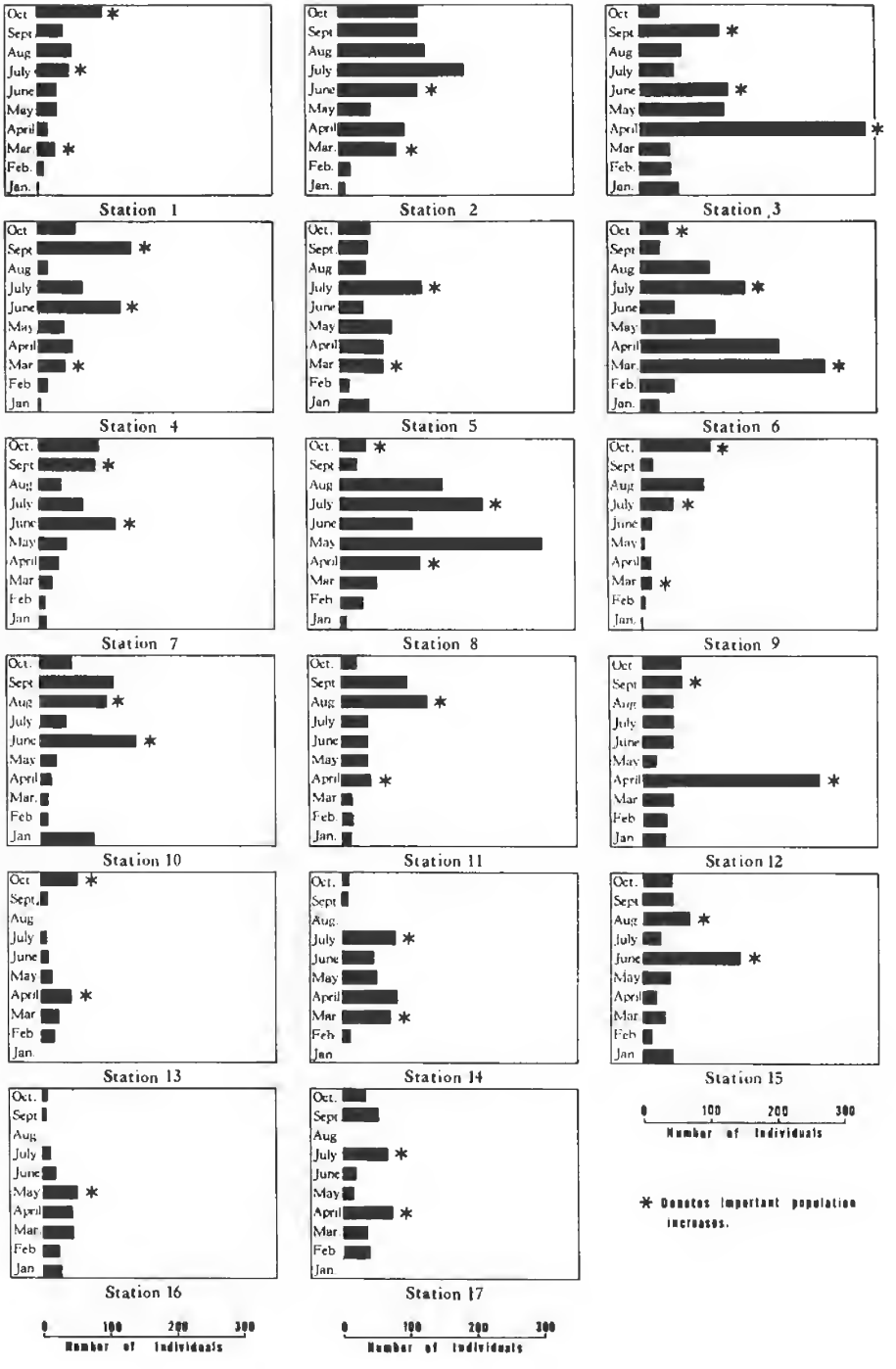
In July, population increases were noted at stations 1, 5, 6, 8, 9, 14 and 17. This was followed by increases at stations 10, 11 and 15 in August. Stations 13 and 16 were not collected during this month, so it is not known if they too had population increases. Four of the five remaining stations (numbers 3, 4, 7 and 12) had population increases in the following month, September.

Samples from the last collection in October showed population increases once more along the eastern side of the bay at stations 1, 6, 8, 9, and 13. It is unfortunate that later samples were not taken to determine if another cycle was beginning then.

The population increases are independent of the reproductive activity of any particular species. If the reproductive period of a species coincided with a population increase, the reproduction of the species was unusually large. This is evident in Figures 3 to 7, especially in Figure 5.

Two alternatives appear to explain the cyclic patterns of population increase. First, progressive increase may move clockwise around the bay, taking from three to four months to complete a full cycle. This, however, does not agree fully with the patterns of water movements about the bay as shown in Figure 1. Second, the population increases may be the result of a flow of nutrient materials into the bay from the land areas. Possibly, there was an unusually large amount of nutrient material released from adjacent marshes during March,

[6]Myers, E. H., (1943), p. 455.


Station 1
Station 2
Station 3
Station 4
Station 5
Station 6
Station 7
Station 8
Station 9
Station 10
Station 11
Station 12
Station 13
Station 14
Station 15
Station 16
Station 17
Oct
Sept
Aug
July
June
May
April
Mar
Feb
Jan
0
100
200
300
Number of Individuals
* Denotes important population increases.

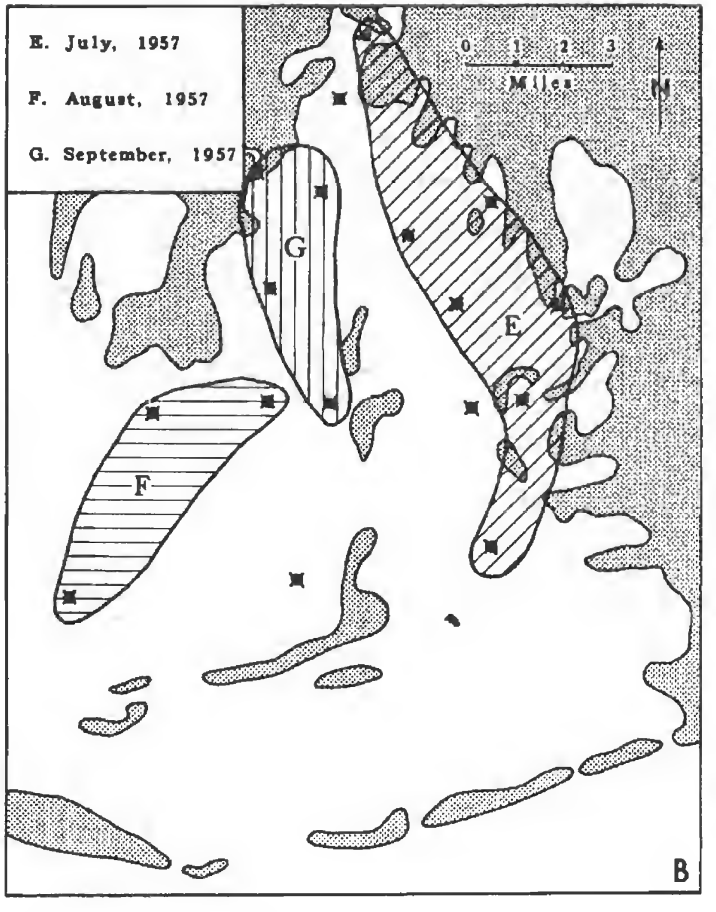


Figure 12b

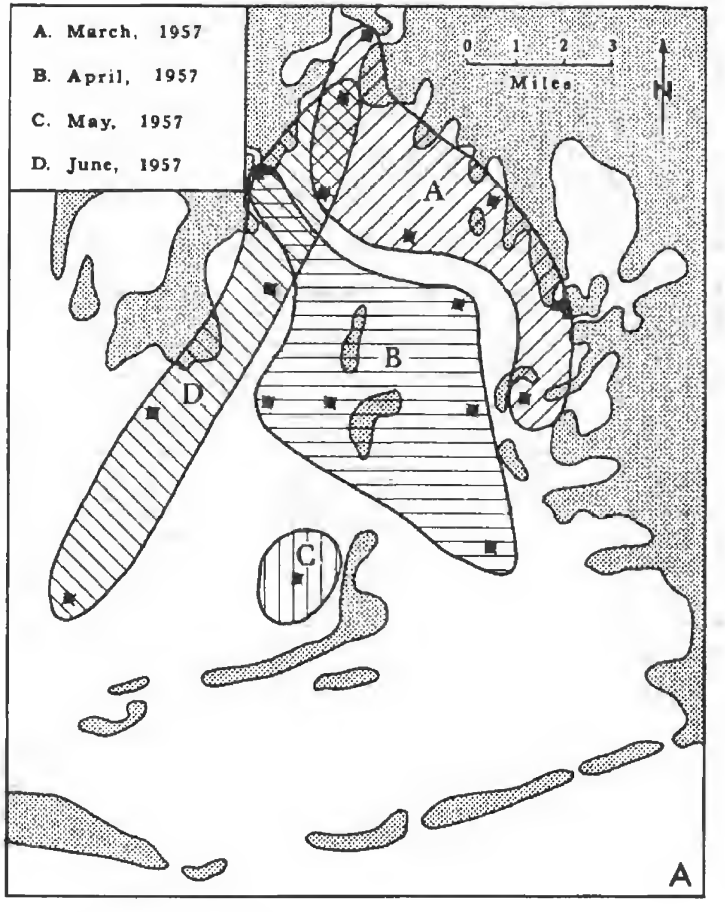


Figure 12a

July and late September. Aided by the increased rainfall at that time, it was carried out into the bay. The material probably then moved along slowly as a mass, while the fresh water mixed with the more saline waters of the bay.

The population increases in March fringed the northeastern shoreline of the bay in the area of the most important fresh water outlets. By April, the increases had moved out into the bay showing a widening in the vicinity of the two large islands, Philo Brice Islands. This suggests that much of the water entering the bay from Deep Bayou and Bayou Blue to east moves west-southwesterly through the pass between these islands. Station 16 shows only a slight increase in May, indicating that the nutrient supply at this time was about exhausted.

The population increases in June were along the western side of the bay, suggesting that the nutrient materials which were responsible for the increases were transported into the area from the vicinity of Terrebonne Bay by the normal water movements.

The July increases along the eastern side of the bay spread farther into the open water than the March increases, indicating possibly more rapid water movements brought on by heavy rainfalls. The known population increases during August suggest that nutrients were once again carried into Timbalier Bay from Terrebonne Bay. The water movements then transported the nutrients into the upper bay by September.

It was not possible to determine from the data available which of the nutrients were responsible for the population increases, but it is likely that they were organic in nature. Data on the inorganic nutrients, nitrates and phosphates (tables 26 and 27), do not indicate any correlation with the population increases. This does not mean, however, that they can be considered unimportant, because it is not known to what extent they were available metabolically to the organisms.

Carbohydrate content of the water (table 28) was determined for only four months, so no decision can be made about its importance. A more detailed biochemical study of the nutrients would be necessary before any definite conclusions as to the cause of these population increases can be drawn.

It was noted that the stations with the highest yearly populations (numbers 2, 3, 6 and 8) were located within two miles of the fresh water outlets. They possibly received a large amount of nutrients in comparison with other bay stations. Stations 1 and 9, although in the mouths of the freshwater outlets, have small populations because of strong water currents.

SUMMARY AND CONCLUSIONS

Land and Water. Timbalier Bay has been undergoing numerous alterations in its outline since termination of deposition by the Lafourche distributary system. Changes in land-water relationship have brought about changes in the direction of water movements within the bay. During the last sixty years, drainage has shifted from southerly to southwesterly.

It is believed that the nutrient materials which controlled the size of the foraminiferal populations were derived from the land areas. Sampling stations which support larger foraminiferal populations (numbers 2, 3, 6 and 8) are close enough to fresh water outlets that they receive abundant amounts of nutrients. Stations 1 and 9, although located in the mouths of these outlets, have small populations because of strong water currents.

Chemistry. Chemical properties of the water which apparently have no noticeable effects upon the foraminiferal populations and species are pH, redox potential, alkalinity and sulphates. Positive correlation between the distribution of nutrient materials (nitrates, phosphates and carbohydrates) and the foraminiferal population were not shown. The only chemical property measured which has a direct influence on the Foraminifera is salinity, which will be discussed below.

Climate, Salinity and Temperature. The climate of the area is generally cool and dry in the winter and warm and wet in the summer. Salinity reflects the effects of precipitation by being highest in the late winter months and lowest in the summer. Rapid changes in precipitation and air temperatures, resulting from rapidly moving storm fronts, have only minor effects upon salinity and temperature of the bottom waters.

Stations. The seventeen stations sampled reflect a relatively complete coverage of the bay area. Sedimentological studies of bay materials showed that there are two distinctive sediment types within the bay. Open bay sediments were derived from the wasting away of marsh and contain a high percentage of silt. Sediments derived principally from eroded natural levees contain more sandsize material.

It was noted that faunas are occasionally restricted to a particular type of bottom. This is the case with stations 8 and 15, which have sandy bottoms.

Biofacies. Timbalier Bay is polyhaline. A foraminiferal faunal division is present within the bay. An upper bay facies, containing principally arenaceous species, includes Lake Raccourci, whereas Timbalier Bay proper is characterized by calcareous, nearly marine species.

Species. After the samples were studied, it was decided that twenty-three foraminferal species were present often enough to be considered common in the area. Many species show restriction to certain salinities, whereas others depend upon bottom sediments and water movements.

It was noted that most species had three or four reproductive periods during the ten months of observation at intervals of two or three months. Reproductive activity of the Foraminifera was extremely low in the winter. Results of this study indicate that reproduction is dependent in part upon salinity and temperature.

Populations. Increases in populations of Foraminifera in the bay seem to follow a distinct pattern. Sudden increases tend to move from one area to another during succeeding months. The manner in which these increases move suggests that they were caused by fluctuation in the amount of organic nutrients transported into the bay from land.

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APPENDIX

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
	2	8	27	15	30	30	47	52	38	97
Ammoastuta salsa		1m								
Ammobaculites crassus			1s			3s	1s		1l	
A. subcatenulatum			1m				1m	2s	4s	13m
Ammotium dilatatus			2s		1s					
A. fragile			3s		1m	5m	2m			4m
A salsum	1s	2m	7s	1s	6s	5s	15s	4m	6m	26m
Arenoparella mexicana			1s			1s	1s	1s		
Bolivina striatula										
Elphidium gunteri			2s	1s	5s	1s	3s	4s	2m	6s
E. limosum			1s						1m	
E. matagordanum				1s		1s	1s	1s		2s
E poeyanum		1m								
Gaudryina exilis										
Hoplophragmoides manilaensis										
H. wilberti										
Miliammina fusca			1s	3s	1s		2s	3s	1s	2s
Quinqueloculina cf Q lamarckiana										
Q rhodiensis										1s
Streblus parkinsoniana	1s	3s	7s	7s	11m	11s	17s	20s	12s	25s
S tepida		1s	1s	2s	5s	3s	3s	16s	11s	18s
Trochammina comprimata							1s			
T inflata										
T macroscens								1s		

Table 1 Populations of living Foraminifera from station 1 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
	9	18	87	99	48	119	188	129	119	120
Ammoastuta salsa	1m								1m	
Ammobaculites crassus		1m	1s	2 l	2m		1m	6m	3m	3m
A. subcatenulatum			1m	2m						
Ammotium dilatatus			1m			4m	1s	2s	1s	5s
A. fragile				2m		15 l	15m	8m	1s	5m
A. salsum		2m	6m	10s	6m	25m	21m	24m	5m	17s
Arenoparella mexicana						4s	2s	1s	2s	1s
Bolivina striatula										
Elphidium gunteri	2s	6s	7s	9s	6s	2s	7s	9s	2s	10s
E. limosum			32s	6m	1s		3s	1s	1s	
E. matagordanum		1s			3s	1s	7s	3s	4s	1s
E. poeyanum	1s		2s	9s					2s	1s
Gaudryina exilis										
Haplophragmoides manilaensis			1s			1s				
H. wilberti				1m	1s		7s	4s	1m	
Miliammina fusca	1s	3m	4m	13s	5s	1m	6s	9s	1s	1m
Quinqueloculina cf. Q. lamarckiana										
Q. rhodiensis							1s	1s		
Streblus parkinsoniana	4m	5s	27s	37s	21s	53s	97s	52s	58s	49s
S. tepida			5s	8s	2s	12s	19s	8s	37s	26s
Trochammina comprimata					1s	1s	1s	1s		
T. inflata										
T. macroscens					1s					1m

Table 2 Populations of living Foraminifera from station 2 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
TOTAL	57	47	46	336	127	132	50	63	119	31
Ammoastuta salsa	1m						1m			
Ammobaculites crassus										
A. subcatenulatum	2m	6s	2s	1s		1s				
Ammotium dilatatus		2m		7m	3s	4m	1 l	1s	1s	
A fragile	3s	2s	7s			4s	6m	7s	2s	
A salsum	2m		2m	280m	93m	114m	12m	35m	17m	1m
Arenoparella mexicana	4s	1s	1s				1s		1s	
Bolivina striatula										
Elphidium gunteri	6s	13s	9s	8s	10s		6s		2s	8s
E. limosum		4s	4s	2s			2s			
E matagordanum							1s			1s
E poeyanum			3s	3s		1s			1s	
Gaudryina exilis										
Haplophragmoides manilaensis										
H. wilberti	17s	6s	4m	1s	1s		2m	2m		
Miliammina fusca	1m			4s	2s		2s	2m		
Quinqueloculina cf Q lamarckiana										
Q. rhodiensis	1s									
Streblus parkinsoniana	11s	4m	8m	9s	8s	4m	10s	10s	75s	15s
S. tepida	4s	7s	5s	21s	9s	4s	6s	6s	20s	6s
Trochammina comprimata	2s	2s	1m							
T. inflata	3s				1s					
T. macroscens										

Table 3 Populations of living Foraminifera from station 3 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
	3	14	41	53	40	123	67	15	140	56
Ammoastuta salsa										
Ammobaculites crassus										
A. subcatenulatum							1m			
Ammotium dilatatus					2s	1m	3s	1s	1m	
A. fragile			4m		8m	46 l	15m	4s	1m	
A. salsum			3s		1m	24m	25m	10m		
Arenoparella mexicana										
Bolivina striatula										
Elphidium gunteri	1s	4s	8s	20s	1s	2s	1s			4s
E. limosum				2s						
E. matagordanum			2s	2s		1s			1s	1s
E. poeyanum				1s						
Gaudryina exilis										
Haplophragmoides manilaensis										
H. wilberti										
Miliammina fusca						2s	1s			
Quinqueloculina cf Q lamarckiana										
Q. rhodiensis										1s
Streblus parkinsoniano	2m	10s	21s	25s	24s	47s	20s		135m	49m
S. tepida			3s	3s	4s		1s		2s	1s
Trochammina comprimata										
T. inflata										
T. macroscens										

Table 4 Populations of living Foraminifera from station 4 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
	44	16	65	66	79	35	123	40	43	47
Ammoastuta salsa										
Ammobacelites crassus							1s			
A. subcatenulatum										
Ammotium dilatatus			3m		4s	2s	3s			
A. fragile	1m			1s	2s	8m	51m			
A salsum			1s		2s	2s	4m	1m		
Arenoparella mexicana										
Bolivina striatula										
Elphidium gunteri	1s	1s	2s	9s	1s	1 l	1s			1s
E. limosum			12s	1s			1m			
E matagordanum	38s	10s	3s	44s	5s	7s	15s	24s	3s	25s
E paeyanum			4s		1s		1s	1s	1s	
Gaudryina exilis										
Haplophragmoides manilaensis										
H. wilberti										
Miliammina fusca	1m		7m	2m	7m		1s	3s		
Quinqueloculina cf Q lamarckiana										
Q rhodiensis										
Streblus parkinsoniana	3s	5s	24s	9s	54s	14s	44s	11s	39s	21s
S tepida			9s		3s	1s	1s			
Trochammina comprimata										
T. inflata										
T macrescens										

Table 5 Populations of living Foraminifera from station 5 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
TOTAL	28	48	274	207	111	50	156	103	30	42
Ammoastuta salsa					1m					
Ammobaculites crassus					1m	1 l	2m			
A. subcatenulatum		1s		2m						
Ammotium dilatatus			1m	4m	40m	11m	5 m	2s		1s
A. fragile	8s	2s	1m	1m	5s	6s	3s	7s	3s	1s
A salsum	3s	1s	2m	2m	18m	17m	111m	76m	6m	
Arenoparella mexicana	1s									
Bolivina striatula										
Elphidium gunteri		12s	18s	123s		1s		1s		2s
E. limosum		12s	153s	8s	3s		5s			
E matagordanum		13s	1s		11s	1s	13s	5s	10s	19s
E poeyanum	1s	3s		2s						
Gaudryina exilis										
Haplophragmoides manilaensis										
H. wilberti			1s					1s		
Miliammina fusca	13s	3m	80s	40s	23s	11s	16s	10s		
Quinqueloculina cf Q lamarckiana										
Q. rhodiensis										
Streblus parkinsoniana	1m	1m	12s	10s	5s	1s		1m	11s	14s
S tepida			5s	15s	4s	1s				5s
Trochammina comprimata	1s						1s*			
T. inflata										
T macroscens										

Table 6 Populations of living Foraminifera from station 6 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
	11	9	19	30	41	114	65	33	84	91
Ammoostuta salsa									1m	
Ammobaculites crassus					1 l			2s		
A. subcatenulatum										
Ammotium dilatatus			1s			52m	4m	9m		
A. fragile					2s			.3s		
A salsum	1s			1s	2m	5s	1m	3m		1s
Arenoparella mexicana					1s	1s				
Bolivina striatula										
Elphidium gunteri	8s	6m	9s	13s	6s	13s	9m	2s	4s	
E. limasum			2s			1s				
E matagordanum					6s	2s	1s			
E poeyanum			1m	3s			1s			
Gaudryina exilis										
Haplophragmoides manilaensis						1m				
H. wilberti		1m			1m	2s	1s	1m	1m	
Miliammina fusca					2s					
Quinqueloculina cf Q lamarckiana										
Q. rhodiensis							1s			
Streblus parkinsoniana	1s	2m	6m	13m	19m	33s	*41s	11s	68s	89m
S tepida	1s					3s	6s	2s	9s	1s
Trochammina comprimata						1s				
T. inflata					1s				1s	
T. macrascens										

Table 7 Populations of living Foraminifera from station 7 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
TOTAL	10	34	55	120	302	109	213	154	26	40
Ammoastuta salsa										
Ammobaculites crassus										
A subcatenulatum			2m	1m						
Ammotium dilatatus			.4s		15m	1s	3s	1s		1s
A fragile					1 l					3s
A salsum	3s			2m	9m	1m	1m			
Arenoparella mexicana					1s		1s	1s		
Bolivina striatula								1m		
Elphidium gunteri		10s	14s	41s	13s	25s	5s	22s		1s
E. limosum			7s	1s				3s		
E matagordanum	1s	1s		1s	3s	2m	7s	2s	3s	
E poeyanum		1s	2s	4s	5s	2s	3s	4s		
Gaudryina exilis										
Haplophragmoides manilaensis										
H wilberti						1s		2s		
Miliammina fusca		1s			1s					1s
Quinqueloculina cf Q lamarckiana										
Q. rhodiensis					4s	2s	4s			
Streblus parkinsoniana	6s	20s	26m	65s	204s	56s	135s	104s	20s	33s
S lepida		1s		5s	45s	19s	54s	14s	3s	1s
Trochammina comprimata										
T inflata					1 l					
T. macrescens										

Table 8 Populations of living Foraminifera from station 8 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
	2	5	16	14	5	17	48	93	18	103
Ammoastuta salsa										
Ammobaculites crassus		1 l								
A. subcatenulatum								4s		2s
Ammotium dilatatus							2s	2m	1s	
A fragile										
A. salsum	1 l		3m			1s			1s	2m
Arenoparella mexicana			1m				16s	1s		1s
Bolivina striatula										
Elphidium gunteri		2s		4s		2s		3s		5s
E. limosum		1s		1s	1s			2s		
E matagordanum	1s	1s	2s			6s		3s		
E poeyanum			1s	1s		1s			2s	
Gaudryina exilis										
Haplophragmoides manilaensis										
H. wilberti							20m	2s		
Miliammina fusca			1s	2s					1s	
Quinqueloculina cf Q lamarckiana										
Q rhodiensis										
Streblus parkinsoniana			2s	6s	1s	4s	11s	42s	8s	87s
S tepida			6s		3s	3s		33s	6s	6s
Trochammina comprimata										
T. inflata										
T macroscens								1s		

Table 9 Populations of living Foraminifera from station 9 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
TOTAL	80	11	11	17	24	143	40	100	109	49
Ammoastuta salsa									1m	
Ammobaculites crassus								1m		
A subcatenulatum					2s	2s	3s	5s	2s	
Ammatium dilatatus	1 l	1s	1 l		3m	3m	2m	2m		
A. fragile							2s	5s		
A salsum	1s				1s			4s	1s	
Arenaparella mexicana										
Bolivina striatula										
Elphidium gunteri	6s	6s	6s	1s	2s	17s	8s	15s	7s	11s
E. limosum					1s	1m		1s		
E. matagordanum	2m				2s	3s		2s	3s	1s
E poeyanum	1m	1s			1s	4s	1s	3s		1m
Gaudryina exilis										
Haplaphragmoides manilaensis										
H. wilberti						1s				
Miliammina fusca									1s	
Quinqueloculina cf Q lamarckiana						1 l			1 l	
Q. rhodiensis									2s	
Streblus parkinsoniana	8s		3m	1m	2s	68s	18s	46s	60s	23s
S. tepida	6s	2s		14s	10s	42s	6s	14s	27s	13s
Trochammina comprimata	1s	1s	1s						4s	
T inflata				1 l				1s		
T. macroscens								1m		

Table 10 Populations of living Foraminifera from station 10 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
TOTAL	14	17	16	43	39	37	41	129	99	23
Ammoastuta salsa		1m								
Ammobaculites crassus										
A. subcatenulatum									1s	
Ammotium dilatatus						1 l		1m		
A. fragile										
A salsum	1s		3m	1s	2s	1s	2m			
Arenoparella mexicana			3s	1s		1s	1s	2s		
Bolivina striatula										
Elphidium gunteri	10s	10s	2s	16s	12s		5s	6s	5s	3s
E. limosum	1s			1s		2s	1s	1s	1m	
E matagordanum		1s	1s			2s		5s	4s	1s
E poeyanum	1s			3s				2s		
Gaudryina exilis										
Haplophragmoides manilaensis										
H. wilberti			2s		3s	1s	1s	2s		
Miliammina fusca	1s									
Quinqueloculina cf Q lamarckiana										
Q. rhodiensis								1s		
Streblus porkinsoniana		2s	1m	15s	11s	21s	28s	84s	79m	17m
S tepida				6s	3s	7s	3s	25s	9s	2s
Trochammina comprimata		2s	2s		2s	1s				
T. inflata					3s					
T. macroscens		1s	2s		3s					

Table 11 Populations of living Foraminifera fron station 11 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
	33	36	47	263	21	45	45	46	59	57
Ammoastuta salsa										
Ammobaculites crassus		1m								
A subcatenulatum					1s					
Ammotium dilatatus	9s	1m	8s		4s	3s			2m	
A. fragile										
A salsum				1s						
Arenoparella mexicana							1s			
Balivina striatula										
Elphidium gunteri	19s	15s	30s	243s	9s	21s	4s	1s	5s	6s
E. limosum										
E matagordanum		2s	1s		2s		4s	3s		1s
E poeyanum	1s		3s	1s						1s
Gaudryina exilis										
Haplophragmoides manilaensis										
H wilberti							1s			
Miliammina fusca	2s	2s		1s	1s					
Quinqueloculina cf Q lamarckiana										
Q rhodiensis										1s
Streblus parkinsoniana	1m	14s	3m	16s	4s	10s	31s	41s	50m	46m
S tepida	1s	1s	2s	1s		11s	4s	1s	1s	2s
Trochammina comprimata										
T. inflata									1m	
T. macroscens										

Table 12 Populations of living Foraminifera from station 12 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
		20	26	44	16	9	8		9	53
Ammoastuta salsa										
Ammobaculites crassus									1m	
A. subcatenulatum			4m							
Ammatium dilatatus		8m	7m		1s					
A fragile				1m						
A. salsum			5s			1s				
Arenoparella mexicana										
Bolivina striatula										
Elphidium gunteri		7s	7s	34s	8s	2s			2s	16s
E. limosum										
E. matagordanum		1s	1s		4s	4s	1s			2s
E. poeyanum		2s	1s	1s		1s				6s
Gaudryina exilis										
Haplophragmoides manilaensis										
H wilberti										
Miliamming fusca			1s							1s
Quinqueloculina cf. Q lamarckiana										
Q. rhodiensis										1s
Streblus parkinsoniana				5s	2s		5s		5s	9s
S tepida		2s		3s	1s	1s	2s		2s	17s
Trochammina comprimata										
T. inflata										
T. macroscens										

Table 13 Populations of living Foraminifera from station 13 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
TOTAL		11	71	18	51	46	79		8	10
Ammoastuta salsa									1m	
Ammoboculites crassus										
A. subcatenulatum			1m	1s			2m			
Ammotium dilatatus		4m	35m		3s	3s				
A. fragile		2s	1m	1s	2s	1s	2s			2s
A salsum			17m	57m	38m	41m	71m		3s	
Arenoparella mexicana										
Bolivina striatula										
Elphidium gunteri										
E. limosum			1s							
E. matagordanum			1s	8s	3s					1s
E. poeyanum				2s						
Gaudryina exilis										
Haplophragmoides manilaensis										
H. wilberti			1s				1s			
Miliammina fusca		3s	12s	3s		1s	3s			
Quinqueloculina cf Q. lamarckiana										
Q. rhodiensis										
Streblus parkinsoniana		2s	2s	9s	4s				2s	4s
S. tepida					1s				1s	3s
Trochammina comprimata									1s	
T. inflata										
T. macroscens										

Table 14 Populations of living Foraminifera from station 14 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
TOTAL	43	12	32	19	41	144	26	69	43	42
Ammoastuta salsa										
Ammobaculites crassus							1s			
A. subcatenulatum						1s				
Ammotium dilatatus					1s		1m	2s		
A. fragile										
A. salsum		1s			1s	1s				
Arenoparella mexicana										
Bolivina striatula	1m					2m		1m		
Elphidium gunteri	30s	6s	24s	8s	12s	72s	3s	11s	5s	7s
E. limosum								1s	1s	
E. matagordanum						3s		1s		1s
E. poeyanum	3s	5s	3s	3s	8s	3s	5s	4s	2s	1s
Gaudryina exilis				1m	1 l	2m		1m		
Haplophragmoides manilaensis										
H. wilberti										
Miliammina fusca										
Quinqueloculina cf. Q lamarckiana			1m		1s		1s	2 l	2 l	3m
Q. rhodiensis				1s		1m		2s	2s	
Streblus parkinsoniana			3s		11s	51m	6m	29s	9s	8m
S. tepida	9s		1s	6s	6s	8s	8s	14s	22s	22s
Trochammina comprimata							1s			
T. inflata										
T. macroscens										

Table 15 Populations of living Foraminifera from station 15 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
	27	24	45	43	51	20	12		6	7
Ammoastuta salsa										
Ammobaculites crassus										
A. subcatenulatum										
Ammotium dilatatus	3s	2s	16m	4l	15m	5m	1m			
A. fragile										
A salsum						5s				
Arenoparella mexicana										
Bolivina striatula										
Elphidium gunteri	17s	14s	14s	21s	20s	5s	4s		1s	1s
E. limosum										
E. matagordanum		3s	6s	2s	2s	2s	2s		1s	
E. poeyanum	3s	2s	4s	9s	3s		1s			1m
Gaudryina exilis										
Haplophragmoides manilaensis										
H. wilberti										
Miliammina fusca						1s				
Quinqueloculina cf Q. lamarckiana										1s
Q. rhodiensis					1s					
Streblus parkinsoniana	2s	2s	4s	5s	4s	2s	3s		3s	3s
S. tepida	2s	1s	1s	2s	6s		1s		1s	1s
Trochammina comprimata										
T. inflata										
T. macroscens										

Table 16 Populations of living Foraminifera from station 16 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

MONTH / TOTAL / SPECIES	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
		38	35	73	15	19	66		53s	33
Ammoastuta salsa									1m	
Ammobaculites crassus										
A. subcatenulatum										
Ammotium dilatatus			8m	2s	2s					
A frogile									2s	
A salsum										
Arenoparella mexicana		1m					2s			
Bolivina striatula										
Elphidium gunteri		29s	23s	41s	6s	5s	9s		12s	7s
E. limosum										
E matagordanum										
E poeyanum		2s	3s	5s	1s	1s	7s		1s	
Gaudryina exilis										
Haplophragmoides manilaensis										
H wilberti										
Miliammina fusca										
Quinqueloculina cf Q lamarckiana										
Q. rhodiensis										
Streblus parkinsoniana		5m		12s	2m	11m	22m		16s	5s
S tepida		1s	1s	13s	4s	2s	26s		21s	21s
Trochammina comprimata										
T inflata										
T. macroscens										

Table 17 Populations of living Foraminifera from station 17 showing average sizes. Small (s) = <0.177 mm; medium (m) = 0.177-0.250 mm; large (l) = >0.250 mm.

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.
1	2	8	27	15	30	30	47	52	38	97
2	9	18	87	99	48	119	188	129	119	120
3	57	47	46	336	127	132	50	63	119	31
4	3	14	41	53	40	123	67	15	140	56
5	44	16	65	66	79	35	123	40	43	47
6	28	48	274	207	111	50	156	103	30	42
7	11	9	19	30	41	114	65	33	84	91
8	10	34	55	120	302	109	213	154	26	40
9	2	5	16	14	5	17	48	93	18	103
10	80	11	11	17	24	143	40	100	109	49
11	14	17	16	43	39	37	41	129	99	23
12	33	36	47	263	21	45	45	46	59	57
13		20	26	44	16	9	8		9	53
14		11	71	81	51	46	79		8	10
15	43	12	32	19	41	144	26	69	43	42
16	27	24	45	43	51	20	12		6	7
17		38	35	73	15	19	66		53	33

Table 18. Total populations of living Foraminifera from all stations, with important population increases underlined.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Total	1050	2690	1720	500	1050	810	850	1240	260	3080	410	840	640	3810	1340	1230	850
Ammoastuta salsa	.1	.3	.5		.2	.5		.2	2	.9	1	.1	.2	1	.2	.1	.4
Ammobaculites crassus	7	.3	.1				.5					.2	.5	.1			.1
A. subcatenulatus	.6	.1	.1				.1		3					.2		.2	
Ammotium dilatatum		.1	.5	.8	1	.1	.8	.1	.4	.4		.8	1	.4	.5	2	.4
A. fragile	1	2	2	3	3	9	6	.3	11	2	.6	2	1	8	.1	10	
A. salsum	39	52	27	34	34	77	13	2	44	14	8	2	3	73	.2	14	2
Arenoparella mexicana	.2	.6	4	.2	1	1	4	.3	2	2	2	.4	.5	3	.1		.5
Bolivina striatula							.1					.1			.1	.1	
Elphidium gunteri	3	2	5	7	5		13	39	3	7	15	23	2		44	23	27
E. limosum	1	.3	.5	.4	.9	.2	2	1		1	2	.4	3		.4	2	4
E. matagordanum	.4	.3	.4	.2	5	.1	.6	.4	1	.2	2	.2	.5	.1	.4	.4	
E. poeyanum		.1	.5		.9	.1	.9	1		.7	2	3	2		.5	1	6
Gaudryina exilis											.2				.5	.2	.4
Haplophragmoides manilaensis	1	.8	14		.3	1	4	.2	3	.7	3	.4	.5	1	.2	.2	.2
H. wilberti	.1	.2	2				.7		.8	.1		.2		.1	.4	.1	
Miliammina fusca	.2	.3	1	1	1	10	.7		8	.3	3	.7	1	10		.2	.1
Quinqueloculina cf. Q.lamarckiana															2	.2	.2
Q rhodiensis	.3	.1	.7				.8	1		.4	1	.4			1		.7
Streblus parkinsoniana	41	25	30	51	43	.9	47	40	17	34	10	42	45	.6	37	28	43
S. tepida	1	3	11	.6	5		5	14	3	32	41	23	28		12	16	13
Trochammina comprimata	.1		.2	.2		.1	.1		.8	.3	.2			.1	.2		
T. inflata	.2	.1	.7	.4	.2	.3	.5	.2	.8	.6	1	.4	.5	.1	.1	.1	.4
T macroscens	.2		.3				.1			.3	1	.2	.2				

Table 19. Total populations of Foraminifera expressed in percent.

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.
1	19.7	22.3	18.4	23.0	29.8	29.8	31.1	32.0	29.4	23.5
2	19.4	22.0	18.0	23.2	30.4	30.0	29.8	30.6	29.7	23.5
3	20.0	22.1	18.2	23.8	28.8	29.4	31.8	30.1	30.0	21.6
4	19.4	21.9	18.0	23.4	28.4	29.8	30.8	29.7	28.4	22.6
5	20.0	21.3	17.5	22.4	28.4	30.0	30.8	29.7	29.0	23.5
6	20.0	22.0	17.8	23.4	30.3	30.4	31.3	33.0	29.1	24.2
7	20.0	19.9	18.2	23.6	29.6	30.2	31.2	30.2	29.0	22.4
8	20.0	22.3	18.7	22.2	28.0	30.0	30.8	29.6	28.5	24.1
9	20.0	22.0	17.9	22.5	30.5	30.1	31.0	31.4	28.0	23.8
10	20.3	21.8	18.3	23.2	29.7	29.8	31.1	29.4	29.5	23.1
11	20.0	21.5	18.1	23.4	30.1	29.6	30.6	29.8	28.8	23.0
12	20.0	21.6	19.0	23.8	29.4	30.1	30.4	29.4	28.4	22.7
13		24.0	19.4	23.6	30.2	30.0	31.0		28.4	24.0
14		23.1	20.1	23.7	29.4	30.3	30.0		28.5	24.5
15	20.4	22.5	19.6	23.4	29.4	30.0	31.4	29.4	28.4	23.2
16	20.6	23.0	19.2	23.3	29.6	30.8	31.2		27.4	23.8
17		23.5	19.0	23.0	29.4	30.0	30.6		27.3	23.2

Table 20. Temperatures of bottom waters from Jnauary to October, 1957, expressed in degree Centigrade.

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.
1	8.3	8.1	7.8	7.9	7.8	7.9	8.0	7.9	8.0	8.0
2	8.4	8.2	7.9	7.9	7.9	8.0	7.9	7.7	8.1	8.2
3	8.2	8.2	7.9	8.0	8.0	8.1	8.0	8.0	8.2	8.3
4	8.3	8.2	7.9	8.1	8.1	8.2	8.0	8.0	8.2	8.2
5	8.2	8.2	8.0	8.1	8.1	8.2	8.1	8.2	8.1	8.2
6	8.2	8.1	7.8	8.1	8.1	8.1	8.1	8.0	8.2	8.2
7	8.1	8.2	8.0	8.1	8.2	8.2	8.1	8.2	8.0	8.1
8	8.1	8.2	8.1	8.2	8.0	8.1	8.2	8.2	8.2	8.3
9	8.5	8.1	8.1	8.1	8.0	8.1	7.9	8.4	8.1	7.2
10	8.0	8.1	7.9	8.1	8.2	8.0	8.0	7.8	8.2	8.1
11	8.1	8.2	7.9	8.2	8.2	8.2	7.9	7.7	8.1	8.2
12	8.0	8.0	8.1	8.1	8.2	8.1	7.8	8.0	8.1	8.2
13		8.2	8.1	7.9	8.1	8.2	7.8		8.0	8.2
14		8.2	8.1	8.3	8.2	8.1	7.8		8.1	8.1
15	8.0	8.1	8.2	8.4	8.4	7.9	8.2	8.0	8.4	8.2
16	8.0	8.2	8.2	8.4	8.3	8.2	8.1		8.2	8.2
17		8.3	8.1	8.3	8.2	8.3	8.1		8.1	8.0

Table 21. Hydrogen ion concentrations (pH) of bottom waters from January to October, 1957.

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.
1	385	319		462	336	322	216		36	91
2	376	363		444	340	327	227		11	67
3	364	337		449	359	322	246		51	100
4	376	340		449	332	316	257		68	71
5	364	321		450	350	316	274		48	71
5	385	303		443	340	317	198		95	79
7	361	337		443	343	316	246		55	103
8	370	358		456	341	320	255		79	53
9	400	311		456	344	311	226		39	24
10	376	356		414	349	327	222		105	103
11	376	349		389	348	331	223		37	95
12	367	350		473	343	321	229		66	89
13		353		461	356	311	279		13	11
14		347		521	361	310	247		45	67
15	363	336		401	340	326	201			127
16		351		426	434	327	204		53	67
17		353		402	353	249	266		30	127

Table 22. Redox potentials (eh) of bottom waters from January to October, 1957, expressed as millivolts. (All of the readings are of positive voltage).

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.
1	11.28	12.16	12.12	9.37	10.49	8.47	8.67	6.23	9.34	7.12
2	11.96	12.83	13.02	9.54	10.67	8.77	8.63	6.93	9.46	6.80
3	13.30	12.39	12.88	10.40	11.54	9.92	9.90	8.89	10.13	7.8
4	12.48	12.41	13.65	10.79	11.29	9.91	8.40	9.16	10.95	7.57
5	12.42	13.62	14.60	10.76	11.19	9.30	9.55	9.28	11.38	7.95
6	11.61	13.49	13.26	9.82	10.59	8.90	9.03		10.04	7.01
7	12.81	13.23	14.10	10.28	12.47	10.11	10.61	9.38	12.27	9.01
8	13.49	14.23	13.72	9.77	11.28	9.15	9.50	10.06	12.82	8.11
9	12.17	12.77	12.16	7.16	9.74	8.21	8.64	7.52	10.80	6.60
10	16.05	14.12	14.93	10.62	12.28	10.68	12.61	13.74	14.45	10.21
11	14.52	13.43	14.61	10.16	12.53	10.37	11.40	13.04	14.48	10.38
12	14.06	15.13	14.52	10.04	12.10	10.04	10.99	11.89	14.03	10.34
13		16.22	13.60	9.25	11.01	9.88	11.13		15.30	8.12
14		16.54	13.06	7.58	10.85	8.89	9.68		14.31	7.18
15	18.09	16.81	16.76	13.52	10.30	10.04	15.92	16.98	16.99	12.28
16	17.28	16.51	15.15	12.67	10.17	10.26	14.79		15.51	11.68
17		16.67	14.88	12.66	10.44	9.93	13.97		16.44	10.93

Table 23. Chlorinities of bottom waters from January to October, 1957, expressed in parts per thousand.

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.
1	20.39	21.98	21.91	16.94	18.96	15.32	15.68	11.44	16.89	12.88
2	21.62	23.19	23.53	17.32	19.29	15.86	15.61	12.54	17.10	12.30
3	24.04	22.39	23.28	18.80	20.86	17.94	17.90	16.24	18.31	12.99
4	22.56	22.43	24.67	19.51	20.41	17.92	15.19	16.56	19.79	13.69
5	22.45	25.61	26.38	19.45	20.23	16.82	17.27	16.78	20.57	14.39
6	20.99	24.38	23.96	17.76	19.14	16.09	16.33		18.15	12.68
7	23.15	23.91	25.48	18.59	22.54	18.28	19.18	16.96	22.18	16.29
8	24.38	25.72	24.79	17.66	20.39	16.55	17.18	18.19	23.17	14.67
9	22.00	23.08	21.98	12.95	17.61	14.85	15.63	13.60	19.52	11.94
10	29.00	25.52	26.98	19.20	22.20	19.29	22.79	24.83	26.11	18.46
11	26.24	24.27	26.40	18.37	22.65	18.75	20.61	23.57	26.17	18.78
12	25.41	27.34	26.24	18.15	21.87	18.15	19.87	21.49	25.35	18.69
13		29.31	24.58	16.73	19.90	17.86	20.12		27.65	14.69
14		29.88	23.60	13.71	19.61	16.08	17.50		25.86	12.99
15	32.68	30.37	30.28	24.43	18.62	18.15	28.77	30.68	30.70	22.20
16	31.22	29.83	27.38	22.90	18.39	18.55	26.73		28.03	21.11
17		30.12	26.89	22.88	18.87	17.95	25.25		29.70	19.76

Table 24. Salinities of bottom waters from January to October, 1957, expressed in parts per thousand.

Station	Jan.	Feb.	Mar.	Apr.	May	June
1	2.42	2.43	2.24	1.81	2.25	2.25
2	2.43	2.45	2.26	1.96	2.31	2.28
3	2.44	2.45	2.28	1.96	2.05	2.31
4	2.49	2.45	2.31	1.81	2.09	2.25
5	2.45	2.45	2.24	1.85	2.05	2.27
6	2.45	2.43	2.26	2.01	2.21	2.28
7	2.41	2.45	2.28	2.01	2.05	2.17
8	2.45	2.45	2.26	2.09	2.00	2.28
9	2.46	2.42	2.15	2.04	2.21	2.29
10	2.45	2.45	2.21	1.81	1.91	1.96
11	2.41	2.45	2.21	1.81	1.91	1.96
12	2.45	2.45	2.36	2.01	2.00	2.09
13		2.46	2.24	2.09	2.03	2.03
14		242	2.19	2.04	2.13	2.37
15	2.42	2.27	2.21	2.00	1.86	2.09
16	2.44	2.41	2.31	2.00	1.86	2.01
17		2.41	2.31	2.00	1.91	2.03

Table 25. Alkalinities of bottom waters from January to June, 1957, expressed in milliequivalents of acid per liter.

Station	March	April	May	June
1	0.45	0.40	0.30	0.30
2	0.78	0.38	0.71	0.37
3	0.47	0.42	0.08	0.39
4	0.60	0.31	0.35	0.35
5	0.26	0.19	0.43	0.39
6	0.87	0.42	0.51	0.37
7	0.32	0.54	0.23	0.38
8	0.25	0.49	0.24	0.43
9	0.37	0.49	0.49	0.57
10	0.45	0.23	0.07	0.30
11	0.24	0.23	0.13	0.33
12	0.26	0.22	0.21	0.33
13	0.28	0.23	0.16	0.49
14	0.12	0.28	0.24	0.63
15	0.34	0.16	0.03	0.27
16	0.45	0.28	0.10	0.37
17	0.24	0.24	0.12	0.29

Table 26. Phosphate phosphorus content of bottom waters form March to June, 1957, expressed in microgram atoms per liter.

Station	March	April	May	June
1	1.0	0.8	0.5	0.6
2	1.2	0.7	1.0	0.5
3	0.8	0.7	1.0	0.4
4	0.4	0.9	0.9	0.3
5	0.9	1.0	1.0	0.1
6	1.1	0.7	0.9	0.2
7	0.4	1.1	0.9	2.7
8	0.6	0.8	0.7	0.4
9	0.6	1.2	0.8	0.4
10	1.5	1.4	1.0	0.2
11	0.5	1.0	0.8	0.5
12	0.4	1.0	0.3	1.0
13	0.4	0.3	1.2	0.1
14	0.5	1.4	1.2	0.3
15	0.4	2.8	1.2	0.5
16	0.7	4.7	1.0	0.3
17	0.7	2.6	0.9	2.4

Table 27. Nitrate — Nitrite nitrogen content of bottom waters from March to June, 1957, expressed in microgram atoms per liter.

Station	March	April	May	June
1	6.4	2.0	3.1	4.3
2	3.0	2.2	3.1	5.2
3	2.2	1.8	3.0	5.3
4	1.9	1.4	3.0	4.1
5	1.7	1.6	2.6	3.9
6	2.3	1.9	3.3	6.6
7	1.7	1.0	3.0	3.5
8	1.4	1.7	3.3	3.4
9	1.4	2.1	4.2	3.9
10	1.8	0.7	1.7	2.0
11	1.1	1.2	2.0	3.1
12	1.0	1.7	1.4	3.2
13	1.1	1.0	2.6	2.1
14	0.9	2.0	2.0	4.3
15	0.5	1.0	2.3	2.4
16	0.9	0.8	2.4	2.8
17	0.9	1.0	2.7	2.3

Table 28. Carbohydrate content of bottom waters from March to June, 1957, expressed as milligrams per liter of sucrose equivalent.

Station	Jan.	Feb.	Mar.	Apr.	May	June
1	1.97	1.64	1.75	1.48	1.45	1.23
	2.13					
2	2.17	1.67	1.55	1.74	1.50	1.51
	2.14	1.84				
3	2.30	1.58	1.64	1.43	1.51	1.45
	2.38	1.70				
4	2.18	1.81	1.62	1.46	1.55	1.34
	2.22	1.69				
5	2.13	1.92	1.54	1.51	1.55	1.30
	2.20	2.01				
6	2.04	1.98	1.64	1.43	1.46	1.25
	2.03	1.88				
7	2.17	2.00	1.60	1.45	1.58	1.75
	2.26	1.96				
8	2.12	2.16	1.58	1.40	1.51	1.48
	2.31	2.12				
9	2.06	2.07	1.77	1.21	1.46	1.30
	2.11	1.84				
10	2.73	1.87	1.77	1.52	1.62	1.53
	2.81	2.07				
11	2.39	1.84	1.64	1.45	1.59	1.60
	2.44	1.88				
12	2.25	2.15	1.64	1.46	1.59	1.46
	2.33	2.16				
13		2.30	1.62	1.43	1.54	1.51
		2.32				
14		2.37	1.64	1.31	1.51	1.25
		2.45				
15	3.17	2.37	1.75	1.55	1.49	1.48
	3.21	2.38				
16	3.05	2.34	1.76	1.68	1.51	1.51
	3.07	2.44				
17		2.44	1.70	1.60	1.51	1.43
		2.36				

Table 29. Sulfate content of surface waters from January to June, 1957, expressed in part per thousand. (January and February bottom water readings are given for comparison.)

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