SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 149, NUMBER 1

Charles D. and Mary Vaux Walcott Research Fund

THE DISTRIBUTION AND ABUNDANCE OF FORAMINIFERA IN LONG ISLAND SOUND

(WITH FOUR PLATES)

BY
MARTIN A. BUZAS
U. S. National Museum
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(PUBLICATION 4604)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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INTRODUCTION

Purpose and Location

This study is a quantitative survey of the benthonic Foraminifera in Long Island Sound. Its purposes are: 1, To ascertain the distribution and abundance of the living population; 2, to discover any seasonal variation in the living population; 3, to investigate the relationship between particle size of the sediment and foraminiferal distribution and abundance; 4, to ascertain the distribution and abundance of the total (living plus dead) population and compare it with that of the living population; 5, to attempt to relate the observed foraminiferal distribution and abundance to environmental factors.

Long Island Sound [1] is a partially enclosed body of water with an area of about 930 square miles. Its location and configuration are shown in figure 1. In the central portion maximum depths of about 40 m. are found about 4 nautical miles from the Long Island shore. At a comparable distance from the Connecticut shore the water is less than 20 m. deep. Mixing with the more oceanic waters of Block Island Sound occurs through the eastern passage. In the narrow western portion a limited amount of exchange takes place with the waters of New York Harbor.

Acknowledgments

I wish to thank Dr. K. M. Waage for his valuable advice, encouragement, and supervision of the study. To Dr. G. A. Riley, who of-

[1] Referred to hereafter as L.I.S.

fered many helpful suggestions and able assistance in the field, I owe my sincere thanks. Capt. H. Glas of the *Shang Wheeler,* a research vessel of the U. S. Fish and Wildlife Service at Milford, Conn., was most helpful in the field. Thanks are due also to Dr. A. McCrone, who arranged for a cruise aboard a New York University research vessel in July 1961. Dr. H. Seal kindly gave advice on statistical methods, and Dr. J. E. Sanders placed some valuable equipment at the writer's disposal. Ruth Todd and Dr. J. F. Mello's constructive criticism of the manuscript was most helpful. The Foraminifera were illustrated by Lawrence B. Isham, scientific illustrator, U. S. National Museum. Figured specimens are deposited at the U. S. National Museum.

The research was supported in part by grants from the Sigma Xi-RESA Research Fund and the Schuchert Fund of Yale Peabody Museum.

Previous Work

OCEANOGRAPHY

One of the reasons why L.I.S. was chosen for the present study is that it is a relatively well known body of water. Riley (1952) studied the hydrography of Long Island and Block Island Sounds. Riley and others (1956 and 1959) have studied the physical and chemical oceanography as well as some of the flora and fauna of L.I.S. Some aspects of their work pertinent to the area of the present study are described below.

Temperature.—The temperature ranges from a minimum of about 2°C. in midwinter to a maximum of about 25°C. in late summer. The temperature gradient from surface to bottom is nearly vertical from August to March, whereas a negative gradient, not exceeding 5°C., is present from March to August.

Salinity.—The salinity varies from a spring minimum of about 25‰ to an autumn maximum of 29‰. Because the effect of fresh-water drainage is more pronounced in the narrow western portion, it is often 3‰ fresher than the central area. The salinity between top and bottom water usually varies not more than 1‰. Fresh-water drainage into L.I.S. is mainly from the Connecticut drainage basin; this fresh water moves eastward and out of L.I.S., being replenished by bottom water entering from Block Island Sound.

Oxygen.—Minimum values for oxygen are found in summer. During autumn and winter oxygen is just slightly undersaturated from the surface to the bottom. The minimum values for bottom water are

40 percent of saturation in the western end and 50 percent of saturation in the central portion.

Phosphate.—Maximum concentrations of phosphate occur in autumn and winter, whereas minimum concentrations are found in summer. The phosphate level is higher in the western end especially during the autumn and winter. Phosphate appears not to be an important limiting factor for phytoplankton growth in the central basin.

Nitrate.—Maximum concentrations of nitrate occur in autumn and early winter. Concentrations are greater in the western area during the maximum. During the remainder of the year, however, there is little nitrate anywhere in the column. Enrichment experiments have shown that nitrogen is probably an important limiting factor for phytoplankton growth in the central basin.

Phytoplankton.—A midwinter flowering with a peak between January and March occurred each year in which L.I.S. was studied. This is normally followed by several irregular summer flowerings of moderate size. In the autumns of 1954 and 1955 there were marked flowerings, whereas none occurred in 1952 and 1953. Illumination, stability of the water column, and nutrient supply were suggested to explain these differences. The amount of chlorophyll in the water column increased progressively from east to west.

Zooplankton.—The seasonal cycle for the zooplankton showed maxima in late spring and late summer, with a minimum occurring in midwinter. There appeared to be no large regional differences in zooplankton concentrations even though the western end could potentially support a larger crop.

Particulate matter.—Measurements of the total particulate matter, organic matter, and chlorophyll in surface water at a station in central L.I.S. indicated that although there was a 20-fold variation in chlorophyll during the year, the organic matter varied within narrow limits. This suggests that at times much of the organic matter occurs as detritus or as organisms that contain very little chlorophyll. About two-thirds of the total particulate matter is composed of nonliving material.

SEDIMENTS

McCrone and others (1961) studied the sediment in selected samples from 23 traverses in L.I.S. They reported silt as the most common sediment and indicated a general increase in grain size toward near-shore sands. The pH of the silts in the tops of 17 cores had a range of 7.6-6.8. The Eh values were all negative, and H_2S was detected in all the silt samples reported. The total organic hydrocarbon content of selected samples was about 0.1 percent. X-ray diffraction analyses indicated the most common minerals are: Quartz, muscovite, biotite, albite, microcline, kyanite, augite, hornblende, chlorite, calcite, and dolomite. Some observations on Foraminifera, corals, mollusks, spores and pollen, and diatoms were reported.

STUDIES OF FORAMINIFERA

Shupack (1934) reported eight species of Foraminifera from six sediment samples taken in New York Harbor. The most abundant constituents were members of the genus *Elphidium.*

Parker (1952b) studied the distribution of the Foraminifera in the Long Island Sound–Buzzards Bay area. She defined the following three foraminiferal facies in the area: Facies 1—confined to the Housatonic and Connecticut Rivers; facies 2—found in L.I.S., Buzzards Bay, and Gardiners Bay; facies 3—found in Block Island Sound and southwest of Cuttyhunk. Facies 1 is composed for the most part of arenaceous species typical of estuarine and marsh environments. Facies 2 and 3 are composed mainly of calcareous forms. A few species are restricted to either facies 2 or 3, and the relative abundance of species differs in the two facies. *Elphidium incertum* was the most abundant form in facies 2. Parker listed 36 species from L.I.S., of which 7 were indicated as persistent in their occurrence.

Charmatz and McCrone (1961) listed 22 species of Foraminifera from L.I.S. They indicated that species of *Elphidium* are most abundant.

Methods of Study

FIELD WORK

A total of 220 samples were obtained from 130 stations occupied during 14 cruises. Most of the stations are located in north–south traverses which are numbered 1 through 5 from west to east (fig. 1). The traverses are spaced about 10-14 nautical miles apart. The first and last stations in each traverse were located alongside buoys or within sight of known shore positions. The stations between were located about 1 nautical mile apart along a north–south bearing. Traverse 3, which is located at about the geographic center of L.I.S., was sampled seasonally. Since only the first and last stations could

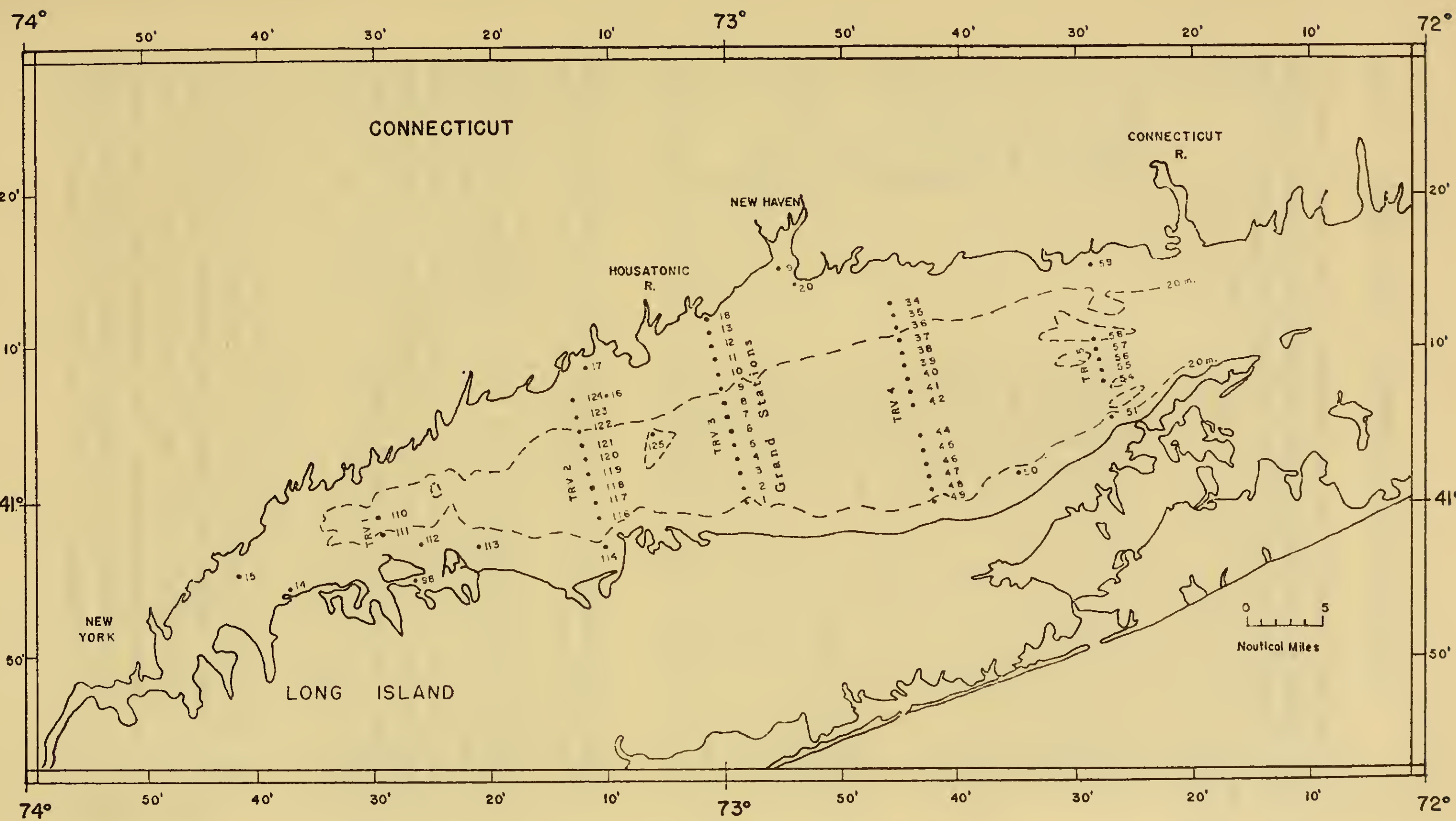

FIG. 1.—Location of traverses and stations in Long Island Sound.

be located accurately, the seasonal samples between were given different station numbers. The station numbers (1-13) shown in figure 1 for traverse 3 are plotted from the first time the traverse was sampled. The traverses, sampling times, and station numbers are as follows:

Traverse	Time	Stations
1	Nov. 19, 1962	110, 111
2	Nov. 19, 1962	114–124
3	June 6, 1961	1-13
3	Oct. 3, 1961	1, 33-22, 13
3	Jan. 15, 1962	71-60, 13
3	Mar. 24, 1962	84-73, 13
3	June 12, 1962	97-86,13
3	Sept. 26, 1962	109-100, 13
3	Nov. 20, 1962	126-135, 13
4	Nov. 7, 1961	49-34
5	Nov. 7, 1961	51-58
Miscellaneous Stations	July 15, 1961	15, 14
" "	Aug. 7, 1961	16, 17, 19, 20
" "	Aug. 24, 1961	18, 19
" "	Nov. 7, 1961	50, 59
" "	Jan. 9, 1962	13
" "	June 13, 1962	98
" "	Nov. 19, 1962	113, 112
" "	Nov. 20, 1962	125

Most of the stations were sampled by means of a small coring tube 3.5 cm. in diameter. A few centimeters of water above the sediment water interface and the top centimeter of the core were placed in a jar with neutralized formalin at the time of collection. The second centimeter of the core was removed for particle-size analysis. At those near-shore stations that have a sandy bottom a snapper-grab sampler was used. About 10 ml. of wet sediment was removed from it and preserved for foraminiferal analysis. An additional 10 ml. was obtained for particle-size analysis.

LABORATORY WORK

The pH of the preserved samples was checked periodically. None of the samples became acidic during the duration of their storage. When the sediment in a sample jar had settled sufficiently, the sediment level was marked with tape. The biological stain Rose bengal, the properties of which are discussed by Walton (1952), was added the day before examination of the material. After staining, the sample was washed in a bank of sieves having openings of 125 and 62μ. The two fractions were then placed in petri dishes under which were fastened grids drawn on black cardboard. The "living" (those Foraminifera which contained protoplasm at the time of collection as indicated by the stain) and "dead" (empty tests) populations were then counted while wet. The wet volume of each sample was measured by refilling the sample jar to the tape level with water and decanting into a graduated cylinder. This procedure was repeated four times and the values averaged. At a few near-shore stations the number of dead individuals was well over 1,000, and in these samples only the living population was counted wet. The sample was then dried and a flotation method using CCl_4, described by Cushman (1948), was used to concentrate the tests. The sample was then aliquoted using a microsplit described by Skolnick (1959), and the dead population was estimated from the fraction counted.

Particle-size analyses were made on 59 stations. The methods used were essentially those described by Krumbein and Pettijohn (1938). After removal of electrolytes by decantation, the sediment was wet-sieved into fractions coarser and finer than 62μ. The coarse fraction was then given a standard Ro-tap sieve analysis. The fine fraction was dispersed in a N/100 solution of sodium oxalate and agitated on a milk-shake machine for 10 minutes before being given a pipette analysis.

SIGNIFICANCE OF A FORAMINIFERAL SAMPLE

Introduction

Some of the objectives of a quantitative study of foraminiferal populations in a given area are: 1, To establish the relative abundance with which various species are distributed; 2, to compare the relative abundance of living and dead populations; 3, to estimate the standing crop or number of living Foraminifera per unit area; 4, to estimate the number of living Foraminifera seasonally, which will also give a better estimate of 3; 5, to estimate the number of dead Foraminifera per unit area so that a living to total (L/T) ratio can be calculated as an indicator of relative rates of sedimentation.

In order to accomplish these ends an undisturbed sample of known surface area and volume must be obtained. Phleger (1951) used a small plastic core liner which has an inner diameter of 3.5 cm. (1$\frac{3}{8}$ inches). He sampled the surface water immediately above the core and the top centimeter of the core for his foraminiferal analysis. Since then other workers have adopted this method of sampling when sediment type permits. Walton (1955) discussed the advantages of using equal wet volumes rather than dry sediment weights in foraminiferal ecology.

A sample is assumed to be representative of both the distribution and abundance of the foraminifers at the sampling site (station) as well as of the total area the sample represents. Phleger (1952) has indicated that in the Gulf of Maine the foraminiferal samples are representative of the total area a sample represents because the distribution of species is not haphazard, has localized centers or highs, and decreases away from these highs in an orderly manner. Walton (1955) discussed the same problem in his study of Todos Santos Bay, Calif. The percentage distributions of the living species in the Bay indicated the highest rate of variation at depths of less than 50 fathoms. In deeper water the amount of fluctuation diminishes. Because of the stability of the percentage distribution of species in deeper areas, Walton concluded that his sampling grid was giving an adequate representation of foraminiferal distribution.

In L.I.S. the percentage distribution of foraminiferal species is meaningful and repeatable. This suggests that the samples from the Sound are representative of the foraminiferal distribution in the area. In order to test the reliability of a sample at a station at a particular time, 12 pairs of samples were taken at various locations. Each member of a sample pair was taken within minutes of the other, by the same method, and at the same location as far as conditions would permit. Theoretically, each pair should be identical. Sample pairs 14-14′ and 125-125′ were grabs, all the rest were cores. In the pair 14-14′ the dead population was estimated.

Statistical Significance of Species Proportions

The species proportions in the sample pairs will now be compared. The data are viewed most conveniently by arranging them in a contingency table (see table 1, page 65). A qualitative approach would be to compare visually the number of individuals in each species of a sample pair and decide arbitrarily whether or not the species proportions are similar. If the species proportions differ widely, then the samples are considered not homogeneous. A more quantitative approach is to choose a statistic which will test for homogeneity of sample pairs. In the present study the statistic chosen was chi-square. Because one of the assumptions on which this statistic is based is violated if the frequency in a given category is too small, only the three most abundant species were used in making the calculations.

These species are: 1, *Elphidium clavatum;* 2, *Buccella frigida;* and 3, *Eggerella advena.* In the pair 59-59′ *Elphidium tisburyense* was substituted for the missing *Eggerella advena.* Table 1 shows the results of the calculations for the living and total populations of the three abundant species in the 12 sample pairs. Even though only the most abundant species were used in the calculation of chi-square, in some sample pairs the expected frequency in a given cell was less than two. In these cases, the species with the low expected value was deleted from the calculation of chi-square. In the living populations of the sample pairs 102-102′, 106-106′, and 108-108′ two of the three abundant species have expected frequencies of less than two and therefore chi-square was not calculated in these instances. The degrees of freedom for chi-square when three species are used in its calculation is two; when two species are used, it is one. The 95-percent level was chosen as significant. A significant value of chi-square indicates the samples are not homogeneous.

Looking at the results we do not find a significant value of chi-square for the living population in six of the nine sample pairs tested. The sample pairs 10-10′, and 24-24′ give a significant value of chi-square. The pair 14-14′ was a near-shore grab, and other near-shore grabs (not shown in table 1) taken a week apart also indicate a wide degree of fluctuation. The pairs 10-10′ and 24-24′ are actually from the same area sampled at different times. This station (18 m. depth) is located in a transition zone between the clearly near-shore and offshore faunal assemblages. The pair 59-59′ is a near-shore core which did not give a significant value of chi-square. The pair 125-125′, however, is a grab from the center of L.I.S. and it also did not give a significant chi-square value. The effect of sampling method, therefore, is not clear, although for reasons already discussed an undisturbed sample from a core is certainly more desirable. In general, we may conclude that in the living population the proportions of the species investigated are homogeneous in the sample pairs from the offshore area.

In the total population 7 of the 12 sample pairs yielded a significant chi-square value. They are the pairs 10-10′, 14-14′, 24-24′, 102-102′, 108-108′, 125-125′, and 129-129′. Curiously, the pair 102-102′ is from the same station (sampled at still another time) as the pairs 10-10′ and 24-24′. We may conclude that in the total population the proportions of the three species investigated are homogeneous in four of the seven sample pairs from the offshore area.

Statistical Significance of Numbers of Individuals

I have suggested, however, that it is desirable not only to establish the relative abundance (species proportions) of the foraminiferal population in a given area, but also to estimate the actual number of individuals living and/or dead per unit area. To do so, it must be assumed that the number of individuals in a given sample is a representative portion of an unknown population which is homogeneously distributed throughout the area the sample represents.

If each member of a sample pair is a reliable estimate of the number of individuals at a station, then a sample pair should be from the same statistical population. Let the total number of individuals in a sample pair be n. The probability of any individual belonging to one or the other sample is p and $q = 1\text{-}p$ respectively. Therefore, we have a binomially distributed variate with a mean of np and a variance of npq. When n is large and p is close to $\frac{1}{2}$, the binomial distribution closely approximates the normal distribution. The transformation is achieved by the formula:

$x = \frac{(r\text{-}np)-\frac{1}{2}}{\sqrt{npq}}$, where x is the standardized normal random variable, r is the number of individuals in a sample, and $\frac{1}{2}$ is a correction for continuity. (Bradley, 1960, gives a discussion of tests based on the binomial distribution.)

The value of x was calculated for the total and living populations in all the sample pairs. The results are shown in table 2 (page 71). If a sample pair has a significant value of x, then we are confident that each member of the pair is from the same population. In the living population, 7 of the 12 sample pairs have a significant x value. In the offshore areas (pairs 104-104′ through 133-133′), 5 of the 7 pairs give a significant x value. In the total population, 5 of the 12 pairs have a significant x value, while in the offshore areas 3 of the 7 pairs are significant. In general, the number of living individuals in the sample pairs give better results than the total number, and the offshore areas give a more reliable estimate of the number of individuals at a station than the near-shore areas.

The possibility that the Foraminifera in L.I.S. are not homogeneously distributed throughout the area that a sample represents has not been thoroughly investigated. As will be seen later, however, in the offshore areas, the number of living individuals in samples from the same traverse does not differ significantly.

Statistical Significance of Numbers of Individuals as Related to the Wet Volume of Samples

The sediment-water interface in most parts of L.I.S. is a transitional boundary. When a few centimeters of water above the core are decanted, often much of it is sediment-laden. The actual wet volume then is variable even though care is taken to remove only 1 cm. of core. Therefore, the wet volume was determined for all samples. The number of individuals in the living and total populations of the sample pairs was corrected to a wet volume of 10 ml. The value of x was then calculated for the corrected number of individuals in the living and total populations. The results are shown on the right side of table 2. The values of x that were significant in the original sample pairs remained so. In addition, the corrected number of living individuals in the pairs 102-102′ and 129-129′ as well as the corrected number of total individuals in the pairs 10-10′ and 104-104′ became significant. The reward hardly seems to justify the effort, and for practical purposes the samples can be considered to be of equal volumes without any serious error.

Summary of Significance of a Foraminiferal Sample

In summary, the analyses of 12 paired samples indicates:

1. The proportions of the species investigated are more homogeneous in the living population than in the total population.
2. The number of living individuals at a station can be more reliably estimated than the total number of individuals.
3. The offshore areas are more homogeneous and the number of individuals at a station can be more reliably estimated than in the near-shore areas.
4. Samples can be considered to be of equal volume without any serious error.

DISTRIBUTION OF THE FORAMINIFERA

Conclusions regarding the distribution of the Foraminifera are based on population counts made on 161 samples from 130 stations. Table 3 (page 72) tabulates the percent of each species in the living (L) and total (T) populations at each station.

General Aspects of the Fauna

Twenty-three species belonging to fifteen genera were found in L. I.S. Most of the species have living representatives, but the species

Ammoscalaria cf. *fluvialis, Trochammina inflata, T. lobata,* and *Nonionella atlantica* are represented only by empty tests. No planktonic Foraminifera were found.

Parker (1952b) recorded 36 species from L.I.S. Of these only 19 were found in the present study. The species *Eggerella advena, Elphidium incertum* (*E. clavatum* of this study), *E. subarticum* (*E. pauciloculum* of this study), *Eponides frigidus* var. *calidus* (*Buccella frigida* of this study), *Nonion tisburyensis* (*Elphidium tisburyense* of this study), *Reophax dentaliniformis,* and *Trochammina squamata* were listed as persistent in occurrence by Parker. All these species were commonly found in the present investigation.

In the present study the species *Elphidium clavatum, E. pauciloculum, E. varium, Buccella frigida,* and *Eggerella advena* usually make up about 90 percent of the total as well as of the living population. Of these, however, *E. clavatum, B. frigida,* and *E. advena* are most abundant and commonly comprise over 75 percent. Parker (1952b) indicated the most abundant species in her facies 2 (L.I.S., Buzzards Bay, Gardiners Bay) were *E. advena, E. incertum, E. subarticum,* and *E. frigidus* var. *calidus.* There is, then, with the exception of *E. varium,* complete agreement. *E. varium* was probably included under *E. incertum* and *E. subarticum* by Parker because this species closely resembles these forms.

The duplicate study of this area is instructive in that it shows that caution must be used when considering the significance of the number of species in a given area. On the other hand the more abundant species are, as one would hope, abundant in both cases. The number of genera also seems to be less variable. Parker found 19, whereas 15 were found by the writer.

Parker (1952b) was able to differentiate between the fauna of L.I.S. and Block Island Sound. She found that some species such as *Reophax dentaliniformis* and *R. nana* are restricted to L.I.S. In addition she found that the fauna in L.I.S. contained a very large percentage of *Elphidium incertum.* Parker (1952b, p. 438) indicated that in the central part of L.I.S. there is a decrease in the percent of this species. Therefore, with the exception of *E. varium,* there is complete agreement between the faunal composition noted by Parker and that noted during my investigation.

Using Parker's data, the average number of species per station in L.I.S. is 8 (7 were found in the present study), whereas in Block Island Sound it is 14. The waters of Block Island Sound are more oceanic in character, having a higher salinity and less variation in temperature than the more restricted waters of L.I.S. On the average, stations in L.I.S. have fewer species and greater dominance by a single species than the more open-ocean waters of Block Island Sound.

In the total population 10 species were found in traverse 1, 13 in traverse 2, 14 in traverse 3, and 19 in traverse 4. In the living population the number of species in the traverses are 8, 10, 12, and 14 respectively. The increase of species to the east is probably due to two factors, namely, migration into L.I.S. by open-ocean species would take place from that direction, and there is an increase in salinity of 3-5‰ from west to east.

Distribution of the Living Population

Frequency distributions were drawn for the percent of all the common species, but only the distributions for *Elphidium clavatum, Buccella frigida,* and *Eggerella advena* show a consistent pattern. Traverse 3 was sampled at seven different times, and the three abundant species show the same pattern over and over again. In order to present the data concisely, the 88 seasonal stations taken in traverse 3 were grouped into 13 "grand" stations. Table 4 (page 80) shows the correlation of the seasonal stations with the grand stations. The number of individuals of each species from the seasonal stations in a grand station were added and the percent distribution calculated.

Figure 2 shows the distribution of *B. frigida, E. advena,* and *E. clavatum* in percent of the living population for the 13 grand stations of traverse 3. Station 1, which is composed of coarse sand (Md ∅ 0.8), is about 1½ nautical miles off the Long Island shore. It was sampled three times and yielded only five foraminifers. The remaining stations (2-13) are about 1 nautical mile apart in a northerly direction. It should be emphasized that the same pattern shown in figure 2 was observed each time traverse 3 was sampled.

Traverse 2 is about 10 nautical miles west of traverse 3. Stations 114-124 are located about 1 nautical mile apart from south to north respectively. No sample was obtained at station 115. The same pattern observed in traverse 3 is repeated in traverse 2 and is shown in figure 3.

Traverse 4 is located about 14 nautical miles east of traverse 3. Stations 34-48 are located about 1 nautical mile apart from north to south respectively. Figure 4 shows the distribution of the abundant species.

Traverses 2, 3, and 4 all show the same general pattern. The north-

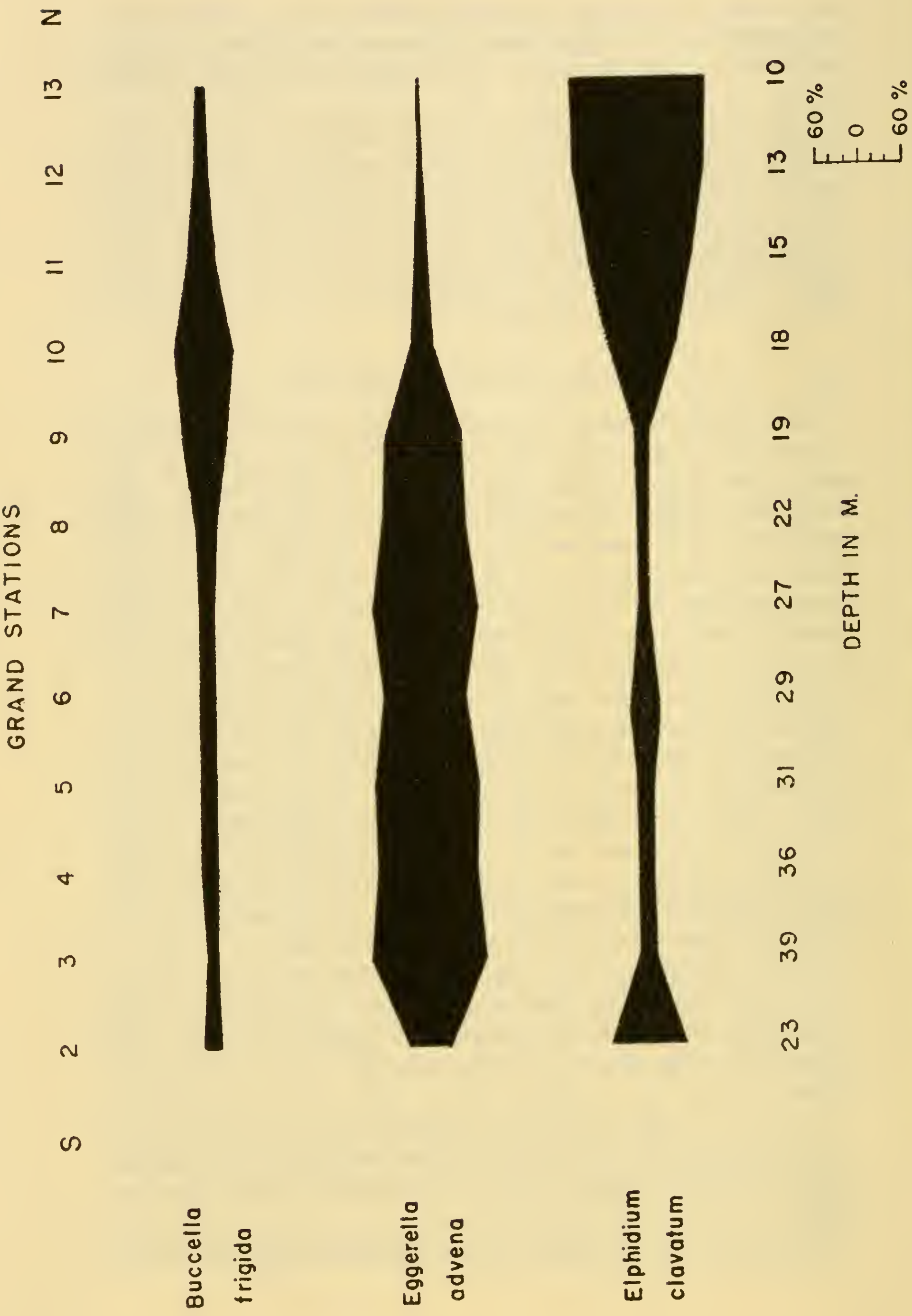

FIG. 2.—Distribution of abundant species in percent of the living population at grand stations of traverse 3.

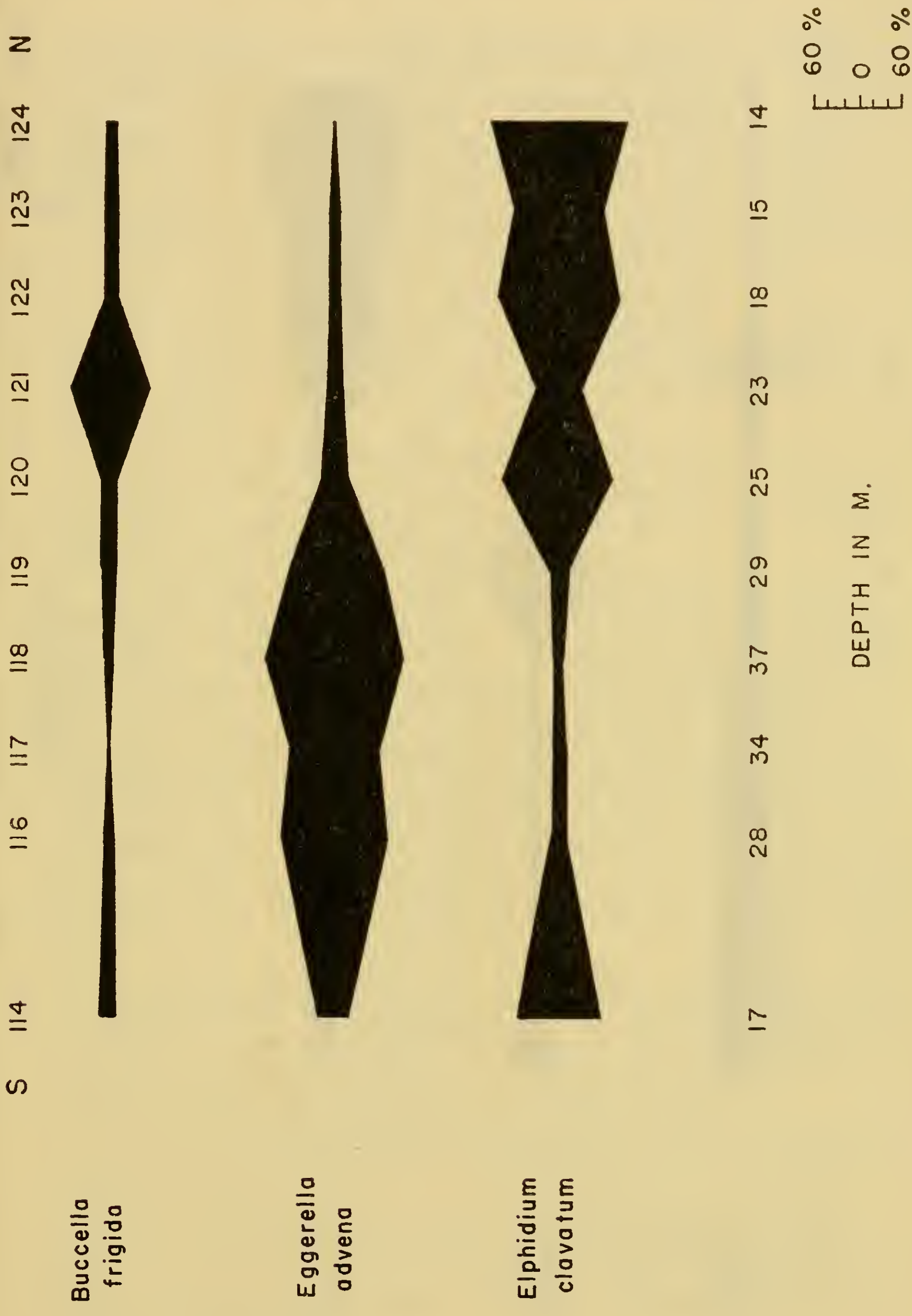

Fig. 3.—Distribution of abundant species in percent of the living population at stations of traverse 2.

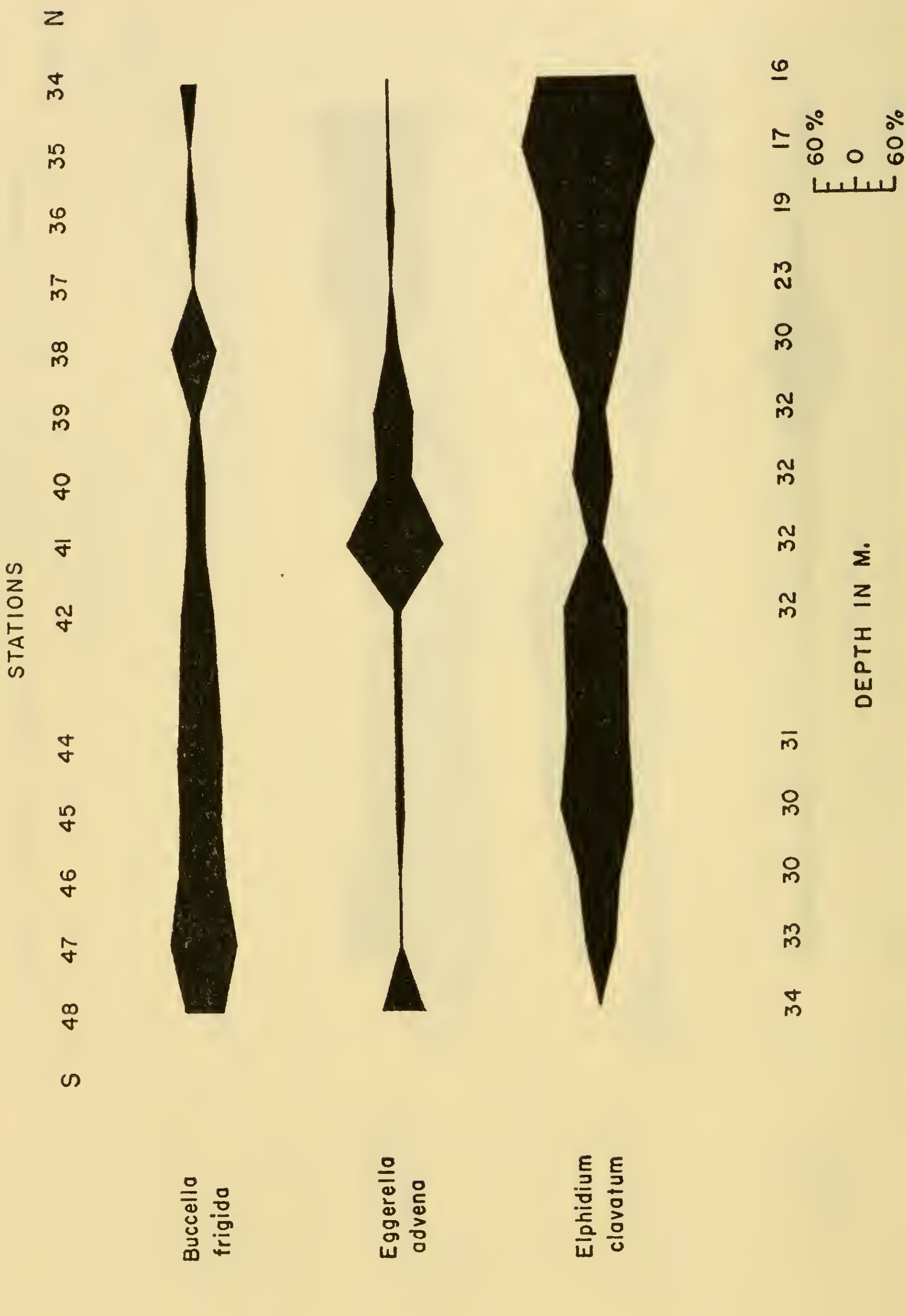

FIG. 4.—Distribution of abundant species in percent of the living population at stations of traverse 4.

ern end of a traverse always has a very high percentage of *E. clavatum,* which diminishes as *B. frigida* becomes more abundant and reaches a maximum 4 or 5 nautical miles from the Connecticut shore. As the percent of *B. frigida* decreases, *E. advena* increases and dominates the central area. At the southern end of the traverses there is a suggestion of another increase in the relative abundance of *B. frigida* and *E. clavatum,* but symmetry is not achieved. *E. advena* is not nearly as well developed in traverse 4 as it is in the other two traverses.

Traverse 5 is located about 12 nautical miles east of traverse 4. It includes stations 51-57 from south to north respectively. Foraminifera are very rare in this traverse. A few living individuals belonging to the species *Trochammina squamata* and *Poroeponides lateralis* were observed.

Traverse 1 is located about 14 nautical miles west of traverse 2. It consists of stations 110 and 111. Table 3 (page 72) shows that these stations have a percentage distribution of species similar to the stations in the central areas of the other traverses.

The areal distribution of *Elphidium clavatum* in percent of the living populations is shown in figure 5. About 3 to 4 nautical miles from shore at depths of less than 20 m., *E. clavatum* usually comprises over 70 percent of the living population. In very shallow water the abundance of this species increases to over 90 percent. *E. clavatum* is abundant in near-shore areas on both sides of the Sound but is not found in the near-shore area of Long Island east of longitude 73°10′. This latter area is composed of coarse quartz sand, and almost no foraminifers were found there except at station 50. In the central areas of L.I.S., *E. clavatum* occurs with much lower frequencies. In traverse 2 its minimum occurs farther south than in traverse 3 and 4.

The areal distribution of *Buccella frigida* in percent of the living population is shown in figure 6. In traverses 1 and 2 its maximum is confined to a narrow band north of center. In traverse 3, however, this species becomes more abundant, and farther east in traverse 4 it commonly comprises over 20 percent of the living population.

The areal distribution of *Eggerella advena* in percent of the living population is shown in figure 7. This species has an almost symmetrical distribution pattern. It reaches a maximum of over 70 percent in the central area and decreases in relative abundance toward the north and south. In traverse 4, *E. advena* occurs with very low frequencies south of its maximum. This species is absent from many of the near-shore stations.

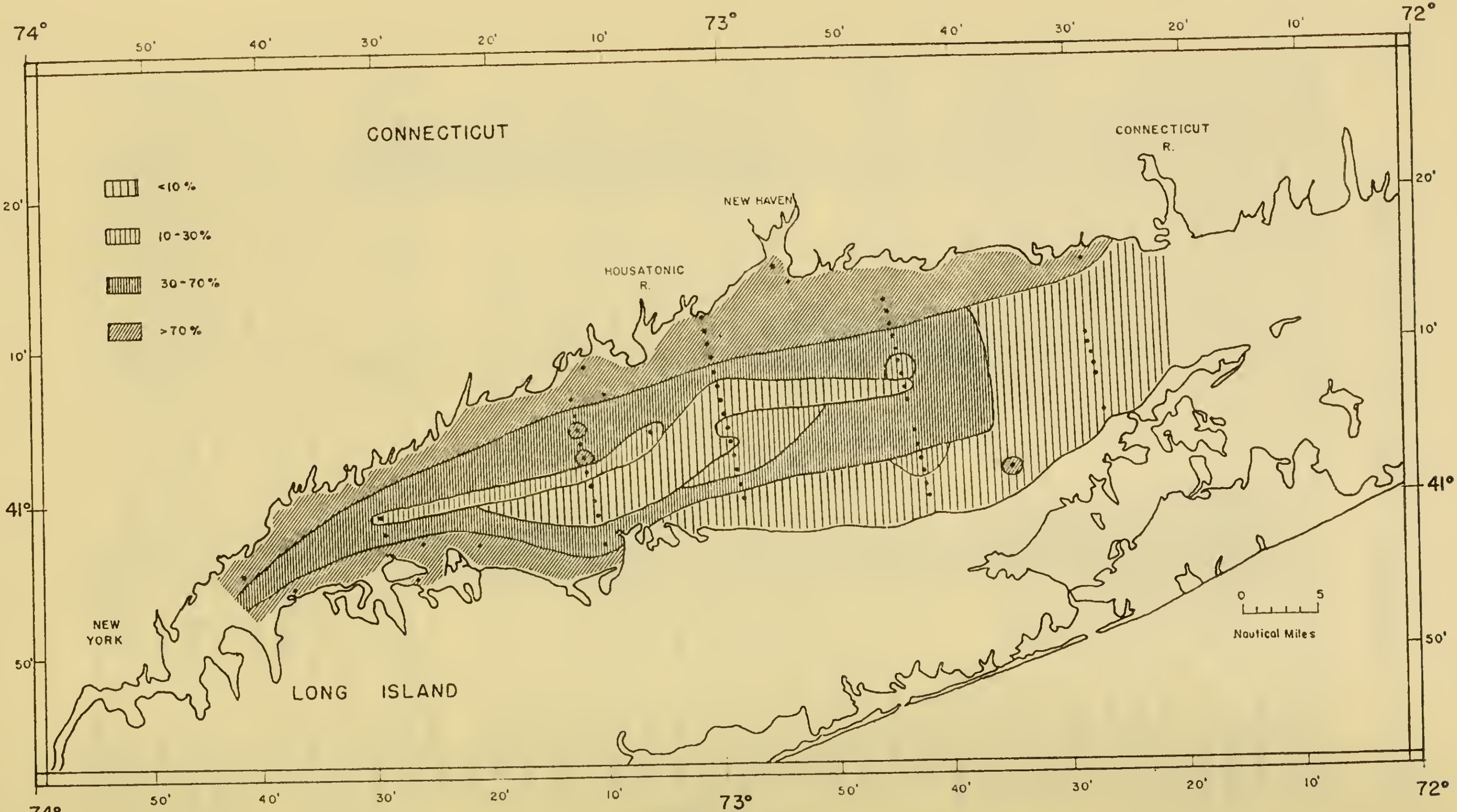

FIG. 5.—Areal distribution of *Elphidium clavatum* in percent of the living population.

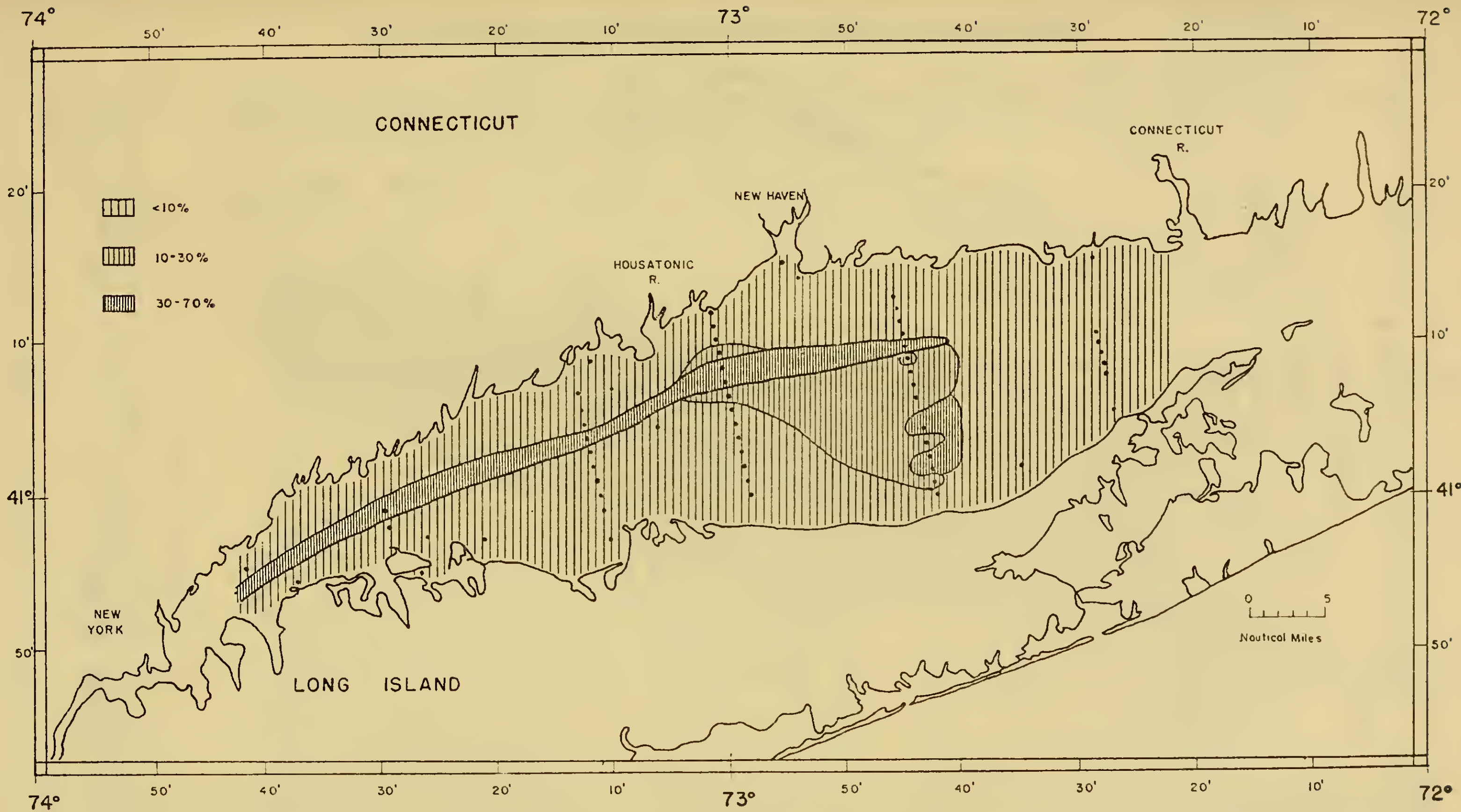

Fig. 6.—Areal distribution of *Buccella frigida* in percent of the living population.

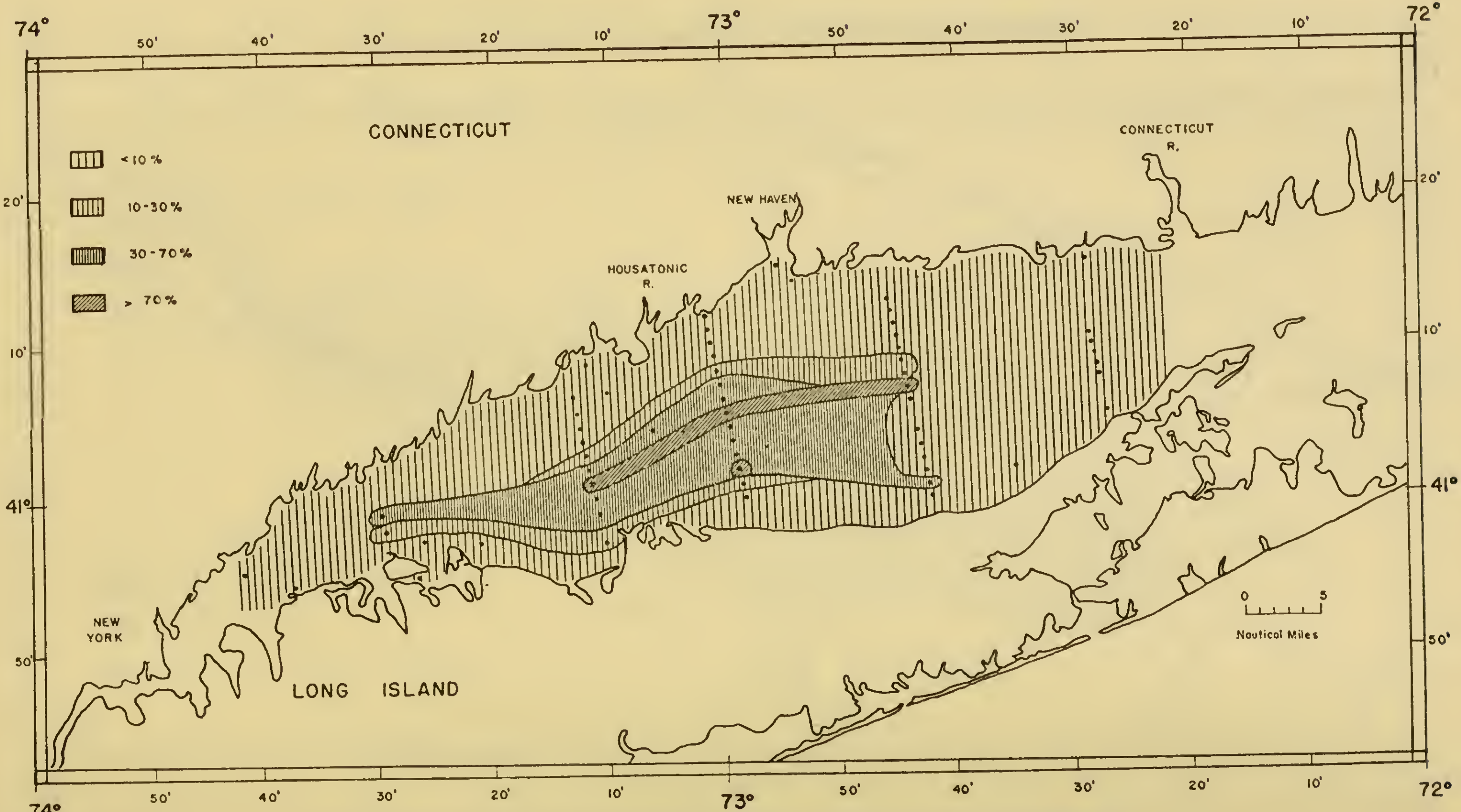

FIG. 7.—Areal distribution of *Eggerella advena* in percent of the living population.

Size of the Living Population

The actual number of living individuals per station for each of the abundant species was averaged for the depth ranges 0-10 m., 10-20 m., 20-30 m., and 30-40 m. The results are shown in figure 8. *Elphidium clavatum* averages over 300 living individuals at depths of less than 10 m. and over 100 at depths of 10-20 m. It averages less than 20 individuals at depths greater than 20 m. *Buccella frigida* shows a maximum in the range 10-40 m., whereas *Eggerella advena* is most abundant at depths of greater than 20 m. Figures 5-7 show that *E. clavatum* is relatively abundant at depths of less than about 20 m. and that *E. advena* is relatively abundant at greater depths. The histograms of figure 8, however, show that in terms of numbers of living individuals *E. clavatum* is by far the most abundant species, and therefore the greatest concentration of living individuals is in the near-shore areas.

Figure 9 shows the distribution of the living population in numbers of individuals per uniform sample. The numbers used for traverse 3 are averages from the seasonal stations. At depths of less than 15 m. the living population is usually over 200 individuals. The larger part of the central areas is in the range of 30-90 individuals per sample. At stations 8-11 in traverse 3 and stations 44 and 45 in traverse 4 the number of living individuals is in the range of 90-200. Occurrences of less than 30 individuals are most common along the north shore of Long Island east of longitude 73° and in traverse 5.

The standing crop of Foraminifera in L.I.S. is estimated to be 110 per sample. This figure was obtained by averaging the number of living Foraminifera in the top centimeter of the 88 seasonal samples of traverse 3. Because this average is based on many stations sampled seasonally, it is believed to be the best estimate attainable. At depths of 10-20 m. the average number of living Foraminifera in the seasonal stations of traverse 3 is 177, while at depths of greater than 20 m. it is 62. The shallowest station in the seasonal traverse is 10 m., and therefore to obtain an estimate of the living population in the 0-10-m. range, miscellaneous shallow-water stations were used. The area just north of Long Island east of longitude 73° was excluded. The average number of living Foraminifera at eight stations in the 0-10-m. range is 335.

Zonation of the Living Population

Examination of the data indicates that the three most abundant species can be used to construct a foraminiferal zonation of L.I.S.

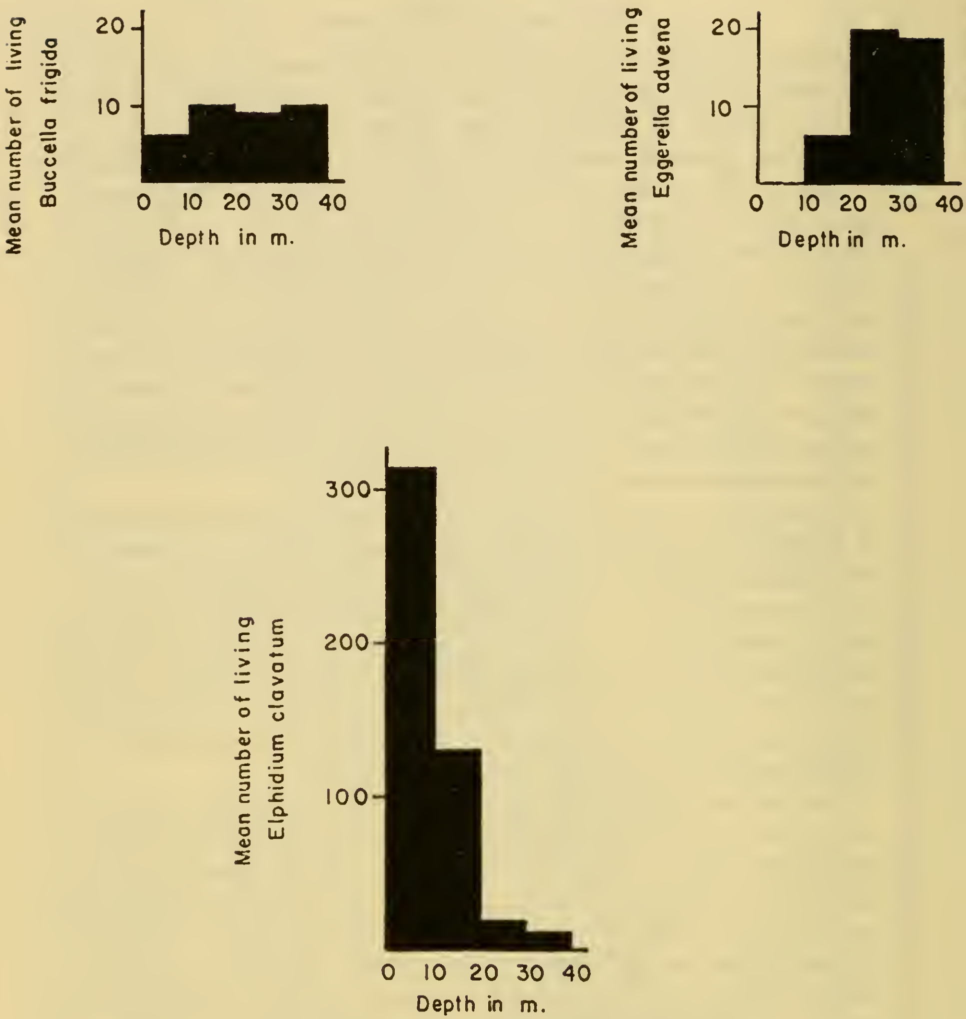

FIG. 8.—Distribution of abundant species with depth.

The exact limits of the zonation were chosen empirically through careful examination of table 3 (page 72). The following zones are recognized:

Elphidium clavatum zone:
E. clavatum $\geqq 60\%$
B. frigida $< 9\%$

Buccella frigida zone:
B. frigida $\geqq 9\%$
E. advena $< 19\%$

Eggerella advena zone:
E. advena $\geqq 19\%$

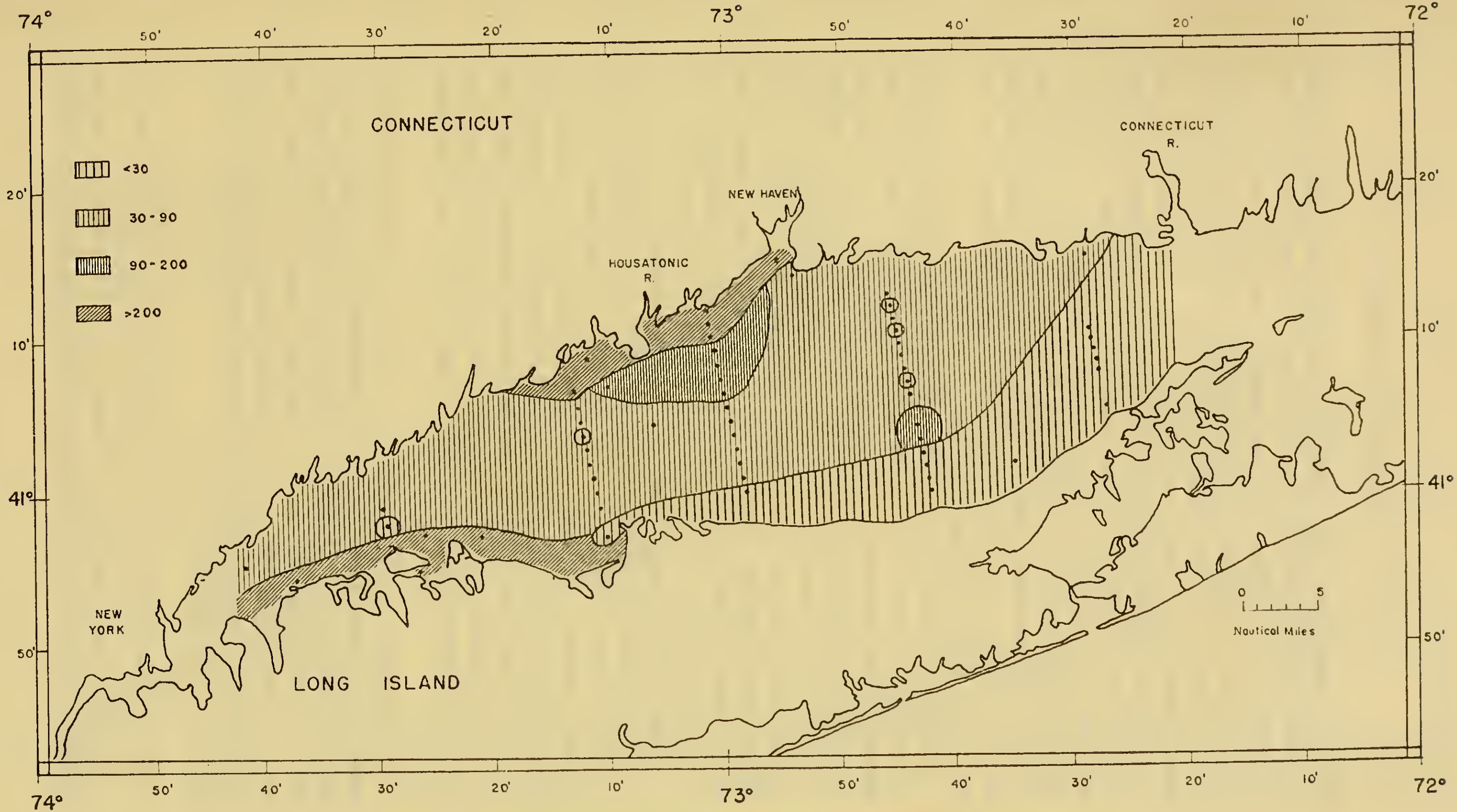

FIG. 9.—Areal distribution of living population in number of specimens per sample.

The percentage limits placed on the zones reflects the pattern which is repeated in the traverses. The limits are, of course, artificial, and in reality the transition from one zone to another is not sharp but gradational. Examination of table 3 indicates that if the percentages from any particular set of seasonal stations in traverse 3 is used, the exact location of a zone's boundary may vary. For instance in June of 1961 the boundary for the *E. clavatum* zone lies about 3 nautical miles off the Connecticut shore, whereas in November of 1962 the boundary lies 2 nautical miles off the Connecticut shore. Similarly, the exact limits of the *B. frigida* and *E. advena* zones also fluctuate. The pattern, however, is always repeated. Figure 10 shows the zonation of the living population in L.I.S. The percentages used for traverse 3 are from the grand stations.

Elphidium clavatum zone.—The percent of *E. clavatum* increases shoreward, and some of the stations less than a mile from shore are almost entirely composed of this species. *E. clavatum* is by far the most abundant species in this zone. The upper limit of *B. frigida* is fixed by definition at 8 percent. *E. advena* either occurs with very low frequencies or is absent altogether. *Elphidium pauciloculum, E. varium,* and *Reophax dentaliniformis* are commonly present, but usually make up less than 15 percent of the living population. The mean depth of stations in this zone is 12 m. and the range 3-23 m.

Buccella frigida zone.—This zone marks a transition between the *E. clavatum* and *E. advena* zones. At many of the stations in this zone *E. clavatum* and/or *E. advena* are more abundant than *B. frigida.* However, *B. frigida* is usually relatively more abundant in its zone than elsewhere. *Elphidium pauciloculum, E. varium, Fissurina laevigata,* and *Reophax dentaliniformis* commonly occur, but usually do not make up more than 15 percent of the living population. The mean depth of stations in this zone is 25 m. and the range 15-33 m.

Eggerella advena zone.—In this zone the living population is dominated by *E. advena.* Occasionally *E. clavatum* or *B. frigida* may be relatively more abundant than *E. advena,* but usually the reverse is true. *Elphidium pauciloculum, E. varium, Fissurina laevigata,* and *Reophax dentaliniformis* occur, but usually make up no more than 20 percent of the living population. The mean depth of stations in this zone is 29 m. and the range 16-39 m.

Comparison of the Number of Living Individuals in Traverses 2 and 3

Traverse 2 was sampled on November 19, 1962, and one of the sampling times of traverse 3 was on November 20, 1962. Owing

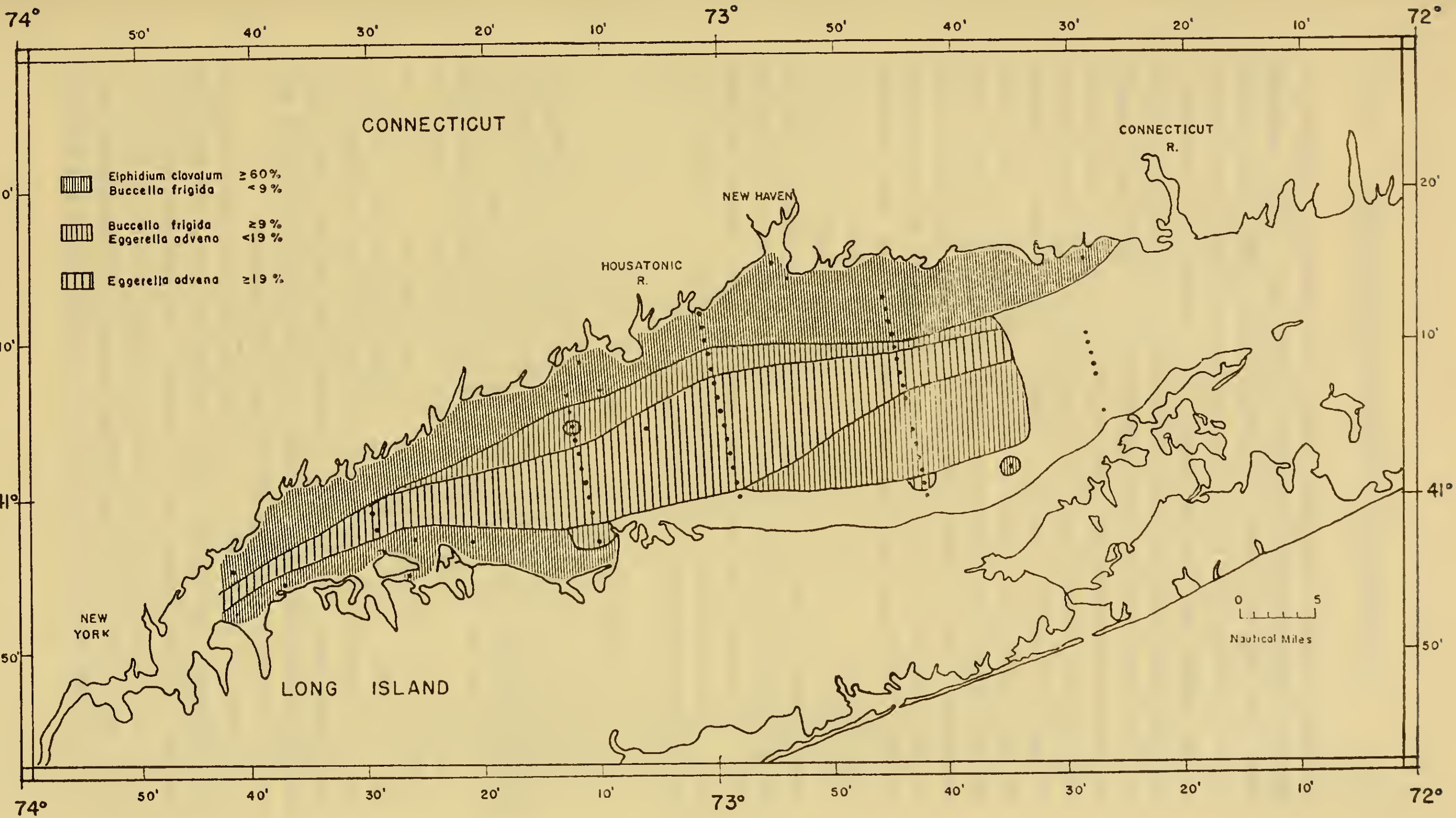

FIG. 10.—Zonation of living population.

to the proximity of sampling times, it was decided to compare the numbers of living individuals in the traverses. I have previously noted that binomial tests on paired samples indicate that samples from the offshore area (*Eggerella advena* zone) give the best estimate of the number of living individuals at a station. Five stations in traverse 2 and seven stations in traverse 3 were in the *E. advena* zone in November 1962. The distribution-free Wilcoxon two sample test was chosen to test for significant differences in the living populations of the two traverses. This statistic tests for location and is discussed at length by Bradley (1960). Under the null hypothesis the two samples (of five and seven stations respectively) come from the same population. The scores (m) of one sample and (n) of the other where ($m \leq n$) are ranked, and the ranks of the smaller sample are summed (R_m). The critical values of R_m are tabled by Owen (1962). The 95-percent level for a two-tailed test was considered significant.

A value of $R_m = 45$ was obtained which is significant at the 95 percent level. There were, then, a significantly greater number of living individuals in the *E. advena* zone of traverse 2 in November 1962. No attempt was made to compare traverse 4 which was sampled in November 1961 because traverse 3 was not sampled at that time and so comparisons would be unwarranted.

Comparison of the Standing Crop with Other Areas

In the Gulf of Maine, Phleger (1952) estimated the standing crop as 30,000 per sq. m. He made this estimate by averaging the number of living individuals in the top centimeter of his cores and multiplying by 1,000 because the area of each sample is about one-thousandth of a square meter. In L.I.S. the number of living Foraminifera, estimated in the same way but from seasonal samples, is 110,000 per sq. m. Phleger used a different staining method, and this may account for some of the difference. The stations from which Phleger made his estimate were almost all from depths of over 100 m., and none of his stations were as shallow as the deepest station in this study. It is, therefore, difficult to compare the two areas.

At depths of less than 10 m. the living population has an average of 335 individuals per sample. This average is based on near-shore samples taken in August and November. The greatest number of living individuals (756) was found at station 112 at a depth of 14 m. This station is located at the entrance to Huntington Bay. In New Haven Harbor at station 19 two samples taken a week apart in August 1961 had 417 and 681 living individuals respectively. Phleger (1956) has reported that in San Antonio Bay, Tex., the largest living populations are located near the entrance of the Guadalupe River, where two stations contained 2,579 and 302 specimens respectively. Lankford (1959) has found very large living populations in the deltaic marine environment of the Mississippi Delta. The average number of living individuals in this area was 2,500. Phleger has suggested that very large living populations near the entrance of river mouths are due to high production of organic matter in these areas. The largest rivers entering L.I.S. are the Housatonic and Connecticut Rivers. Unfortunately, none of the stations in this study is located near the entrances of these rivers. Riley (personal communication) has indicated that at the entrances of these rivers the concentration of phytoplankton is about the same as in other areas of the Sound. He suggested that the mortality of fresh-water phytoplankton as they enter marine waters might constitute an additional source of food. At any rate, the large living population in New Haven Harbor, which has several small rivers entering it, and at the entrance to the inside of Huntington Bay is consistent with similar observations in other areas.

Walton (1955) based his estimate of the standing crop in Todos Santos Bay, Calif., on seasonal samples. Most of his samples were from deeper water, but he has given averages for every 10 fathoms of depth in the 0-50-fathom range. His average living population per sample in the depth range of 10-20 fathoms is 66. The average living population in the comparable depth range of 20-40 m. in the present study is 62. In the 0-10-fathom range, however, Walton found less than 40 individuals per sample. In L.I.S. this depth range would have over 200 individuals per sample.

Distribution of the Total Population

Figure 11 shows the distribution of the three most abundant species in percent of the total population for the 13 grand stations of traverse 3. The distributions are similar to those of the living population. However, the maxima of *Buccella frigida* and *Eggerella advena* are much less pronounced. *Elphidium clavatum* is still most abundant at the ends of the traverse, but it is relatively more abundant in the central area than it was in the living population. Figures 12 and 13 show the distributions at traverses 2 and 4 respectively.

The areal distribution of *Elphidium clavatum* in percent of the total population is shown in figure 14. The distribution pattern is

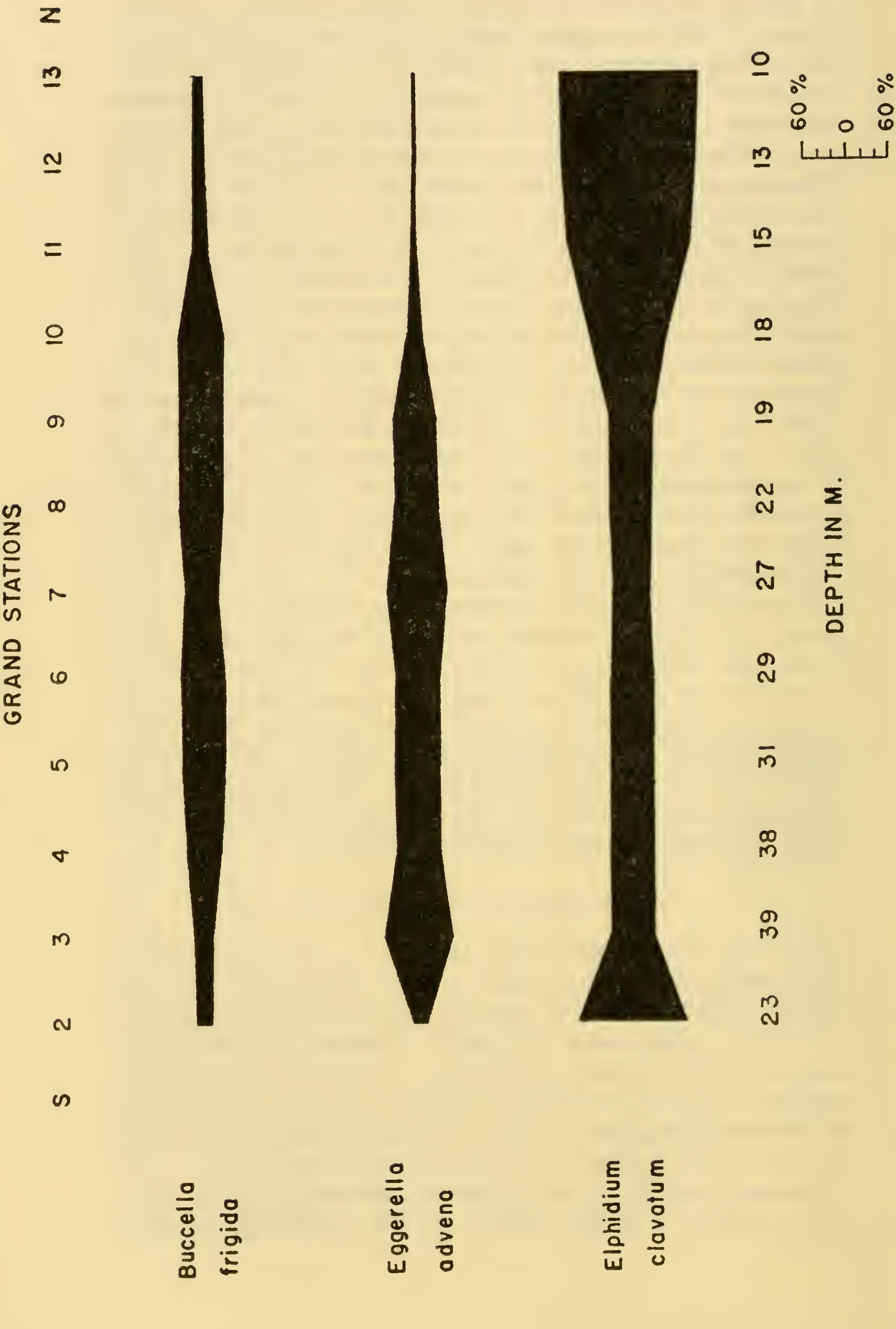

FIG. 11.—Distribution of abundant species in percent of the total population at grand stations of traverse 3.

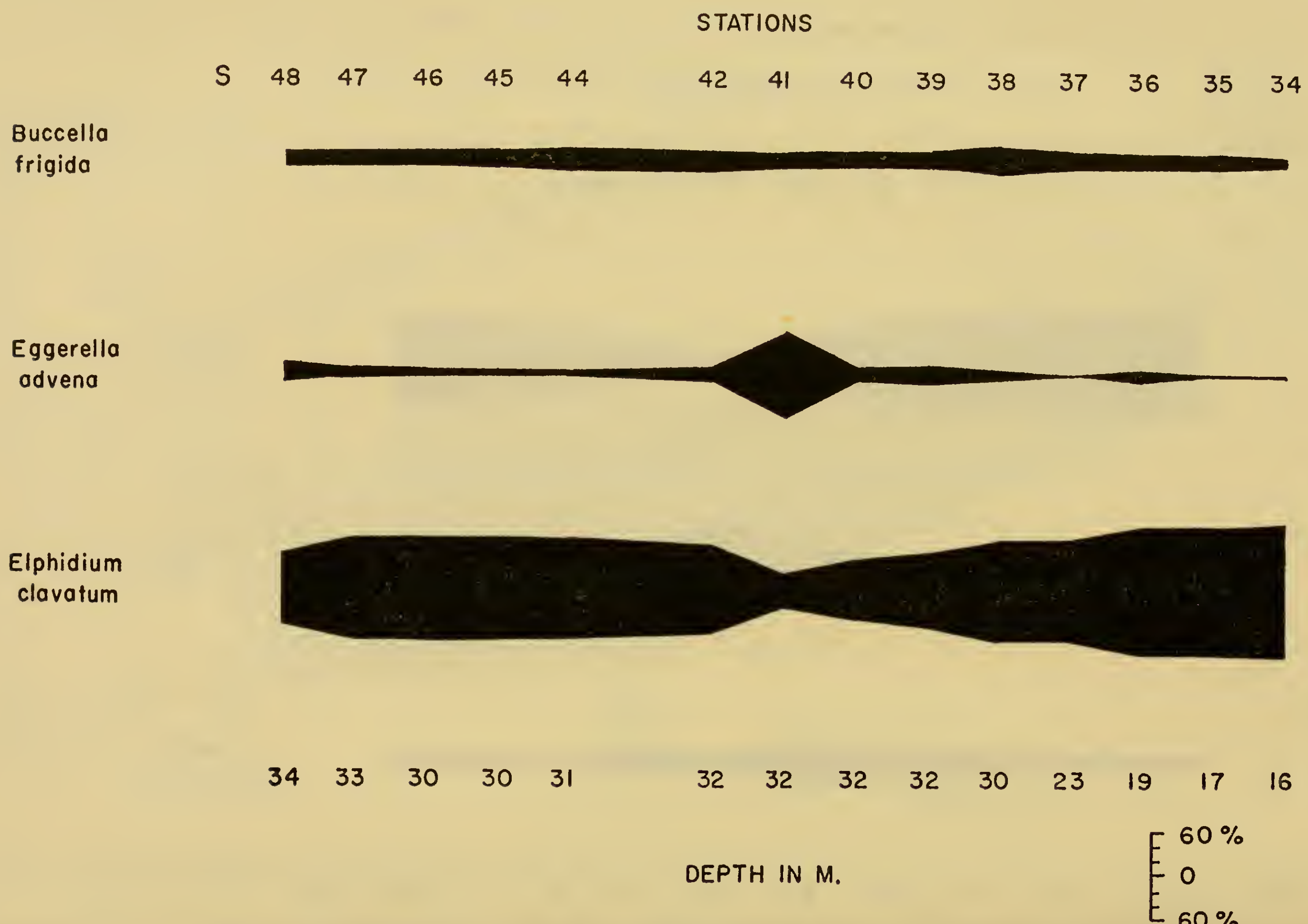

FIG. 13.—Distribution of abundant species in percent of the total population at stations of traverse 4.

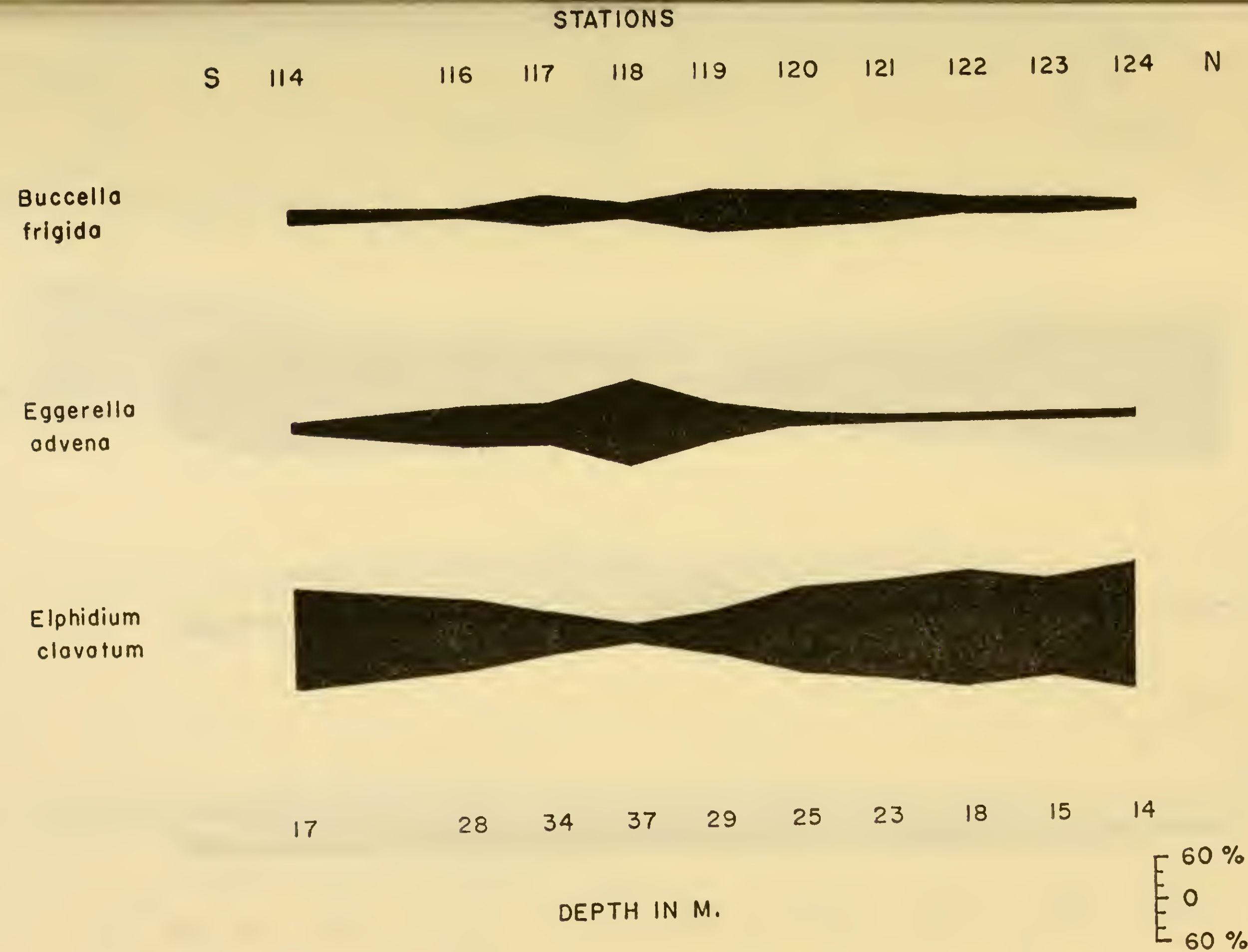

FIG. 12.—Distribution of abundant species in percent of the total population at stations of traverse 2.

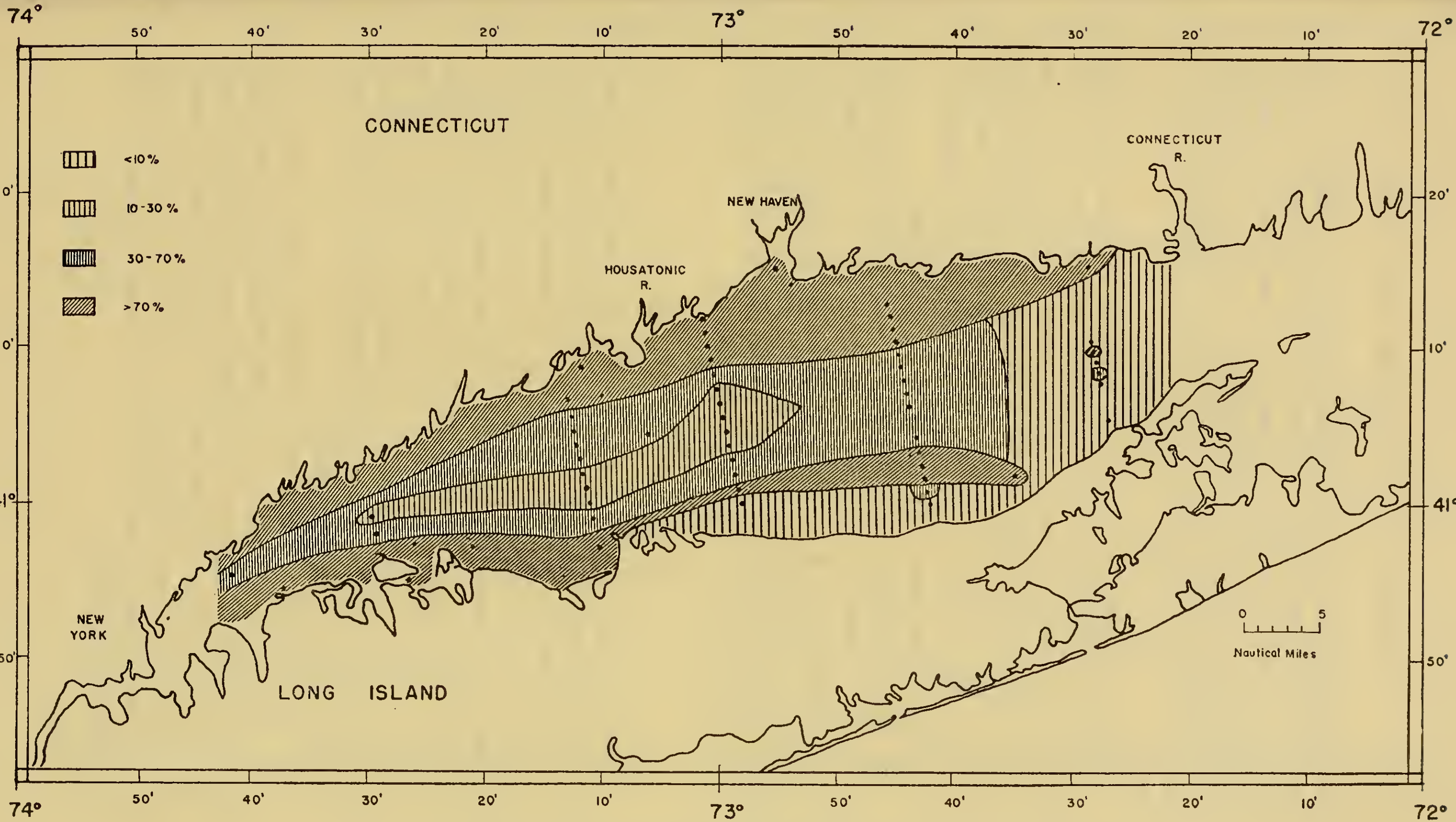

FIG. 14.—Areal distribution of *Elphidium clavatum* in percent of the total population.

quite similar to that of the living population shown in figure 5. The principal difference is that in percent of the total polulation *E. clavatum* is more abundant in all areas. The areas where *E. clavatum* comprises over 70 percent of the population have been extended for about another mile offshore, and even in the central areas of the Sound *E. clavatum* commonly occurs with a frequency of over 20 percent.

The areal distribution of *Buccella frigida* in percent of the total population is shown in figure 15. The distribution pattern of *B. frigida* is somewhat different from that previously noted. Instead of a narrow maximum-frequency band in the east which expanded to the west, we have a large area where *B. frigida* occurs with a frequency of 10-30 percent. There is, however, a general increase in frequency toward the central areas from a minimum along the shore.

The areal distribution of *Eggerella advena* in percent of the total population is shown in figure 16. This distribution of *E. advena* is not as symmetrical as it was in the living population. There is still a general increase toward the central areas, but the maximum frequency is only 63 percent instead of 92 percent, and in traverse 3 the area of maximum frequency is somewhat south of center.

Size of the Total Population

Figure 17 shows the distribution of the total population in numbers of specimens per uniform sample. The numbers used for traverse 3 are from the grand stations. The near-shore areas, with the exception of the north shore of Long Island east of longitude 73° and traverse 5, contain over 500 individuals per sample. An area of 200-500 individuals per sample occurs on the north side of traverses 2 and 3 and expands eastward to cover nearly the entire area of traverse 4. The western portion of the central area contains a large area of 90-200 individuals per sample which decreases in size eastward and is nearly absent in traverse 4.

The general pattern of the total population is similar to that of the living population. The near-shore areas contain the greatest numbers of individuals, whereas the offshore areas contain far fewer. The north shore of Long Island east of longitude 73° and traverse 5 is conspicuously barren in both cases. In general, the areas where the greatest number of empty tests occur are also the areas of maximum living Foraminifera.

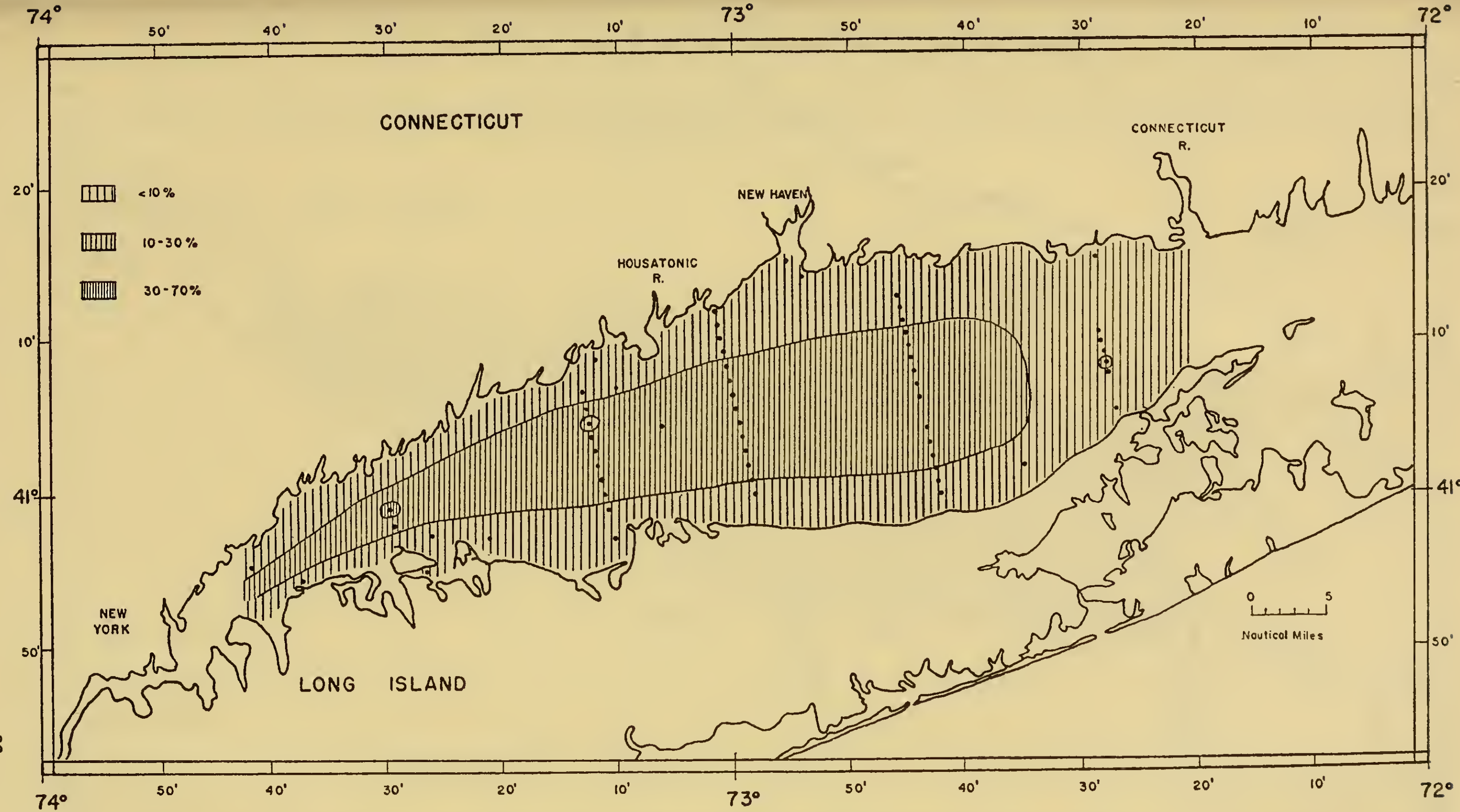

Fig. 15.—Areal distribution of *Buccella frigida* in percent of the total population.

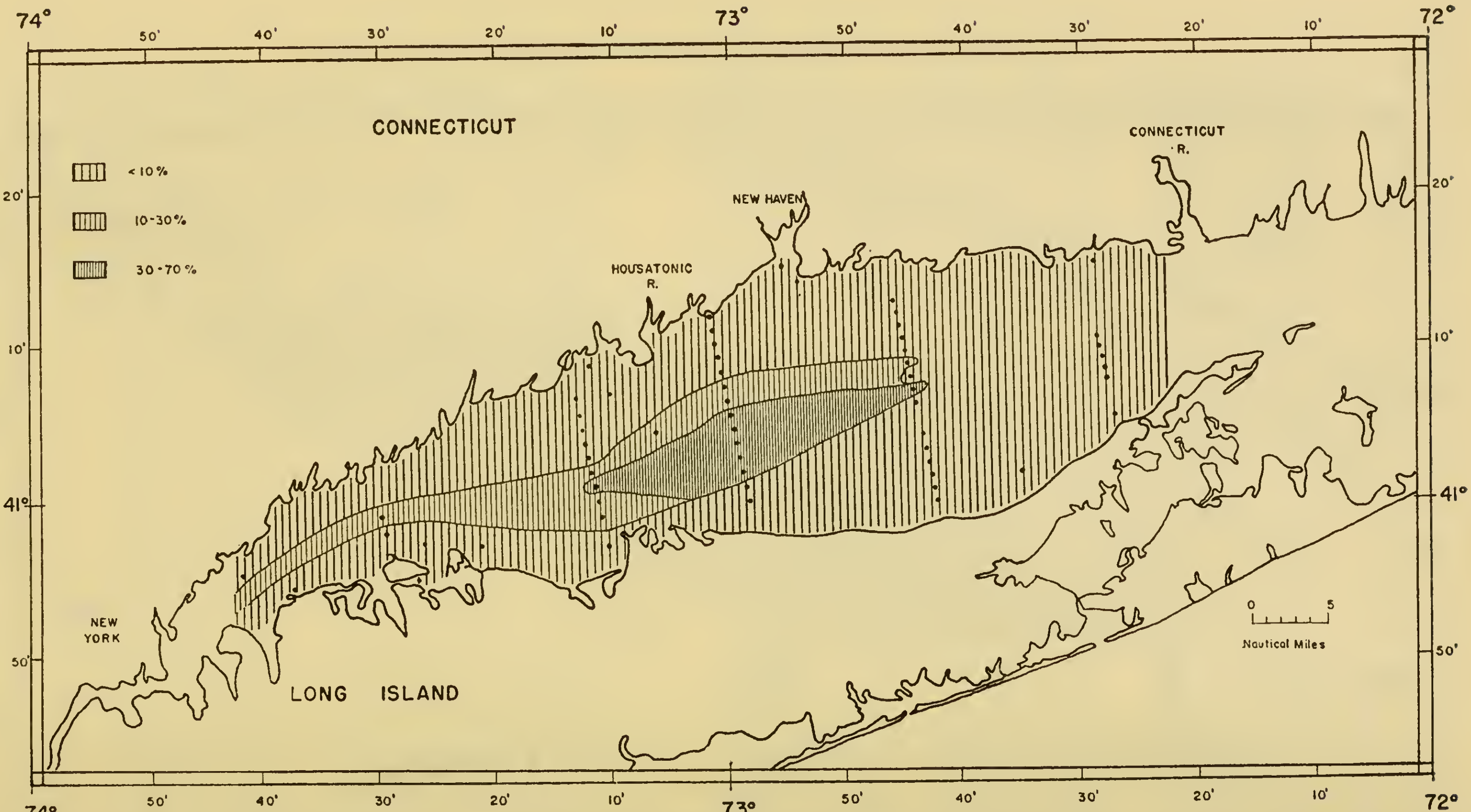

FIG. 16.—Areal distribution of *Eggerella advena* in percent of the total population.

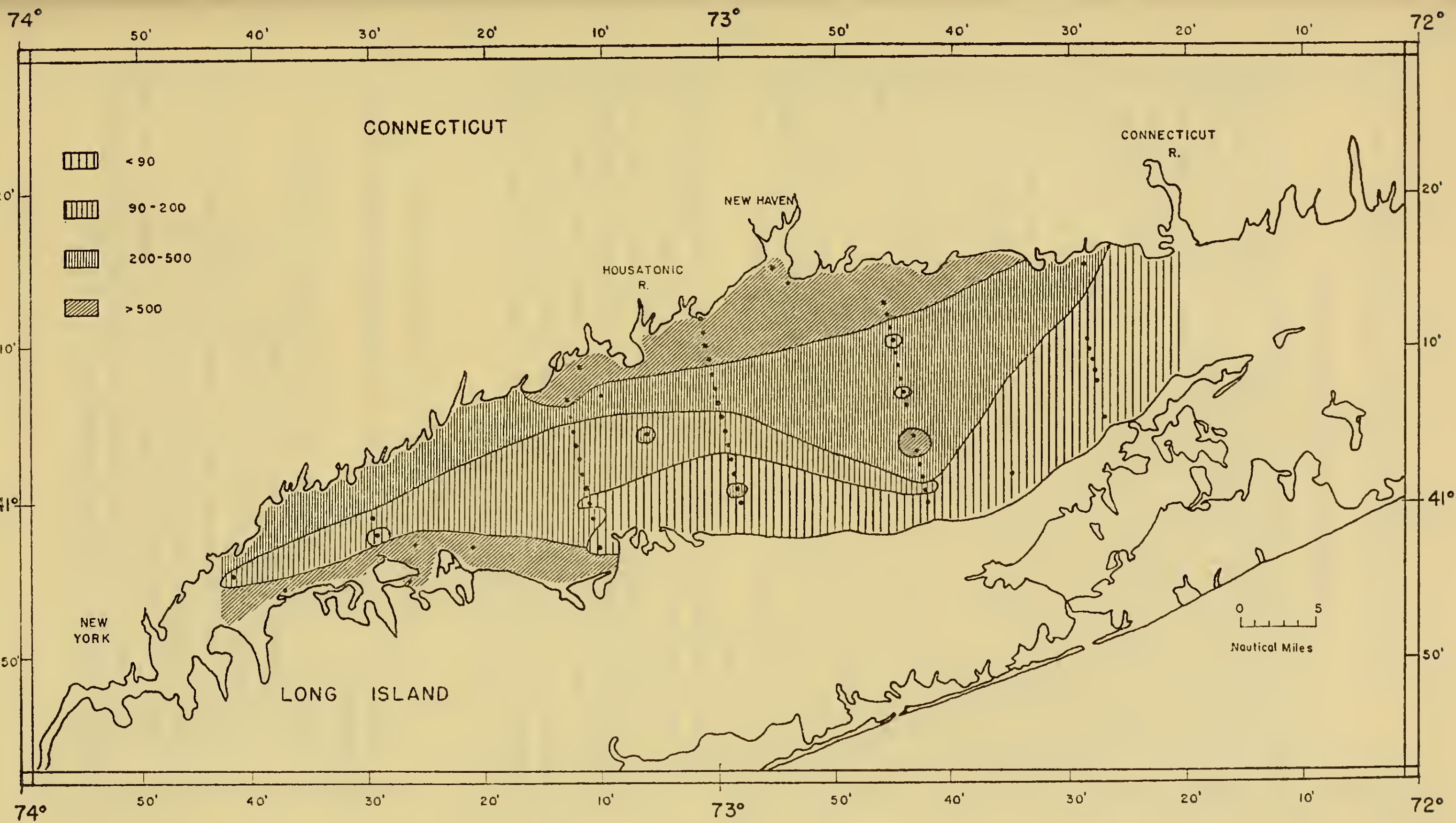

FIG. 17.—Areal distribution of total population in number of specimens per sample.

Zonation of the Total Population

Zonation of the total population using the same percent limits that were used for the living population is shown in figure 18. The *Buccella frigida* zone is now somewhat more extensive and the *Eggerella advena* zone correspondingly more compressed. This is due to the lower frequencies with which *E. advena* occurs in the total population. This species is usually represented by only a few dead individuals, so its percent in the total population depends heavily on the number of living individuals. In general, the agreement between the zonation of the living and total populations is quite good. The average depth of stations in the *E. clavatum* zone based on the total population is 11 m. and the range 3-19 m. Stations in the *B. frigida* zone based on the total population have an average depth of 26 m. and a range of 15-33 m. In the *E. advena* zone based on the total population the average depth of the stations is 30 m. and the range 19-39 m. The mean depth of stations in the *E. advena* and *B. frigida* zones is 1 m. deeper than it was in the zonation of the living population, whereas the mean depth of the *E. clavatum* zone is 1 m. shallower. The ranges are more restricted except in the case of the *B. frigida* zone, where it remained the same.

Figures 14-16 show that the distribution of the abundant species in the total population are comparable to their distributions in the living population (figs. 5-7). The major difference is that in the total population there is less accentuation of the species distribution, that is, *E. clavatum* and *B. frigida* are more evenly distributed in the deeper areas. It is likely that dead individuals of these species are transported into deeper areas, and so the total population in these areas has a higher percentage of them.

Summary of the Distribution of the Foraminifera

In summary the distribution of the Foraminifera has the following characteristics:

1. The fauna is composed of 23 species belonging to 15 genera.
2. No planktonic Foraminifera were found.
3. The number of species increases from west to east.
4. *Reophax dentaliniformis* and *R. nana* are common in L.I.S. but are not found in adjacent open ocean waters.
5. The species *Elphidium clavatum, E. pauciloculum, E. varium, Buccella frigida,* and *Eggerella advena* make up about 90 percent of the total as well as of the living population.

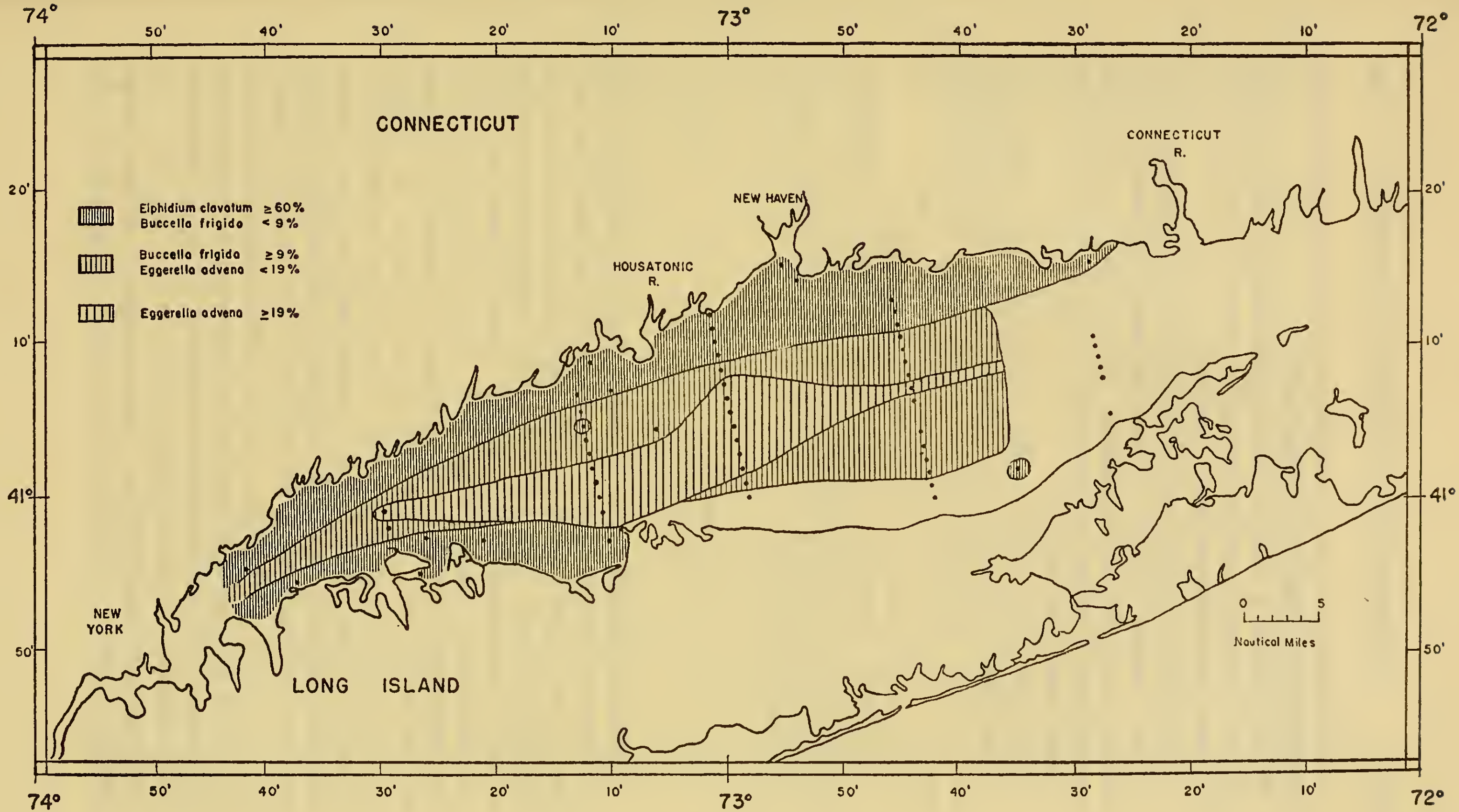

FIG. 18.—Zonation of total population.

6. Of these *E. clavatum, B. frigida,* and *E. advena* are most abundant and usually comprise over 75 percent.

7. *E. clavatum* is most abundant in near-shore areas (<20 m.), whereas *E. advena* is most abundant in offshore areas (>20 m.). *B. frigida* is abundant at depths of 10-40 m.

8. These three abundant species can be used to construct a foraminiferal zonation of L.I.S. In the living population the mean depth of stations in the *Elphidium clavatum, Buccella frigida,* and *Eggerella advena* zones is 12 m., 25 m., and 29 m. respectively. The depth ranges of these zones overlap.

9. The size of the living population based on seasonal samples is 110 individuals per sample. At depths of 10-20 m. the living population averages 177 individuals per sample, while in the 20-40-m. range it averages 62. Miscellaneous shallow-water stations in the 0-10-m. range average 335 living individuals per sample.

10. The *E. advena* zone of traverse 2 contained a significantly greater number of living individuals than did traverse 3.

11. The distribution of the total population closely approximates that of the living population.

SEASONAL SAMPLES

Introduction

Traverse 3 was sampled seven times during the period June 1961 to November 1962 for the purpose of establishing whether or not there is any seasonal variation in the living population. To do so, the samples must be shown to be a reliable estimate of the number of living Foraminifera at a given time. Table 2 shows that in the near-shore areas (<20 m.) only two of the five sample pairs tested have numbers of living individuals that can be considered to be from the same distribution. In the offshore area (>20 m.) five of the seven sample pairs tested indicate they are from the same distribution. The offshore area, then, is more likely to give a better estimate of the actual number of living individuals at a station. However, in the offshore area it is impossible to sample at exactly the same location each time the traverse is sampled. Consequently, it is desirable to treat the entire offshore area of traverse 3 as a single unit or population. At any given time a sample of the living population will be composed of several subsamples (stations).

In order to test the reliability of this assumption, it was decided to compare stations in the *Eggerella advena* zone at a given time. Five of the ten stations in this zone on the traverse of March 1962 were chosen at random for comparison with the remaining five. The ten stations in the *E. advena* zone on the traverse of June 1962 were subdivided in the same way. The next step was to test whether two samples (five stations each) taken at the same time came from the same population. The test statistic chosen was the distribution-free Wilcoxon two sample test which was discussed earlier.

Table 5 (page 80) shows the results of the Wilcoxon test on the total living population and the living populations of *Elphidium clavatum, Buccella frigida,* and *Eggerella advena* for the traverses of March 1962 and June 1962. No significant R_m value was obtained, indicating that the two samples for March 1962 and the two samples for June 1962 are from respective identical populations.

Seasonal Variations in the Living Population

Eggerella advena is the most abundant species in the *E. advena* zone and therefore it was the most rigorously tested. The stations in the *E. advena* zone at each sampling time are considered a sample and the Wilcoxon two sample test was made on all the possible 21 pairs from the seven sampling times. The results are shown in table 6 (page 81). Frequency distributions for the mean number of total individuals and the mean numbers of living *Elphidium clavatum, Buccella frigida,* and *Eggerella advena* in the *E. advena* zone at the seven sampling times are shown in figure 19. The number of living *E. advena* in October 1961 was significantly greater than at any other time with the exception of January 1962. During the winter of 1962 the number of living *E. advena* declined, and then in June 1962 there was a small maximum after which they declined to the significantly lower levels of September and November 1962. The early autumn maximum so pronounced in October 1961 was not observed in 1962.

The frequency distribution of *Elphidium clavatum* in the *E. advena* zone shows a maximum in June 1962. Table 7 (page 81) shows that June 1962 was significantly greater than September, November, and March, 1962. No significant difference was found between November and January 1962.

The frequency distribution of *Buccella frigida* in the *E. advena* zone has maxima in June 1961 and June 1962. Table 8 (page 82) shows that June 1962 was significantly greater than September and November 1962. None of the other pairs tested gave a significant value. Examination of the stations of June 1961 indicates that the

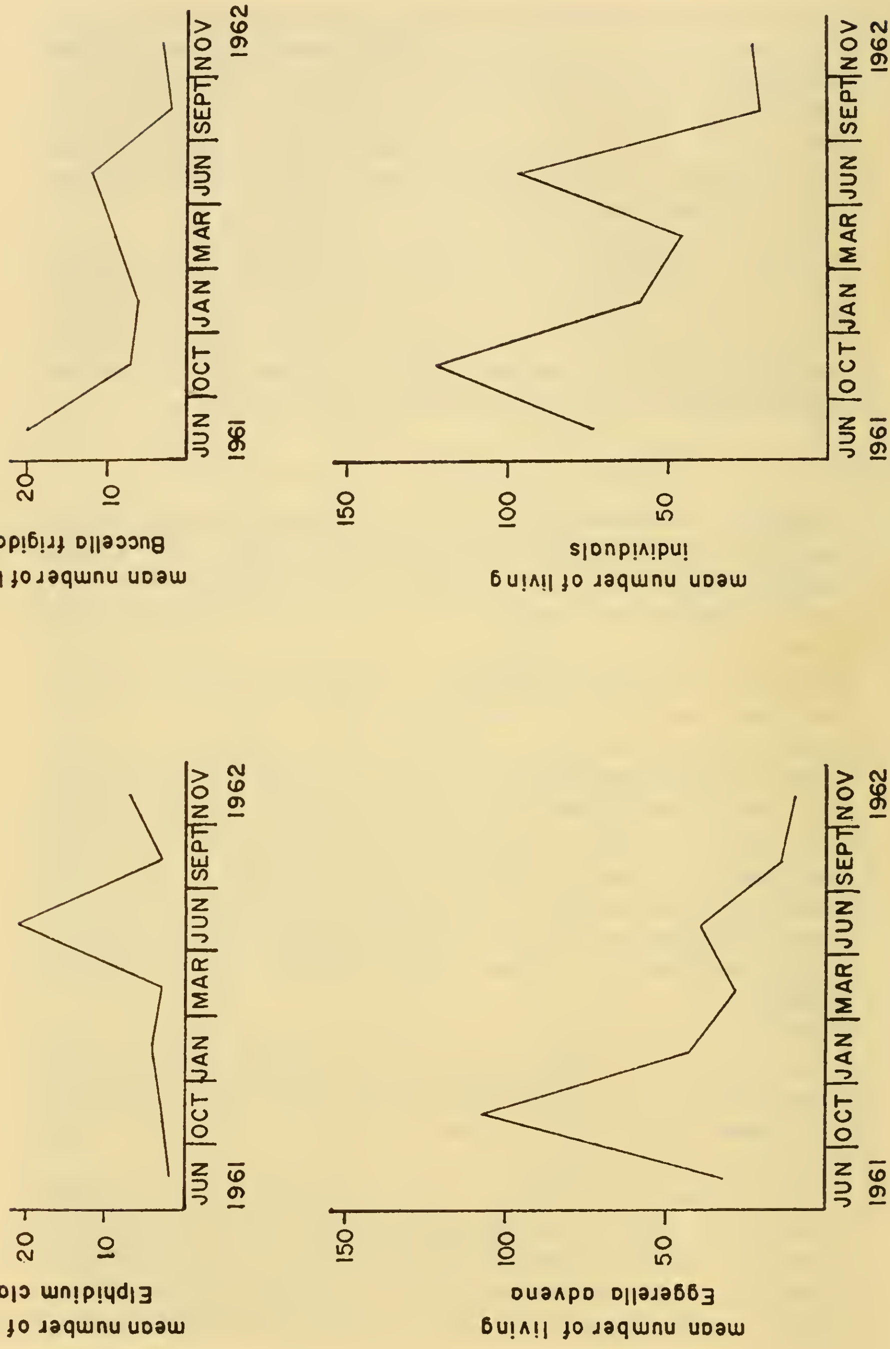

FIG. 19.—Seasonal distribution of living Foraminifera in the *Eggerella advena* zone.

high mean obtained for *B. frigida* at this time is misleading. Although 127 individuals were found at one station, the others contained comparatively few. Because the Wilcoxon test uses ranked sums, it is not sensitive to extreme values, and therefore June 1961 was not found to be significantly greater than any other time.

The frequency distribution of the total living population is similar to that of *E. advena,* the most abundant species in this zone. The June 1962 maximum, however, is accentuated owing to the abundance of *E. clavatum* and *B. frigida* at this time. Table 9 (page 82) shows the results of the Wilcoxon test performed on the total living population in the *E. advena* zone. October 1961 was not found to be significantly greater than June 1961. October 1961 was found to be significantly greater than January 1962, but not June 1962. June 1962 in turn was significantly greater than March and September 1962, but not January 1962.

Although the frequency distributions show times of maximum foraminiferal production, they do not indicate whether or not reproduction is occurring at all times of the year. Live megalospheric juveniles of *E. clavatum* with three or four chambers are easily recognizable and were counted during the period January 1962 to November 1962. The juveniles of this species are most abundant in the near-shore area, but because the variability of the actual number of individuals in a given sample in this area is great, the data are not treated quantitatively. Juveniles of *E. clavatum* are present throughout the year, and in the *E. advena* zone (as well as in the near-shore areas) the greatest number of juveniles was observed in June 1962. It is therefore likely that *E. clavatum* is reproducing all year long and only the rate of reproduction varies.

Significance of Seasonal Samples

In L.I.S. there was a significant increase in the number of living individuals in October 1961 and June 1962. The June maximum was due to an increase of all species, whereas the October maximum was due to an increase of *Eggerella advena.* In the water of Plymouth, England, Myers (1943) found that *Elphidium crispum* began gametogenesis in March and April right after the midwinter phytoplankton flowering. He reasoned that the increase in nutrients and light which precede a flowering are also beneficial to the benthonic microflora upon which *E. crispum* principally feeds, and therefore the phytoplankton cycle is a reliable index for the productivity of the microflora in general. Walton (1955) found maximum populations of living Foraminifera in June and August in Todos Santos Bay, Calif., and he believed that these maxima were in response to the abundance of phytoplankton in late spring and summer. Parker and Athearn (1959) found the largest living population in Poponesset Bay, Mass., in June and suggested that this maximum might be related to maximum temperature because Myers (1935) and Bradshaw (1955) have shown that some species of foraminifers increase reproduction rates at higher temperatures.

Riley (1959) has shown that although there is a 20-fold variation in chlorophyll, the amount of organic matter in surface waters of L.I.S. varies within narrow limits. If the Foraminifera are indiscriminate feeders, and depend either directly or indirectly on organic matter in the water column, then the amount of food available is the same throughout the year. On the other hand if they depend on the phytoplankton either directly or indirectly, then their food will vary seasonally.

In L.I.S. the phytoplankton have a large midwinter flowering in February and March, several irregular summer flowerings, and in some years a large autumn flowering. The zooplankton have maxima in late spring and late summer. The Foraminifera were not abundant in March, and the next sampling time was in June. Therefore, if a late-spring increase had occurred it would not have been detected. Likewise, no samples were taken in July and August, and so it is not known whether or not the Foraminifera maintained their June maxinum throughout the summer. In October 1961 *Eggerella advena* had a significant maximum, whereas none occurred in early autumn 1962. No data are available concerning possible phytoplankton flowerings during the autumns of 1961 and 1962.

The maximum temperature in L.I.S. occurs in August and the minimum in January or February. The temperature in June and October is about 16-18°C, the former being one month prior to the maximum and the latter one month after it.

The seasonal maxima obtained in this study are based on sampling times which are widely spaced. It may be said that the abundance of Foraminifera in October 1961 and June 1962 correlates in a general way with times of maximum temperature and with the increase of zooplankton in late summer and late spring, which in turn is correlated with the phytoplankton cycle. Until information regarding the feeding habits and importance of temperature for the species in question are available, these variables cannot be evaluated.

Summary of Seasonal Samples

In summary, the frequency distributions and statistical tests indicate the following seasonal characteristics for the living population in the *Eggerella advena* zone:

1. The total number of living individuals was significantly greater in June 1962 than in March, September, or November, 1962.
2. *Elphidium clavatum, Buccella frigida,* and *Eggerella advena* showed a significant maximum in June 1962.
3. *Eggerella advena* was most abundant in October 1961 but did not show any maximum in early autumn of 1962.
4. Juveniles of *Elphidium clavatum* are present throughout the year, and it is likely that only the rate of reproduction varies.
5. The abundance of living Foraminifera in October and June correlates in a general way with the zooplankton and phytoplankton cycles in L.I.S. and with times of maximum temperature.

THE FORAMINIFERA IN RELATION TO THE SEDIMENTS

Foraminifera in Short Cores

Cushman (1948, p. 8) stated that benthonic Foraminifera live on the surface of muds and oozes or attached to objects on the bottom. Myers (1942) reported that *Elphidium crispum* could not extricate itself from the sediment if buried to a depth of 5-8 times its diameter. The benthonic Foraminifera have always been considered as epifaunal organisms.

In the present study samples were taken every centimeter to a depth of 4 centimeters in cores from five stations. Table 10 (page 83) shows the number of individuals in each species for the living and total populations The suffix a indicates the sample is from the second centimeter, b the third centimeter, and c the fourth centimeter. The total population in the samples from any core is remarkably consistent. There appears to be little difference between the first and second centimeters in the cores, and at stations 74 and 107 there are actually more living individuals in the second centimeter. There is a trend toward fewer living individuals in the third and fourth centimeters of the cores.

The soft muds of L.I.S. contain a large number of molluscs and polychetes. The sediment is being continually turned over by the activities of these animals. In order for a foraminifer to remain on the surface, it would have to spend a considerable amount of its time climbing. Myers (1942) has shown that *Elphidium crispum* is dormant during the winter and therefore would not offer any resistance to burial. Station 74 was sampled in March 1962 and stations 101-109 were sampled in September 1962. If the Foraminifera were dormant during this period then they certainly would be expected to become buried by the activities of the worms. On the other hand, even if they were active, it is likely that they would become buried by the activities of relatively much larger animals. If the benthonic Foraminifera in L.I.S. are truly epifaunal, then only these Foraminifera would survive and reproduce that were fortunate enough to remain on or be brought back to the surface. The alternative possibility is that the Foraminifera in L.I.S. are infaunal rather than epifaunal animals. Actually the sediment-water interface is not a sharp boundary in the soft muds of L.I.S. and so the terms epifaunal vs. infaunal at the interface are inexact. However, it must be remembered that living foraminifers were found 4 centimeters down in the cores.

Cytological investigations on a seasonal basis must be carried out in order to find out whether or not the foraminifers beneath the surface are feeding and reproducing. Since such investigations are beyond the scope of the present study, the answer must await further research.

Particle-Size Analyses

Particle-size analyses were made on 59 samples using the standard methods of analysis described by Krumbein and Pettijohn (1938). The phi notation of Krumbein (1934) was used for the class limits where $\phi = -\log_2$ of the diameter in millimeters. The results of each analysis were plotted on probability paper, and four of the statistical measures described by Inman (1952) were tabulated. These measures are: The phi median diameter (Mdϕ), phi mean diameter (Mϕ), phi deviation ($\sigma\phi$), and phi skewness ($\alpha\phi$). They are defined as follows:

$$\mathrm{Md}\phi = \phi 50$$
$$\mathrm{M}\phi = \tfrac{1}{2}(\phi 16 + \phi 84)$$
$$\sigma\phi = \tfrac{1}{2}(\phi 84 - \phi 16)$$
$$\alpha\phi = \frac{\mathrm{M}\phi - \mathrm{Md}\phi}{\alpha\phi}$$

where $\phi 50$, $\phi 84$, and $\phi 16$ are percentiles. Table 11 (page 84) shows the results of the analyses. The letter *a* after each station number indicates that the second centimeter of core was used for the analysis. Stations 98, 56, 57, and 58 are exceptions.

Several different approaches were used in attempting to draw a generalized sediment map. One consisted of classifying the sediments by their Mdϕ into sand, silt, or clay. The result was a map so overgeneralized that it was useless. The percent of sand, silt, and clay at each station was plotted on a triangular diagram in hope of obtaining discrete groups. The plots showed only two major groups with a transitional boundary. Plots of Mdϕ vs. $\sigma\phi$, and Mdϕ vs. $\alpha\phi$ also lacked more than two clearly discrete mappable units. The classification of Niggli (1935), adapted to the Wentworth size classes by Pettijohn (1957) and modified by Dunbar and Rodgers (1957), which utilizes the first and third quartiles was finally adopted because it divides the sediment types into objective, manageable (six categories for L.I.S. sediments), and mappable units. The right-hand side of table 11 shows the sediments classified according to Niggli's scheme.

Examination of figure 20 shows that nearly the entire central area of L.I.S. is composed of clayey silt and silty sands. In traverses 2 and 3 more than half of the stations are composed of clayey silt. The sediment in these traverses changes to silty sand as Long Island is approached. Stratford shoal which is a topographic high in the center of the Sound midway between traverses 2 and 3 is composed of pebble sand. Farther east in traverse 4 silty sand is the dominant sediment. The area of silt shown between traverses 3 and 4 is probably of no significance because examination of table 11 shows that with the exception of station 34, the stations in traverse 4 classified as silt differ little from the stations called silty sand. Likewise, station 10 in traverse 3 differs little from stations 9 and 11 which are classified as clayey silts. The northern coast of Long Island east of longitude 73° is composed of coarse sand. Traverse 5 shows that the area of sand increases as the Sound narrows at its eastern end, and the silty sands become restricted into a narrow band. West of longitude 73° the northern coast of Long Island is irregular and the area of clayey silt shown on the map might have been anticipated from the shoreline configuration. Very little information is available for most of the near-shore areas, but the work of Ellis (1962) shows that the distribution of near-shore sediments is complex.

Examination of table 11 indicates that most of the sediments are poorly sorted. The silty sands have an average $\sigma\phi$ of 2.3; the clayey silts, 2.8. Most of the silty sands are skewed toward the fines, whereas the clayey silts are skewed toward the coarser sizes. The sands are, in general, better sorted and have an average $\sigma\phi$ of 1.5.

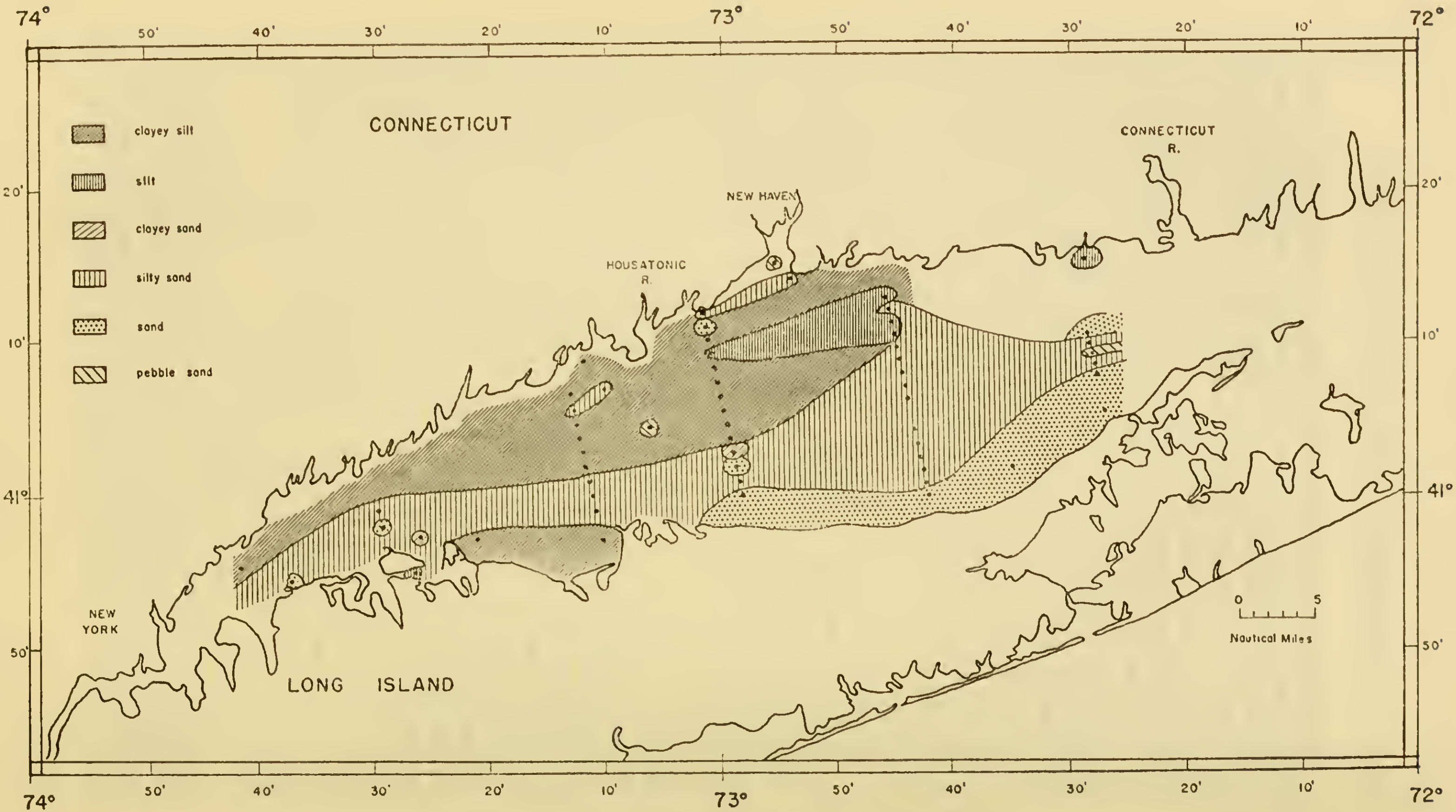

FIG. 20.—Areal distribution of sediments in Long Island Sound.

Microscopic examination of the fraction $>125\mu$ showed the most abundant constituent to be quartz. Diatoms, Foraminifera, micas, worm tubes, polychetes, copepods, amphipods, ostracods, gastropods, and pelecypods are common. In the silty sands and clayey silts, the most abundant constituent in the 125-62μ fraction is elliptical fecal pellets. Diatoms, nematodes, Foraminifera, quartz, and micas are also common. Quantitative counts were made only of the Foraminifera.

Significance of Particle-Size Analyses

Since clay-size particles tend to bind organic matter, the clay content of the sediment is often an important factor in governing the distribution and quantity of benthonic organisms. Sanders (1956, p. 404) found the largest infaunal populations in L.I.S. at silt-clay concentrations of 13-25 percent. He was also able to relate the abundance of various infaunal organisms to the particle size of the sediment.

In L.I.S. where the silt and clay content of the sediment is less than 2 percent there are usually no Foraminifera. Otherwise, there is no meaningful relation between the particle size of the sediment and the living Foraminifera. For example, at station 19 the sediment is a pebble sand consisting of 29 percent gravel, 59 percent sand, 8 percent silt, and 4 percent clay; the number of living Foraminifera is 681. At station 14 the sediment is a sand consisting of 13 percent gravel, 82 percent sand, 3 percent silt, and 2 percent clay; the number of living Foraminifera is 441. At station 113 the sediment is a clayey silt consisting of 4 percent gravel, 16 percent sand, 36 percent silt, and 44 percent clay; the number of living Foraminifera is 478. The above stations are all in near-shore areas and although the sediment ranged from pebble sand to clayey silt, all the stations contained a large living population. Some further examples will illustrate the situation in the offshore areas. Station 116 is a silty sand consisting of 0.5 percent gravel, 70 percent sand, 14 percent silt, and 15 percent clay; the number of living Foraminifera is 47. Station 125 is a pebble sand consisting of 54 percent gravel, 40 percent sand, 2 percent silt, and 4 percent clay; the number of living Foraminifera is 48. Station 119 is a clayey silt consisting of 10 percent sand, 44 percent silt, and 45 percent clay; the number of living Foraminifera is 40. These examples and careful examination of the data indicate that particle size has no influence on the numbers of living Foraminifera in L.I.S.

Similarly, the distribution of species cannot be related to particle size of the sediment. For example, at station 12 the sediment is a clayey silt consisting of 11 percent sand, 58 percent silt, and 31 percent clay; the number of living *Elphidium clavatum* is 600, *Buccella frigida* 53, and *Eggerella advena* 0. At station 8 the sediment is a clayey silt consisting of 14 percent sand, 55 percent silt, and 30 percent clay; the number of living *E. clavatum* is 0, *B. frigida* 23, and *E. advena* 106. Examination of the data indicates numerous examples of faunal change without any relation to the particle size of the sediment.

The lack of Foraminifera in traverse 5 is puzzling. Stations 54 and 58 contain less than 2 percent silt and clay, but stations 55 and 57 contain over 50 percent while station 56 contains 8 percent. Clearly, the absence of living Foraminifera (stations 54 and 55 contain one individual each) at all these stations cannot be attributed to an insufficient amount of silt and clay.

Ratios of Living to Total Populations in L.I.S.

Phleger (1951) discussed and used the living and total populations of Foraminifera in estimating relative rates of sedimentation in the Gulf of Mexico. Walton (1955) used the ratio of living to dead populations to indicate relative rates of sedimentation in Todos Santos Bay. Phleger (1955) expressed the ratio of living to total populations (L/T) in percent and estimated relative rates of sedimentation in the southeastern Mississippi delta area. The use of an L/T ratio is based on several assumptions which have been discussed in the papers mentioned above. If the living population represents the rate of addition of tests to the sediment and the total population represents this accumulation over a period of time, then the ratio L/T indicates the relative rate of sedimentation providing tests are not removed from the sediment. If sedimentation is rapid, the L/T ratio will be high because empty tests are being rapidly buried.

The frequency distribution for the L/T ratio expressed in percent is shown in figure 21 for all species, *Elphidium clavatum, Buccella frigida,* and *Eggerella advena,* in the 13 grand stations of traverse 3. The frequency distribution of the L/T ratio of all species has maximum values in the central area of the traverse and minimum values at the ends. It would appear, then, that sedimentation is relatively more rapid in the central areas than near shore.

Let us examine the L/T frequency distribution of all species in greater detail by examining the L/T frequency distributions of the

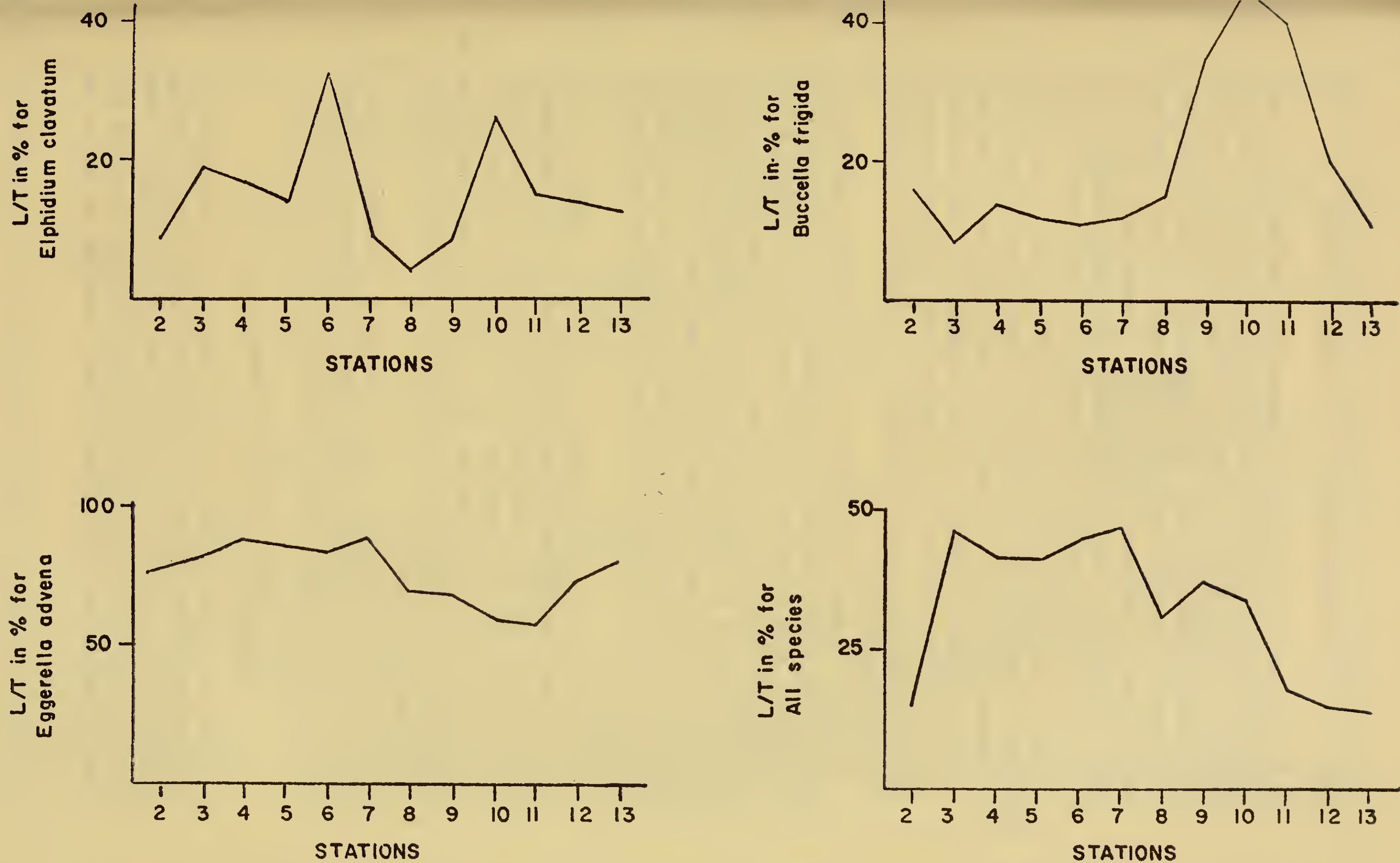

FIG. 21.—Distribution of living population in percent of total population at grand stations.

three abundant species. The L/T frequency distribution of *E. clavatum* has values of less than 20 percent at all stations except 6 and 10. The high at station 6 is due to a slight increase in the living population of *E. clavatum* combined with a slight decrease in the dead population. At station 10 both the living and dead populations are increasing, but the living population is increasing at a greater rate. The L/T ratio of *B. frigida* is less than 20 percent at all stations except 9, 10, and 11. The maximum is the result of an increase in the living population combined with a decrease in the dead population at these stations. The L/T ratio of *E. advena* is greater than 70 percent at all stations except 8, 9, 10, and 11. At stations 8 and 9 the dead population increases whereas the living population remains constant, resulting in lower L/T values. At stations 10 and 11 both the living and dead populations are decreasing, but the living population decreases more rapidly.

The L/T frequency distribution of all species indicates that at stations 3 to 8 the distribution is controlled by the L/T ratio of *E. advena,* the most abundant species in this area. At station 9, the L/T ratio of *B. frigida* becomes important, while at stations 10 and 11 the L/T ratios of *B. frigida* and *E. clavatum* control the distribution. Stations 12 and 13 are in an area where *E. clavatum* is most abundant and its L/T ratio controls the distribution of these stations. Station 2 also has a low L/T value for all species owing to the influence of *E. clavatum.*

If the L/T ratio of all species is an accurate indicator of the relative rate of sedimentation, then the L/T ratios of the component species should show the same pattern. In traverse 3, the L/T ratios of the three abundant species each give a different interpretation of the relative rate of sedimentation. The L/T ratio for *E. advena* is always high, and it is likely that empty tests of this fragile arenaceous species are being destroyed.

Figure 22 shows the L/T ratios expressed in percent for the stations in L.I.S. The values for traverse 3 are seasonal averages. In general, the ratios are higher in the central area (*E. advena* zone).

SIGNIFICANCE OF ENVIRONMENTAL FACTORS

I have shown that the number of foraminiferal species increases to the east and that the number of living Foraminifera in the *Eggerella advena* zone of traverse 2 (west) is greater than in traverse 3 (central). It was also observed that the most striking change in the foraminiferal fauna is with depth. Broadly speaking, the fauna can

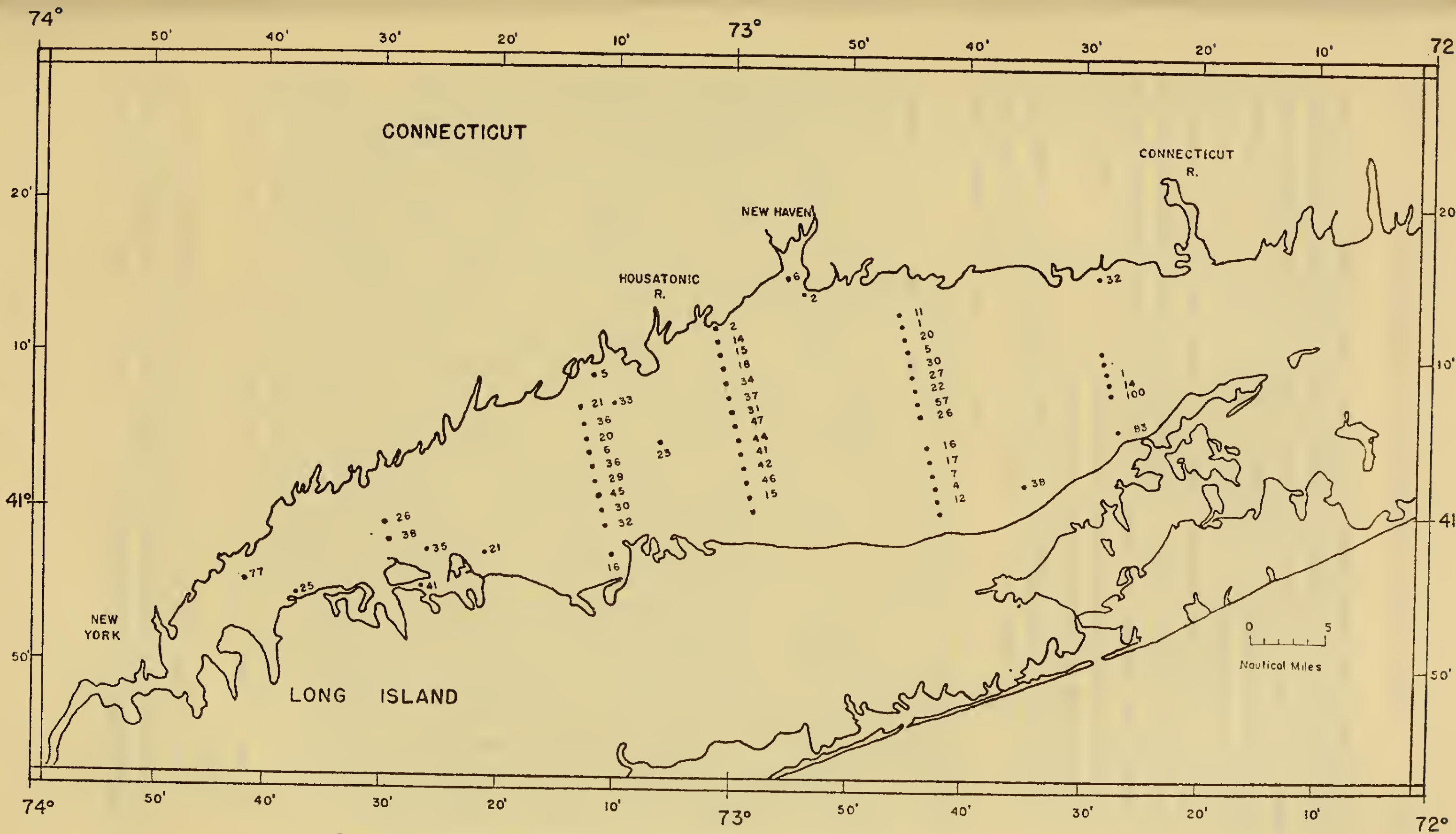

FIG. 22.—Areal distribution of living population in percent of the total population.

be divided into near-shore (<20 m.) and offshore (>20 m.) assemblages. In terms of numbers of living individuals, the near-shore areas (10-20 m.) average 177 per sample, while the offshore areas (20-40 m.) average 62. At depths of less than 10 m. the living population has an average of 335 individuals per sample.

Riley (1959) has shown that the western end of the Sound is usually about 3-5‰ fresher than the eastern end. The increase in foraminiferal species to the east is most likely due to the more oceanic conditions found there and to the proximity of the open ocean from which migration into the Sound can occur.

In L.I.S. the concentration of nutrients and phytoplankton increases to the west (Riley, 1959). The significantly larger living population in the *E. advena* zone of traverse 2 is probably related to the potentially greater food supply in the western area.

To relate the foraminiferal zonation with depth to environmental factors is more difficult. Riley (1956, pp. 17, 18) has shown that the seasonal cycle and range of variation in temperature and salinity at near-shore (8-12 m.) and offshore (19-28 m.) stations in the central part of L.I.S. are about the same. Moreover, the seasonal cycles and range of variation in phosphate, nitrate, and oxygen at near-shore and offshore stations do not show significant differences (Riley and Conover, 1956, pp. 51, 52, 54). Since the Foraminifera are holozoic, the seasonal cycle and amount of nutrients should affect them only insofar as it affects the organisms upon which they feed. Very little is known concerning the oxygen requirements of the Foraminifera. At several stations a strong odor of H_2S emanated from the black muds in the cores, and at some of these stations the living population was abundant. Riley (1959) has indicated that minimum values of oxygen for bottom water are about 40 percent of saturation. It would appear, then, that although reducing conditions may be prevalent in the sediments below the surface, the sediments at or near the surface (within 1 cm. or so) are not oxygen deficient.

The pH and Eh of the sediments have not been investigated during the present study. McCrone and others (1961) have shown that the pH is usually about neutral, whereas the Eh is negative. They did not indicate any differences between near-shore and offshore stations.

I have already pointed out that in L.I.S. both the distribution of species and the number of living individuals bear no relation to the particle size of the sediment.

Conover (1956, p. 69) reported that the concentration of phytoplankton under a unit area of sea surface is usually greater in the offshore areas. Although planktonic diatoms were shown to be an important source of food for *Elphidium crispum,* Myers (1943) indicated that this foraminifer fed for the most part on benthonic unicellular plants. No data are available on the distribution or quantity of benthonic microflora in L.I.S. Riley (personal communication) has indicated that calculations from Secchi disc readings indicate that the lower limit of the benthonic microflora in L.I.S. is about 11 m. None of the species in this study is restricted to depths of less than 11 m., but *Elphidium clavatum* is most abundant at depths of less than 10 m. and is relatively rare at depths of greater than 20 m. (fig. 8).

Bradshaw (1955) found that one of the species of foraminifers which he was culturing would feed only on the living diatom *Nitzchia,* whereas another species would accept living and dead flagellates as well. In L.I.S., species of *Nitzchia* are more often found in nearshore areas (Conover, 1956, p. 94). Lee and others (1961) found that an algal flora of eight species of pennate diatoms and three of blue-green algae best supported the species they were culturing. Myers (1943, p. 442) suggested that below the photic zone the growth of bacteria on fecal pellets might constitute an important source of food for the Foraminifera. Apparently the food requirements of the Foraminifera are complex and vary from species to species. Although a given species may accept many kinds of food, it is likely that certain types or associations are more beneficial to it than others. Perhaps in this way niche diversification among benthonic foraminifers is achieved. Because temperature, salinity, nitrate, phosphate, oxygen, pH, Eh, particle size of the sediment, and concentration of phytoplankton do not apparently control the observed depth zonation, I suggest that the foraminiferal species in L.I.S. are selective feeders, and that their depth zonation is, therefore, related to the distribution of the material upon which they feed. The environmental parameters which might control the distribution of such material are not readily apparent from this study.

PALEOECOLOGIC IMPLICATIONS

Most of the sediments in L.I.S. are clayey silts and silty sands. They are black in color, are high in organic content, and show no stratification. Ellis (1962) has indicated that these muds would become ". . . black silty or sandy shales containing abundant pyrite or marcasite."

If the sediments of L.I.S. and the fauna contained therein were preserved, the Foraminifera could be used to reconstruct the general aspects of the environment. I have shown that the distribution of the living and total populations closely approximate one another. Therefore, a study of the total population would in general give an accurate account of foraminiferal distribution in L.I.S. The low number of species per sample and the dominance by a single species would indicate a restricted marine environment. The lack of planktonic forms would substantiate this. If the species living in L.I.S. today were still living when the hypothetical fossil fauna was studied, a knowledge of the distribution of such forms as *Reophax dentaliniformis* and *R. nana* would also indicate a restricted or bay environment. The increase in numbers of species to the east would indicate the approach of more oceanic conditions in that direction. The distribution of the abundant species would allow the future paleontologist to distinguish between offshore and near-shore environments and he could, thereby, reconstruct the former geographic configuration of the Sound. Even if the relatively fragile tests of *Eggerella advena* were destroyed, offshore and near-shore environments could still be distinguished by the relative abundances of *Elphidium clavatum* and *Buccella frigida.*

In short, providing the sediments could be correlated and the future paleontologist knew as much about the Foraminifera as we do now, the general environmental features of the fossilized sediments of L.I.S. could be worked out.

SYSTEMATIC CATALOG OF SPECIES

Most of the foraminiferal species found in L.I.S. have been adequately described by Cushman (1944) and Parker (1952a, 1952b). No detailed descriptions or synonomies are given because the taxonomy of the species involved is fairly straightforward. The *Elphidium* group is an exception and some notes on the author's views are offered. A brief account of the distribution of each species is included.

Family REOPHACIDAE

Genus REOPHAX Montfort, 1808

REOPHAX DENTALINIFORMIS Brady

Plate 1, figure 1

Reophax dentaliniformis Brady, Quart. Journ. Micr. Sci., vol. 21, p. 49, 1881.—PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 457, pl. 1, fig. 19, 1952.

Living and dead individuals belonging to this species occur with low frequencies throughout L.I.S. This species is not, however, found at depths of less than 13 m. Parker (1952b) suggested that *R. dentaliniformis* may be confined to sediments containing mud. The present study substantiates her suggestion somewhat. *R. dentaliniformis* is often found in the offshore stations which are usually muds. It was not found, however, at stations 125 and 80, which are offshore sands. As mentioned above, this species is conspicuously absent from all shallow stations including those whose particle-size distribution is similar to the offshore muds.

REOPHAX NANA Rhumbler

Plate 1, figure 2

Reophax nana Rhumbler, Ergeb. Plankton-Exped. Humboldt Stiftung, Bd. 3, pt. 2, p. 471, pl. 8, figs. 6-12, 1913.—Parker, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 457, pl. 1, figs. 14, 15, 1952.

Living and dead individuals of this species are found in L.I.S., but their occurrence is scattered and never comprises more than 2 percent of the total fauna.

Family LITUOLIDAE

Genus AMMOSCALARIA Hoglund, 1947

AMMOSCALARIA cf. FLUVIALIS Parker

Plate 1, figure 3

A few specimens that probably belong to this species, which was described by Parker (1952b, p. 444, pl. 1, figs. 24, 25), were found at station 98a in Lloyd's Harbor at a depth of 4 m. None of the specimens was living at the time of collection, and no complete individuals were observed. Most of the specimens were so fragile that they disintegrated when the sample was dried.

Family VALVULINIDAE

Genus EGGERELLA Cushman, 1933

EGGERELLA ADVENA (Cushman)

Plate 1, figures 4, 5

Verneuilina advena Cushman, Contr. Can. Biol., No. 9, p. 141, 1921.
Eggerella advena (Cushman) Parker, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 447, pl. 2, fig. 3, 1952.

This species is found throughout L.I.S., but has its greatest abundance in the central areas of the traverses. In the central areas the relative abundance of *E. advena* in the living population is usually 25-30 percent greater than it is in the total population. The L/T ratio of this species is usually much higher than it is for the other common species, and it is likely that specimens of this species may be fragile enough to be destroyed after death. Specimens of *E. advena* are almost entirely confined to the 0.125-0.062 mm. size fraction.

Family MILIOLIODAE

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA SEMINULUM (Linné)

Plate 1, figure 6

Serpula seminulum LINNÉ, Syst. Nat., ed. 10, p. 786, 1758.
Quinqueloculina seminula (Linné) PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 456, pl. 2, figs. 7a, b, 1952.

The individuals from L.I.S. are smaller than the figured specimen of Parker (1952b). All specimens have a simple tooth, lack a neck, and are similar in overall shape.

Living and dead individuals of this species are found with very low frequencies in all parts of L.I.S.

QUINQUELOCULINA SEMINULUM (Linné) var. JUGOSA Cushman

Plate 1, figure 7

Quinqueloculina seminula (Linné) var. *jugosa* Cushman, CUSHMAN Lab. Foram. Res. Spec. Publ. 12, pp. 13-14, pl. 2, fig. 15, 1944.—PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 456, pl. 2, figs. 8a, b, 1952.

One live specimen belonging to this variety was found at station 1, and four dead specimens were found at station 20.

Family OPHTHALMIDIIDAE

Genus CORNUSPIRA Schultze, 1854

CORNUSPIRA PLANORBIS Schultze

Plate 1, figure 8

Cornuspira planorbis SCHULTZE, Organismus Polythal., p. 40, pl. 2, fig. 21, 1854.—CUSHMAN and TODD, Cushman Lab. Foram. Res., Spec. Publ. 21, p. 7, pl. 1, fig. 24, 1947.—TODD and LOW, Contr. Cushman Found. Foram. Res., vol. 12, p. 15, pl. 1, fig. 9, 1961.

A few dead specimens were found at stations 47, 48, 59, 114, and 133. Five living individuals were found at station 125.

Family TROCHAMMINIDAE

Genus TROCHAMMINA Parker and Jones, 1859

TROCHAMMINA COMPACTA Parker

Trochammina compacta PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 458-459, pl. 2, figs. 13a, b, 14a, b, 15a, b, 1952.

A few living representatives of this species were found at stations 48, 62, and 71. One dead specimen was found at station 51. The specimens were most fragile and when dried became distorted.

TROCHAMMINA INFLATA (Montagu)

Plate 1, figures 9a, 9b

Nautilus inflatus MONTAGU, Testacea Britannica, Suppl., p. 81, pl. 18, fig. 3, 1808.
Trochammina inflata (Montagu) PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 459, pl. 3, figs. 1a, b, 1952.

One dead specimen referable to this species was found at station 59.

TROCHAMMINA LOBATA Cushman

Plate 1, figure 10, plate 2, figure 1

Trochammina lobata CUSHMAN, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 18, pl. 2, fig. 10, 1944.—PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, pp. 459-460, pl. 3, figs. 2a, b, 1952.

One dead specimen belonging to this species was found at station 48.

TROCHAMMINA SQUAMATA Parker and Jones

Plate 2, figures 2a, 2b

Trochammina squamata PARKER and JONES, Philos. Trans. Roy. Soc. London, vol. 155, p. 407, pl. 15, figs. 30, 31a, b, c, 1865.
Trochammina propria CUSHMAN, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 19, pl. 2, fig. 11, 1944.
Trochammina squamata Parker and Jones, and related species, PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 460, pl. 3, figs. 4a, b, 1952.

This species is somewhat variable in form. The test is often fragile, and some specimens have very indistinct morphological features. Most individuals are concavo-convex, the dorsal side being convex. The umbilicus is usually deep, and the sutures on the ventral side become curved as they approach the periphery. The final chamber on the ventral side is often inflated.

Living and dead individuals of *T. squamata* are widely distributed in

L.I.S. but were not found in the westernmost traverses. This species always occurs with low frequencies.

Family LAGENIDAE

Genus **FISSURINA** Reuss, 1850

FISSURINA LAEVIGATA Reuss

Plate 2, figure 3

Fissurina laevigata REUSS, Denkschr. Akad. Wiss. Wien, vol. 1, p. 366, pl. 46, fig. 1, 1849.

Entosolena laevigata (Reuss), CUSHMAN, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 28, pl. 4, fig. 12, 1944.

Living and dead individuals belonging to this species were found throughout L.I.S. *F. laevigata* usually accounts for no more than a few specimens in any sample.

Family POLYMORPHINIDAE

Genus **PSEUDOPOLYMORPHINA** Cushman and Ozawa, 1938

PSEUDOPOLYMORPHINA NOVANGLIAE (Cushman)

Plate 2, figure 4

Polymorphina lactea (Walker and Jacob) var. *novangliae* CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 4, p. 146, pl. 39, figs. 6-8, 1923.

Pseudopolymorphina novangliae (Cushman) PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 455, pl. 3, figs. 11, 12, 1952.

Living and dead individuals belonging to this species are found with very low frequencies in all parts of L.I.S.

Family NONIONIDAE

Genus **NONIONELLA** Cushman, 1926

NONIONELLA ATLANTICA Cushman

Plate 2, figures 5a, 5b

Nonionella atlantica CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 4, p. 90, pl. 20, figs. 4, 5, 1947.—PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 453, pl. 3, figs. 15a, b, 1952.

Two dead specimens belonging to this species were found in L.I.S. One came from station 48, the other from 106.

Family ELPHIDIIDAE

Genus **ELPHIDIUM** Monfort, 1808

ELPHIDIUM CLAVATUM Cushman

Plate 2, figures 6, 7; plate 3, figures 1, 2

Elphidium incertum (Williamson) var. *clavatum* CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 7, p. 20, pl. 7, figs. 10a, b, 1930.

Elphidium incertum (Williamson) and variants, PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 448, pl. 3, figs. 14, 16, 17; pl. 4, figs. 1, 2, 1952.
Elphidium clavatum Cushman, emend. LOEBLICH and TAPPAN, Smithsonian Misc. Coll., vol. 121, No. 7, pp. 98-99, pl. 19, figs. 8-10, 1953.

The forms included under this species exhibit a very wide range of variation. Adult specimens have 8 to 11 chambers in the final whorl. Individuals vary in color and transparency from brown translucent to white opaque. All specimens have short retral processes, but their number and arrangement vary. The typical *E. clavatum* form (brown translucent) has several umbilical bosses which sometimes extend part way up the sutures or may form a single umbonal mass. White opaque individuals often have several distinct umbilical bosses which are sometimes fused by the addition of shell material so that only irregular slits appear in the umbilical region. Examination of many specimens indicates that the range of variation is in all respects continuous. Moreover, when the $CaCO_3$ of the test is dissolved, all the specimens examined showed a thick brown organic inner lining which is not found in any of the other species in this area.

Cushman (1930) originally described this species as a variety of *E. incertum* (Williamson). Loeblich and Tappan (1953) raised the variety to specific rank and discussed its relation to *E. incertum.* They found on slides in the U. S. National Museum referred to *E. incertum* a mixture of several species of *Elphidium,* none of which matched Williamson's original figure. The hypotypes of *E. clavatum* deposited at the U. S. National Museum by Loeblich and Tappan (1953) are identical with the brown translucent form of *E. clavatum* described above. White opaque individuals with retral processes and irregular sutures and/or umbonal bosses have been in the past and are still referred by various workers to *E. incertum.* Parker (1952b) recognized that the variation in morphology between the typical *E. clavatum* and what has been referred to as *E. incertum* is continuous. She chose, however, to call the species *E. incertum* (Williamson) and variants. My views are similar to hers, but I believe it is best to refer to this species as *E. clavatum* because none of the morphological types so frequently referred to *E. incertum* matches Williamson's original figure.

This species is most abundant in L.I.S. It occurs in all areas, but is far more abundant at depths of less than 15 m. In shallow waters this species comprises about 90 percent of the total population, whereas in the central part of L.I.S. it makes up about 20-35 percent of the total population. In the shallow areas the living population is usually 5-10 percent smaller than the total population, but in the central area it is often 20 percent smaller.

ELPHIDIUM PAUCILOCULUM (Cushman)

Plate 3, figure 3

Nonion pauciloculum Cushman, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 24, pl. 3, fig. 25, 1944.
Elphidium subarcticum Cushman, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 27, pl. 3, figs. 34, 35, 1944.—Parker, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 412, pl. 5, fig. 9, 1952a.—Parker, ibid., vol. 106, No. 10, p. 449, pl. 4, figs. 3-6, 8, 1952b.

In the material from L.I.S. some specimens have wide white bands of amorphous material covering the sutural areas. Others have a deep slit along the suture and white bands on either side. Still others exhibit a combination of the two. Retral processes were observed on some of the specimens. The holotype of the species described by Cushman as *N. pauciloculum* is a form with depressed slitlike sutures, while the holotype on *E. subarcticum* is a form with retral processes. In L.I.S. the range of variation between these extremes is continuous. Parker (1952a) observed the same relationships in her study of the fauna from the Gulf of Maine. However, she chose to use the name *E. subarcticum*. Cushman (1944) described both species in the same paper, but *N. pauciloculum* was described on an earlier page and therefore has priority.

This species is common throughout L.I.S. It usually comprises less than 10 percent of the total population, although at a few stations it comprises as much as 30 percent of the living population.

ELPHIDIUM TISBURYENSE (Butcher)

Plate 3, figure 4

Nonion tisburyensis Butcher, Contr. Cushman Lab. Foram. Res., vol. 24, p. 22, text figs. 1-3, 1948.

This species closely resembles *E. orbiculare* (Brady). It differs from the latter in that the individual chambers are more inflated and the test is not as thick and orbicular. Nevertheless, the two species are morphologically very similar, and further study on the expected range of variation is desirable. The material from L.I.S. was identified as *E. tisburyense* because as a group the specimens more closely resemble this form.

A few living and dead individuals of this species were found at stations 59 and 98a. A few dead individuals were found at stations 19, 74, and 123.

ELPHIDIUM VARIUM Buzas

Plate 3, figure 5

Elphidium incertum (Williamson) CUSHMAN, (non *Polystomella umbilicatula* var. *incerta* Williamson, 1858), Cushman Lab. Foram. Res., Spec. Publ. 23, pp. 56-57, pl. 6, fig. 7a, b, 1948.
Elphidium varium BUZAS, Smithsonian Misc. Coll. vol. 145, No. 8, p. 21, pl. 2, fig. 7; pl. 3, figs. 1, 2a, 2b, 1965.

This species is translucent to opaque in appearance. It is finely perforate, and only some individuals have retral processes. The translucent individuals can be easily confused with *E. pauciloculum* or *E. tisburyense,* whereas the opaque individuals with retral processes can be confused with opaque specimens of *E. clavatum.* This species does, however, from a distinct recognizable morphologic group. Moreover, the wall structure of *E. varium* is granular, whereas the other species of *Elphidium* in L.I.S. are all radial.

This species is common in all areas of L.I.S. but usually comprises less than 10 percent of the total population. Living individuals were found in all areas with low frequencies. Some of the living individuals were found in cysts composed of quartz and organic matter.

Family BULIMINIDAE

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA VARIABILIS (Williamson)

Plate 3, figure 6

Textularia variabilis WILLIAMSON, Rec. Foram. Great Britain, p. 76, pl. 6, figs. 162, 163, 1858.
Bolivina variabilis (Williamson) PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 445, pl. 4, fig. 12, 1952.

A few living specimens belonging to this species were found at stations 76, 78, 63, 64, 86, and 125′. A few dead individuals were found at stations 64 and 132.

Genus VIRGULINA d'Orbigny, 1826

VIRGULINA FUSIFORMIS (Williamson)

Plate 3, figure 7

Bulimina pupoides d'Orbigny var. *fusiformis* WILLIAMSON, Rec. Foram. Great Britain, p. 63, pl. 5, figs. 129, 130, 1858.
Virgulina fusiformis (Williamson) PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 461, pl. 4, fig. 10, 1952.

Living and dead individuals of this species were found with low frequencies in traverses 3 and 4 and at station 59.

Family ROTALIIDAE

Genus AMMONIA Brunnich, 1771

AMMONIA BECCARII (Linne)

Plate 4, figures 1a, 1b

Nautilus beccarii LINNÉ, Syst. Nat., ed. 10, p. 710, 1758.
Rotalia beccarii (Linné) PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, pp. 457-458, pl. 5, figs. 5a, b, 7a, b, 8a, b, 1952.

Living and dead individuals of this species are found with low frequencies in traverses 2 and 4 as well as at stations 98 and 17.

Genus BUCCELLA Andersen, 1952

BUCCELLA FRIGIDA (Cushman)

Plate 4, figures 2a, 2b, 3a, 3b

Pulvinulina frigida CUSHMAN, Contr. Can. Biol., No. 9 (1921), p. 12 (144), 1922.
Eponides frigidus (Cushman) PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, pp. 449, pl. 5, figs. 2a, b, 1952.
Eponides frigidus (Cushman) var. *calidus* Cushman and Cole, PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, p. 450, pl. 5, figs 3a, b, 1952.
Buccella frigida (Cushman) ANDERSEN, Journ. Washington Acad. Sci., vol. 42, No. 5, p. 144, figs. 4a-c, 5, 6a-c, 1952.

This species is very common in L.I.S. Living and dead specimens are found at almost all stations. The living population has its maximum frequency on the north side of traverses 2 and 3 about 3-5 miles offshore at a depth of 15-25 m. In traverse 4, *B. frigida* is more abundant, and the living population is developed on both the north and south sides of the Sound. The frequency distribution of the total population has fewer maxima and usually makes up 20-30 percent of the total population in the offshore stations.

Genus POROEPONIDES Cushman, 1944

POROEPONIDES LATERALIS (Terquem)

Plate 4, figures 4a, 4b

Rosalina lateralis TERQUEM, Mem. Soc. Geol. France, ser. 3, vol. 1, Mem. 3, p. 25, pl. 2, figs. 11a-c, 1878.
Poroeponides lateralis (Terquem) PARKER, Bull. Mus. Comp. Zool., vol. 106, No. 10, pp. 453-454, pl. 5, figs. 6a, b, 1952b.

One living specimen was found at station 54. One dead specimen was found at station 42 and another at station 45.

GENERAL SUMMARY

This study is based on 220 samples obtained during 14 cruises on Long Island Sound. Living and total populations were counted in 161 samples, while particle-size analyses were made on 59.

Statistical analyses of 12 paired samples indicate that the species investigated are more homogeneous in the living than in the total population, and the number of living individuals per sample can be more reliably estimated than the total number of individuals. The offshore area is more homogeneous and gives a better estimate of the number of individuals per sample than the near-shore area.

Of the 23 species found in the Sound, 19 were represented by living individuals. The number of species increases as the more oceanic waters of Block Island Sound are approached. *Elphidium clavatum, Buccella frigida,* and *Eggerella advena* comprise about 75 percent of the living as well as of the total population. Three zones are defined by the change in relative abundance of these species with depth. In the living population, the mean depth of stations in the *E. clavatum, B. frigida,* and *E. advena* zones is 12 m., 25 m., and 29 m. respectively. The distribution of the total population closely approximates that of the living population.

In the *E. advena* zone, a significantly greater number of living individuals occurs in the western area than in the central area. This difference probably is related to the greater concentration of nutrients and phytoplankton in the western part of the Sound.

In seasonal sampling of the central area, a significant maximum for the living population in the *E. advena* zone occurred in June 1962. *E. advena* was most abundant in October 1961 but did not show any maximum in early autumn 1962. Maximum seasonal abundances correlate in a general way with the seasonal cycle of the phytoplankton and with times of maximum temperature. Juveniles of *E. clavatum* were found throughout the year, and probably only the rate of reproduction varies.

Most of the sediments are silty sands and clayey silts. The distribution of species, as well as numbers of living individuals, bear no relation to the particle size of the sediment. Living to total population ratios of the abundant species indicate that this ratio is not a reliable indicator of relative rates of sedimentation in the Sound.

The distribution of the Foraminifera with depth cannot be related to temperature, salinity, phosphate, nitrate, oxygen, pH, Eh, concentration of phytoplankton, or particle size of the sediment. It is suggested that the foraminifers in the Sound are selective feeders, and their distribution is related to the distribution of the material upon which they feed.

TABLE 1.—*Chi-square analyses of sample pairs. The actual number of individuals observed is columned under (o). The expected frequency (e) of a species in a sample is calculated by multiplying the sum of the species row by the sum of the sample column and dividing by the total sum of both samples. Chi-square is calculated by the formula* $\sum_{\text{cells}} \frac{(o-e)^2}{e}$.

SAMPLE PAIR 10-10′

Total Population

	10 o	10′ o	Total	10 e	10′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	671	873	1,544	739.12	804.81	6.28	5.78
2	266	163	429	205.38	223.62	17.89	16.43
3	43	31	74	35.43	38.57	1.62	1.48
Totals	980	1,067	2,047	979.93	1,067.00	25.79	23.69

$\chi_2^2 = 49.48$ *

Live Population

	10 o	10′ o	Total	10 e	10′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	288	484	772	364.71	407.29	16.13	14.45
2	203	71	274	129.44	144.56	41.80	37.43
3	23	19	42	19.84	22.16	0.50	0.45
Totals	514	574	1,088	513.99	574.01	58.43	52.33

$\chi_2^2 = 110.76$ *

SAMPLE PAIR 14-14′

Total Population

	14 o	14′ o	Total	14 e	14′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	1,678	2,664	4,322	1,639.21	2,702.22	0.92	0.54
2	9	117	126	47.79	78.78	31.82	18.54
Totals	1,687	2,781	4,448	1,687.00	2,781.00	32.74	19.08

$\chi_1^2 = 51.82$ *

* Significant at the 95 percent level.

Live Population

	14 o	14′ o	Total	14 e	14′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	404	191	595	389.18	205.82	0.56	1.07
2	29	38	67	43.82	23.18	5.01	9.48
Totals	433	229	662	433.00	229.00	5.57	10.55

$\chi_1^2 = 16.12$ *

TABLE 1—*Continued*

SAMPLE PAIR 24-24′

Total Population

	24 o	24′ o	Total	24 e	24′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	91	11	102	83.90	18.10	0.60	2.78
2	103	0	103	84.72	18.28	3.94	18.28
3	47	41	88	72.38	15.62	8.90	41.24
Totals	241	52	293	241.00	52.00	13.44	62.30

$\chi^2_2 = 75.74$ *

Live Population

	24 o	24′ o	Total	24 e	24′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	10	3	13	9.39	3.60	0.04	0.10
2	42	0	42	30.35	11.65	4.47	11.65
3	34	30	64	46.25	17.75	3.24	8.45
Totals	86	33	119	85.99	33.00	7.75	20.20

$\chi^2_2 = 27.95$ *

* Significant at the 95 percent level.

SAMPLE PAIR 59-59′

Total Population

	59 o	59′ o	Total	59 e	59′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	197	195	392	190.93	201.07	0.19	0.18
2	9	10	19	9.25	9.74	0.01	0.01
3	20	33	53	25.81	27.18	1.31	1.25
Totals	226	238	464	225.99	237.99	1.51	1.44

$\chi^2_2 = 2.95$

Live Population

	59 o	59′ o	Total	59 e	59′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	63	61	124	58.66	65.34	0.32	0.29
3	16	27	43	20.34	22.66	0.93	0.83
Totals	79	88	167	79.00	88.00	1.25	1.12

$\chi^2_1 = 2.37$

TABLE 1—*Continued*

SAMPLE PAIR 102-102′

Total Population

	102 o	102′ o	Total	102 e	102′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	187	151	338	172.73	165.26	1.18	1.23
2	44	65	109	55.70	53.29	2.46	2.57
3	0	5	5	2.56	2.44	2.56	2.68
Totals	231	221	452	230.99	220.99	6.20	6.48

$\chi_2^2 = 12.68$ *

* Significant at the 95 percent level.

Live Population

	102 o	102′ o	Total	102 e	102′ e
1	3	3	6	1.56	4.43
2	3	9	12	3.13	8.87
3	0	5	5	1.30	3.70
Totals	6	17	23	5.99	17.00

SAMPLE PAIR 104-104′

Total Population

	104 o	104′ o	Total	104 e	104′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	80	38	118	75.63	42.37	0.25	0.45
2	60	37	97	62.17	34.83	0.08	0.20
3	1	4	5	3.20	1.80	1.51	3.20
Totals	141	79	220	141.00	79.00	1.84	3.85

$\chi_2^2 = 5.69$

Live Population

	104 o	104′ o	Total	104 e	104′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	2	3	5	2.08	2.92	0.00	0.00
2	2	0	2	0.83	1.17		
3	1	4	5	2.08	2.92	0.56	0.40
Totals	5	7	12	4.99	7.01	0.56	0.40

$\chi_1^2 = 0.96$

TABLE 1—*Continued*

SAMPLE PAIR 106-106′

Total Population

	106 o	106′ o	Total	106 e	106′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	16	13	29	17.61	11.39	0.15	0.23
2	7	5	12	7.28	4.71	0.01	0.02
3	11	4	15	9.11	5.89	0.39	0.61
Totals	34	22	56	34.00	21.99	0.55	0.86

$\chi^2_2 = 1.41$

Live Population

	106 o	106′ o	Total	106 e	106′ e
1	2	1	3	2.12	0.88
2	2	1	3	2.12	0.88
3	8	3	11	7.76	3.24
Totals	12	5	17	12.00	5.00

SAMPLE PAIR 108-108′

Total Population

	108 o	108′ o	Total	108 e	108′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	49	37	86	40.00	46.00	2.02	1.76
2	19	31	50	23.26	26.74	0.78	0.68
3	12	24	36	16.74	19.26	1.34	1.17
Totals	80	92	172	80.00	92.00	4.14	3.61

$\chi^2_2 = 7.75$ *

* Significant at the 95 percent level.

Live Population

	108 o	108′ o	Total	108 e	108′ e
1	2	0	2	0.88	1.13
2	2	2	4	1.75	2.25
3	10	16	26	11.38	14.62
Totals	14	18	32	14.01	18.00

TABLE 1—*Continued*

SAMPLE PAIR 125-125′

Total Population

	125 o	125′ o	Total	125 e	125′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	124	128	252	127.12	124.88	0.08	0.08
2	21	8	29	14.63	14.37	2.77	2.82
3	25	31	56	28.25	27.75	0.37	0.38
Totals	170	167	337	170.00	167.00	3.22	3.28

$\chi^2_2 = 6.50$ *

Live Population

	125 o	125′ o	Total	125 e	125′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	12	14	26	10.33	15.67	0.27	0.18
2	1	2	3	1.19	1.81		
3	16	28	44	17.48	26.52	0.12	0.08
Totals	29	44	73	29.00	44.00	0.39	0.26

$\chi^2_1 = 0.65$

* Significant at the 95 percent level.

SAMPLE PAIR 129-129′

Total Population

	129 o	129′ o	Total	129 e	129′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	11	37	48	16.55	31.45	1.25	0.98
2	4	17	21	7.24	13.76	1.45	0.76
3	25	22	47	16.21	30.79	4.76	8.79
Totals	40	76	116	40.00	76.00	7.46	10.53

$\chi^2_2 = 17.99$ *

Live Population

	129 o	129′ o	Total	129 e	129′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	2	3	5	2.07	2.93	0.00	0.00
2	0	4	4	1.67	2.34		
3	15	17	32	13.27	18.73	0.22	0.16
Totals	17	24	41	17.01	24.00	0.22	0.16

$\chi^2_1 = 0.38$

TABLE 1—*Continued*

SAMPLE PAIR 131-131′

	131 o	131′ o	Total	131 e	131′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	55	69	124	61.73	62.27	0.73	0.73
2	42	27	69	34.35	34.65	1.70	1.69
3	16	18	34	16.92	17.07	0.05	0.05
Totals	113	114	227	113.00	113.99	2.48	2.47

$\chi^2_2 = 4.95$

* Significant at the 95 percent level.

Live Population

	131 o	131′ o	Total	131 e	131′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	11	13	24	12.00	12.00	0.08	0.08
2	5	1	6	3.00	3.00	1.33	1.33
3	7	9	16	8.00	8.00	0.12	0.12
Totals	23	23	46	23.00	23.00	1.53	1.53

$\chi^2_2 = 3.06$

SAMPLE PAIR 133-133′

Total Population

	133 o	133′ o	Total	133 e	133′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	202	161	363	201.74	161.26	0.00	0.00
2	101	78	179	99.48	79.52	0.02	0.03
3	1	4	5	2.78	2.22	1.14	1.43
Totals	304	243	547	304.00	243.00	1.16	1.46

$\chi^2_2 = 2.62$

Live Population

	133 o	133′ o	Total	133 e	133′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
1	3	4	7	2.67	4.33	0.04	0.02
2	4	8	12	4.57	7.43	0.07	0.04
3	1	1	2	0.76	1.24		
Totals	8	13	21	8.00	13.00	0.11	0.06

$\chi^2_1 = 0.17$

TABLE 2.—*Binomial test on numbers of individuals in sample pairs.*

Sample pair	Live No.	x	Total No.	x	Vol. ml.	Live No. corrected	x	Total No. corrected	x
10	527	−1.88*	1002	2.69	11.0	479	−1.04*	911	−1.56*
10′	591		1127		11.5	513		890	
14	441	8.01	1786	14.91	12.1	364	8.18	1476	−10.21
14′	234		2796		13.4	175		2086	
24	95	5.24	258	11.15	18.3	52	3.19	141	7.49
24′	36		60		14.6	25		41	
59	86	−0.74*	269	−0.51*	13.5	64	−0.52*	199	−0.30*
59′	97		282		13.7	71		206	
102	7	−2.16	276	1.40*	15.5	5	−1.83*	178	0.32*
102′	19		245		14.2	14		173	
104	6	−0.75*	165	3.05	17.2	3	−0.67*	96	1.85*
104′	10		115		15.8	6		73	
106	16	2.08	51	2.57	14.8	11	2.06	34	2.68
106′	7		29		17.7	4		16	
108	18	−0.16*	99	−0.28*	19.7	9	0.00*	50	−0.39*
108′	20		104		19.0	10		55	
125	48	−1.42*	205	−0.24*	11.2	43	−0.52*	183	1.18*
125′	64		211		13.0	49		162	
129	26	−2.14	57	−4.15	14.8	18	−0.77*	38	−2.03
129′	45		112		18.9	24		59	
131	28	−0.26*	127	−0.19*	18.3	15	−0.68*	69	−1.21*
131′	31		131		15.4	20		85	
133	8	1.25*	345	3.32	13.6	6	−0.97*	254	2.93
133′	15		264		13.7	11		193	

* Significant at the 95 percent level.

TABLE 3.—*Distribution of the Foraminifera in percent of the living and total populations. Frequencies of less than 1 percent are tabulated to the nearest tenth of a percent. X denotes a frequency of less than one-tenth of a percent.*

TRAVERSE	1				2															
STATIONS	110		111		114		116		117		118		119		120		121		122	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii																				
Ammoscolaria cf. fluvialis																				
Bolivina variabilis																				
Buccella frigida	31	35	4	11	9	8	2	6		21	1	10	5	29	6	25	54	21	7	7
Cornuspira planorbis						4														
Eggerella advena	34	20	22	11	18	3	68	26	59	27	92	63	60	27	19	8	8	1	3	1
Elphidium clavatum	11	29	44	55	54	70	8	52	6	27	2	14	12	30	73	62	31	67	80	83
E. pauciloculum	6	5	11	11	18	10	4	2	12	9		2	2	4		2	8	4	7	4
E. tisburyensis																				
E. varium	6	4	11	5			6	6	6	7	1	3	5	3	1	3		6		2
Fissurina laevigata		.8									2	1	5	2						
Nonionella atlantica																				
Poroeponides lateralis																				
Pseudopolymorphina novangliae				1		1						1								
Quinqueloculina seminula						1		3	6	2			2	1						
Q. seminula var. jugosa																				
Reophax dentaliniformis	3	2	4	1			4	2	12	7	1	1	8	3				.5		
R. nana	3	2																		
Trochammina compacta																				
T. inflata																				
T. lobata																				
T. squamata																				
Virgulina fusiformis																				
Unknown	6	4	4	3		1	6	3			1	1				.5		.5	3	2
TOTALS	35	132	27	72	11	70	47	149	17	56	80	178	40	136	67	185	·13	198	30	149
DEPTH IN METERS	28		19		17		28		34		37		29		25		23		18	
VOL. IN ML.	18.0		17.4		18.5		19.2		16.9		17.7		15.3		18.6		19.4		14.7	

TRAVERSE	2																			
STATIONS	123		124		125		125'		112		113		14		14'		15		98a	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii	11	5	2	2															3	5
Ammoscolaria cf. fluvialis																				.9
Bolivina variabilis							2	.9												
Buccella frigida	10	11	6	5	2	10	3	4	1	6	.6	3	7	5	16	4	4	3	.7	2
Cornuspira planorbis					10	3														
Eggerella advena	3	.9		.1	33	12	44	15									3	2		
Elphidium clavatum	60	68	87	89	25	60	22	61	98	92	99	94	92	94	82	95	76	61	90	84
E. pauciloculum	5	5	1	1	19	7	8	9	.3	2		2		X	1	1				.3
E. tisburyensis		3																	3	3
E. varium	5	4	3	2							.2	1		.2			4	3		1
Fissurina laevigata	3	.9	.2	X																
Nonionella atlantica																				
Poroeponides lateralis																				
Pseudopolymorphina novangliae				.1		.5		.5								X				
Quinqueloculina seminula				X		2	3	3												
Q. seminula var. jugosa																				
Reophax dentaliniformis	1	.9	.2	.2						X		X					1	1		
R. nana																				
Trochammina compacta																				
T. inflata																				
T. lobata																				
T. squamata					2	.5	8	3												.3
Virgulina fusiformis							2	.5												
Unknown	1	.5	·	X	8	3	9	3		X		.1	2	1	X	X	11	29	3	4
TOTALS	73	203	386	1804	48	205	64	211	756	2148	478	2301	441	1786	234	2796	72	93	534	1299
DEPTH IN METERS	15		14		16		16		14		15		10		10		15		4	
VOL. IN ML.	14.0		16.6		11.2		13.0		17.4		18.9		12.1		13.4		16.6		14.0	

TABLE 3—*Continued*

TRAVERSE	3																										3													
STATIONS	2		3		4		5		6		7		8		9		10		10'		11		12		13		1		1'		33		32		31		30		29	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii																																								
Ammoscalaria cf. fluvialis																																								
Bolivina variabilis											1		1	1					1	1																				
Buccella frigida			8	25		53	33	67	33	71	1	26	10	33	52	37	39	27	12	14	2	5	8	4	4	2					30	9	14	11	1	5		26	9	29
Cornuspira planorbis														1																										
Eggerella advena	100	50					17	2	44	11	64	34	50	29	31	26	4	4	3	3	.8	.3		.1									14	2	95	80	97	32	88	48
Elphidium clavatum			62	52		20	17	29		13		8		12	4	36	55	67	82	77	97	91	88	94	88	92					70	90	59	78	1	13	-	29	1	17
E. pauciloculum			8	3	60	20	28	7	22	5	31	27	29	18	1	1		.3		.2	.2	.1	2		2	1						.2								
E. tisburyensis																																		1						
E. varium			23	20	40	7	6	2		1	2	4	7	4	2	3	1	.7		2		.6		.7		1						.3	3	4				5	1	4
Fissurina laevigata														1		.1																								
Nonionella atlantica																																								
Poroeponides lateralis																																								
Pseudopolymorphina novangliae																																								
Quinqueloculina seminula																																								
Q. seminula var. jugosa																											100	50												
Reophax dentaliniformis													1	1	5	2	2	1	1	1													3	.4						
R. nana														1		1																								
Trochammina compacta																																								
T. inflata																																								
T. lobata																																								
T. squamata																												50	100	100										
Virgulina fusiformis																																								
Unknown		50						2							7	2		1	2	2	.2	.9	2	.9	6	4						.3	7	5	3	3	3	8	1	2
TOTALS	2	4	13	73	5	30	18	120	9	109	85	200	211	992	249	762	527	1002	591	1127	531	3415	680	2157	146	324	1	2	3	3	20	638	29	288	77	101	35	111	93	169
DEPTH IN METERS	19		40		39		35		30		26		22		16		14		14		11		10		9		14		14		24		30		39		36		31	
VOL. IN ML.	25.1				7.1		12.6		8.1		7.2		9.8		7.5		11.0		11.5		10.8		9.6		12.4		4.9		8.6		17.6		14.6		17.5		14.4		18.4	

TABLE 3—*Continued*

TRAVERSE	3																		3																					
STATIONS	28		27		26		25		24		24'		23		22		13		71		70		69		68		66		65		64		63		62		61		60	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii																																								
Ammoscalaria cf. fluvialis																																								
Bolivina variabilis																															2	1	5	1						
Buccella frigida		12	2	2					44	40			53	34	19	11	1	3	4	16	8	27		18			6	28	8	29	25	30	24	30		48	50	48	14	6
Cornuspira planorbis																																								
Eggerella advena	97	82	95	94	94	92	91	91	36	18	83	68	11	7	5	.6		X	44	14	67	30	94	50	98	98	77	30	80	24	53	19	56	18		3	14	13	3	1
Elphidium clavatum	2	3	1	1	2	3	4	3	10	35	8	18	9	48	68	86	95	97	30	55	8.	25	2	27			5	26	2	30	5	37	8	42		26	23	29	70	89
E. pauciloculum																	.3	.2	4	2		2					2	1	2	1	3	2		.9					1	.2
E. tisburyensis																																								
E. varium									2	1					2	7		.1	7	6		7		2			5	12	6	8	1	6	6	6		10			1	.5
Fissurina laevigata																			4	.9																				
Nonionella atlantica																																								
Poroeponides lateralis																																								
Pseudopolymorphina novangliae																																							1	.5
Quinqueloculina seminula																																								
Q. seminula var. jugosa																																								
Reophax dentaliniformis			.4	.7					6	5	3	10	15	8	3							2		.9				.3		.5			2	.4	33	6	4	3		.2
R. nana					.5	.9	2	2			3	2						X																						
Trochammina compacta																				.9																				
T. inflata																																								
T. lobata																																								
T. squamata		1	.4	.7		.5																													33	3				
Virgulina fusiformis																											2	.7	3	1										
Unknown	2	3	1	1	4	3	3	3	1	.4	3	2	6	3	3		4		7	6	17	7	4	3	2	2	5	2		2	11	5		.4	33	3	9	6	9	2
TOTALS	13	75	21	266	18	217	165	173	95	258	36	60	124	320	149	1453	395	7226	27	109	12	44	48	107	57	65	108	301	65	192	93	305	63	229	3	31	22	31	86	393
DEPTH IN METERS	29		27		22		19		18		18		15		13		10		42		40		28		30		28		27		23		20		18		18		13	
VOL. IN ML.	11.6		15.7		19.0		20.3		18.3		14.6		18.4		14.6		14.7		30.2		15.4		18.0		16.1		14.2		18.8		15.6		17.4		9.6		15.7		13.6	

TABLE 3—*Continued*

TRAVERSE	3		3																												3									
STATIONS	13		84		83		82		81		80		79		78		77		76		75		74		74a		73		13		97		96		95		94		93	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii																																								
Ammoscalaria cf. fluvialis																																								
Bolivina variabilis															2	.5			2	.8					.6	.1														
Buccella frigida	4	3		11	3	3			5	13	15	31	6	44	20	28	26	30	30	33	52	43	49	26	56	29	8	5		.7	52	8	3	5		4	5	16	10	19
Cornuspira planorbis																																								
Eggerella advena	.3	.1	30	3	93	94	100	100	84	73	58	32	83	46	59	20	50	15	53	26	31	13	10	4	4	1		X	4	1			37	30	74	61	73	52	39	25
Elphidium clavatum	88	92	30	72						4	5	24	4	5	4	40	12	46	7	27		31	20	56	35	61	89	94	83	94	43	84	40	40	24	29	8	21	28	32
E. pauciloculum	3	2		.8							7	3			2	2	3	2	.9	.8	3	2	4	1	.6	3	.9	.3	4	1		2	10	10			3	4	12	13
E. tisburyensis																								.2																
E. varium			30	10	3	3				2	10	9			2	5	8	7	4	10	3	7	12	9	2	6		.6	2	.9	4	4	.8	4		3			2	3
Fissurina laevigata	1	.4													2	.5			.9	.4	7	2			1	.4														
Nonionella atlantica																																								
Porosponides lateralis																																								
Pseudopolymorphina novangliae				'																																				
Quinqueloculina seminula																										.1														
Q. seminula var. jugosa																																								
Reophax dentaliniformis			10	2					5	4			2	2		.5			2	1						1		X					.8				5	4		.6
R. nana														.8								.8		.4																
Trochammina compacta																																								
T. inflata																																								
T. lobata																																								
T. squamata				1																				.2					.6	.2									1	.6
Virgulina fusiformis	.3	.1																																					1	.6
Unknown	4	2		1					5	4	5	2	4	2	8	3		.7		1	3	2	6	3	1	.9	2	X	7	2		1	8	10	3	4	5	4	8	6
TOTALS	368	990	10	254	29	37	12	14	37	52	73	173	48	125	49	191	64	270	112	260	29	127	82	440	170	688	116	4634	157	575	23	267	124	166	72	107	37	56	104	181
DEPTH IN METERS	10		26		41		37		28		24		26		23		21		19		18		15		15		13		9		21		22		37		40		35	
VOL. IN ML.	16.6		17.0		17.4		17.4		15.4		15.0		16.7		15.0		14.9		16.4		14.4		13.6		14.0		17.4		14.9		15.5		13.9		14.9		14.9		14.6	

TABLE 3—*Continued*

TRAVERSE	3																3																							
STATIONS	92		91		90		89		88		87		86		13		104		109a		109b		109c		108		108'		107		107a		107b		107c		106		106'	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii																																								
Ammoscalaria cf. fluvialis																																								
Bolivina variabilis													.4	.2																										1
Buccella frigida	3	6	12	16	7	26	24	30	32	36	41	40	22	23	1	.8	2	16	2	13	2	16	12	20	11	19	10	30		24	20	28	33	22	25	23	12	22	20	22
Cornuspira planorbis																																								
Eggerella advena	49	33	29	25	49	27	32	19	22	9	28	35	6	4			92	40	88	43	85	43	82	46	56	12	80	23	64	7	52	12	17	1	25	1	50	22	40	7
Elphidium clavatum	30	32	39	36	4	19	4	21	16	35	12	12	51	56	94	96	4	28	5	36	8	35	6	27	11	49		36	18	61	8	49	50	70	25	69	12	31	20	60
E. pauciloculum	10	8	10	11	15	12	21	18	15	7			11	8	1	.9		6	2	3		3		4		7		2		1	12	3		2	12	4	6	14		6
E. tisburyensis																																								
E. varium					4	5	2	4	8	9				5	.4	.3		4			2	3		1	11	7		4		4	4	4		1		2				
Fissurina laevigata			.6												.4	.2																							10	1
Nonionella atlantica																																						8		
Poroeponides lateralis																																								
Pseudopolymorphina novangliae																																								
Quinqueloculina seminula																	2	2							6	3						.7								
Q. seminula var. jugosa																																								
Reophax dentaliniformis	1	.8	.6	.4	1	2							.4	.2				2						1		1			9	.7				1						
R. nana													.4	.2															9	.7										
Trochammina compacta																																								
T. inflata																																								
T. lobata																																								
T. squamata														.2	.4	.1			2	1																			10	1
Virgulina fusiformis	1	.8	1	.9		.7																			6	1	10	2	9	.7	4	.7			12	.5	19	6		
Unknown	4	3	12	9	17	9	16	8	6	3	19	12	8	4	3	1		4		3	2	.9		1				4		.7		1		2		1		16		
TOTALS	69	129	160	222	135	268	131	279	99	317	32	48	144	391	285	922	53	133	41	91	40	103	34	81	18	99	20	104	11	140	25	145	6	201	8	192	16	51	10	68
DEPTH IN METERS	32		28		25		22		20		18		16		11		42		42		42		42		41		41		35		35		35		35		31		31	
VOL. IN ML.	18.0		14.1		19.7		15.0		17.6		17.5		15.5		4.8		16.4		18.1		18.2		19.9		19.7		19.0		13.5		14.4		19.7		18.9		14.8		17.7	

TABLE 3—*Continued*

TRAVERSE	3																											
STATIONS	105		104		104'		103		103a		103b		103c		102		102'		101		101a		101b		100		13	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii												.5																
Ammoscalaria cf. fluvialis																												
Bolivina variabilis																												
Buccella frigida		25	33	36		32	19	29	48	41	37	24	44	23	43	25	47	26	38	13	8	11	19	14	.9	2	1	2
Cornuspira planorbis																												
Eggerella advena	73	12	17	.6	40	3	54	14	20	3		.5	6	1			26	2				2					4	.7
Elphidium clavatum	27	56	33	48	30	33	16	47	12	42	37	59	31	69	43	68	16	62	56	81	85	81	66	80	98	96	91	96
E. pauciloculum		1		7	10	13			8	3	5	6	6	3		.7	5	2		2		.9		.8	.5	.2	1	.8
E. tisburyensis																												
E. varium		4		6	10	12	3	6	4	7		4		2	14	6	5	7	6	3		5	.6	4		1		
Fissurina laevigata					10	2		.5		1		1								.2							1	.3
Nonionella atlantica																												
Poroeponides lateralis																												
Pseudopolymorphina novangliae																									.5	.1	1	.3
Quinqueloculina seminula																												
Q. seminula var. jugosa																												
Reophax dentaliniformis		1						.5	4	.7	5	1						.4		.2		.5				.1		
R. nana						.9																						
Trochammina compacta																												
T. inflata																												
T. lobata																												
T. squamata																										.1		
Virgulina fusiformis							5	1				.5																
Unknown			17	1		3	3	1	4	2	16	3	12	2		.4		1		.6	8	.8	9	1				.2
TOTALS	11	75	6	165	10	115	37	191	25	270	19	213	16	176	7	276	19	245	16	493	13	651	32	520	212	822	91	590
DEPTH IN METERS	27		24		24		21		21		21		21		18		18		16		16		16		13		11	
VOL. IN ML.	15.0		17.2		15.8		18.4		17.1		18.4		18.7		15.5		14.2		18.7		17.8		11.2		11.3		7.8	

TRAVERSE	3											
STATIONS	126		127		128		129		129'		130	
	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii									2	.9		
Ammoscalaria cf. fluvialis												
Bolivina variabilis												
Buccella frigida		23	7	20	31	21		7	9	15		15
Cornuspira planorbis												
Eggerella advena	43	15	78	46	44	16	58	44	38	20	29	14
Elphidium clavatum	21	46	11	30	19	51	8	19	7	33	56	47
E. pauciloculum		1				4		4	2	3		7
E. tisburyensis												
E. varium	7	5	4	4		5	8	7		4	5	7
Fissurina laevigata							4	2	13	5		
Nonionella atlantica												
Poroeponides lateralis												
Pseudopolymorphina novangliae	7	1										
Quinqueloculina seminula	7	1								.9		
Q. seminula var. jugosa												
Reophax dentaliniformis	14	2										1
R. nana										.9		
Trochammina compacta												
T. inflata												
T. lobata												
T. squamata												
Virgulina fusiformis					6	1	19	9	29	12	10	4
Unknown		5				1	4	9		6		4
TOTALS	14	84	28	80	16	76	26	57	45	112	41	95
DEPTH IN METERS	28		35		43		32		32		30	
VOL. IN ML.	20.8		18.9		19.2		14.8		18.9		15.2	

TABLE 3—*Continued*

TRAVERSE	3																	
STATIONS	131		131'		132		133		133'		134		135		13		13'	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii																		
Ammoscalaria cf. fluvialis																		
Bolivina variabilis						.5												
Buccella frigida	18	33	3	21	47	35	50	29	53	30	20	18	3	6	1	2	21	14
Cornuspira planorbis								.3										
Eggerella advena	25	12	29	14	29	5	12	.3	7	2		1	.3	.1	1	.8		
Elphidium clavatum	39	43	42	53	12	46	38	59	27	61	80	72	97	92	90	90	80	84
E. pauciloculum	4	3	3	2	12	5		1		2		2		1	4	4		
E. tisburyensis																		
E. varium		2	6	6		7		8	7	3		6		1				3
Fissurina laevigata	11	2	3	2				.3										
Nonionella atlantica																		
Poroeponides lateralis																		
Pseudopolymorphina novangliae																		
Quinqueloculina seminula								.3										
Q. seminula var. jugosa																		
Reophax dentaliniformis						1		.9	7	3								
R. nana	4	.8	3	.8				.3										
Trochammina compacta																		
T. inflata																		
T. lobata																		
T. squamata								.6		.4						.8		
Virgulina fusiformis				2														
Unknown		3				1		.3						.1		2		
TOTALS	28	127	31	131	17	208	8	345	15	264	10	78	287	802	71	121	19	37
DEPTH IN METERS	26		26		23		20		20		16		14		10		10	
VOL. IN ML.	17.3		15.4		17.0		13.6		13.7		15.4		12.0		18.3		5.8	

TRAVERSE	4																					
STATIONS	48		47		46		45		44		42		41		40		39		38		37	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii				1							1	.4			7	3	2	2				.6
Ammoscalaria cf. fluvialis																						
Bolivina variabilis											1	.4					2	.5				
Buccella frigida	25	6	44	10	35	12	29	13	36	18	21	15	12	10	14	10	2	10	36	20		12
Cornuspira planorbis		2		1																		
Eggerella advena	33	10		.4		.3	.9	.5	2	.7	3	4	71	60	26	8	28	12	8	3		
Elphidium clavatum		46	22	72	27	70	58	72	46	68	46	62	6	23	28	42	18	53	45	66	62	71
E. pauciloculum		7		5	4	2	2	4		1	1	4			3	1	4	4	3	4	25	10
E. tisburyensis																						
E. varium		3		4	19	10		4	3	7	4	5			4	1	2	4	3	4		3
Fissurina laevigata				.4					3	.5	6	2			1	.3						
Nonionella atlantica		.9																				
Poroeponides lateralis								.2				.4										
Pseudopolymorphina novangliae				.4																		
Quinqueloculina seminula				.4													2	2				1
Q. seminula var. jugosa																						
Reophax dentaliniformis						1	2	1	3	.5	10	4			1	.9		.5	1	.4		
R. nana																						
Trochammina compacta	8	.9																				
T. inflata																						
T. lobata		.9																				
T. squamata	8	12	22	4		1	3	4		1		.1	6	3				.5	3	.8		
Virgulina fusiformis				.4		.3			.9	.2	4	.1			8	2	32	8				
Unknown	25	12		.4	15	3	6	2	7	3	3	1	6	3		1	9	3	3	2	12	.6
TOTALS	12	104	9	234	26	349	107	616	107	646	72	281	17	30	76	342	57	214	76	249	8	153
DEPTH IN METERS	34		33		30		30		3,		32		32		32		32		30		23	
VOL. IN ML.			16.7		16.4		13.7		17.2		16.4		17.2		18.6		14.6		12.2		14.6	

TABLE 3—*Continued*

TRAVERSE	4						5																																	
STATIONS	36		35		34		51		54		55		57		59		59'		50		16		17		18		19		19'		20		13							
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii																		.4					.5	.2																
Ammoscalaria cf. fluvialis																																								
Bolivina variabilis																																								
Buccella frigida	7	8		7	7	4						14				3		4	2	4	1	2	.9	1	.7	.8	1	2	1	3	2	5	1	1						
Cornuspira planorbis																1																								
Eggerella advena	1	1																	3	2													6	1						
Elphidium clavatum	70	86	100	90	75	93						43		100	73	73	63	69	74	79	92	91	98	98	99	99	98	97	98	93	70	94	84	94						
E. pauciloculum				.2	3	.3									5	8		7	6	4		2		.4		x		.8	.5	3	2	1	4	1						
E. tisburyensis															19	7	28	12										X		.1										
E. varium	19	4		2		.7						14					1	3	2	1																				
Fissurina laevigata															1	.4	1	.4																						
Nonionella atlantica																																								
Poroeponides lateralis									100	100																														
Pseudopolymorphina novangliae															1	.4																								
Quinqueloculina seminula																4	1	.7		.6		1								X										
Q. seminula var. jugosa																																.1								
Reophax dentaliniformis	1	.3																																						
R. nana																																								
Trochammina compacta							33	6																																
T. inflata																.4																								
T. lobata																																								
T. squamata				.1		.4	100	94			100	28				1		1	2	1														.1						
Virgulina fusiformis															1	.4																								
Unknown	1	.3		.2	14	2										3	6	4	11	7	7	4	.9	.4	.5	X	.6	X	1	X	26	.8	4	2						
TOTALS	67	336	6	996	65	588	15	18	1	1	1	7		1	86	269	97	282	62	163	102	306	232	4716	427	25171	681	10573	417	13481	61	2848	137	674						
DEPTH IN METERS	19		17		16		12		37		37		25		3		3		15		12		5		7		3		3		4		10							
VOL. IN ML.	19.5		14.6		14.0		4.8		4.1		17.8		10.0		13.5		13.7		2.6		13.2		12.9		20.4		13.8		14.8		18.3		11.4							

TABLE 4.—*Grouping of seasonal stations into 13 grand stations.*

Grand stations	Station							
1	1							
2	2	33	32	84	96	126		
3	3	31	70	71	82	83	95	109	127
4	4	30	69	81	93	94	108	128	
5	5	29	68	80	92	107	129		
6	6	28	66	79	91	106	130		
7	7	27	65	78	90	105	131		
8	8	26	64	77	89	104	132		
9	9	25	63	76	88	103			
10	10	24	62	75	87	102	133		
11	11	23	61	74	86	101	134		
12	12	22	60	73	100	135			
13	13								

TABLE 5.—*Wilcoxon test on stations chosen at random in the* E. advena *zone in March 1962 and June 1962.*

Total Living Population

Mar. 1962	$n=5$, $m=5$	$R_m=27$	June 1962	$n=5$, $m=5$	$R_m=23$

Numbers of Living *E. clavatum*

Mar. 1962	$n=5$, $m=5$	$R_m=24$	June 1962	$n=5$, $m=5$	$R_m=22$

Numbers of Living *B. frigida*

Mar. 1962	$n=5$, $m=5$	$R_m=25$	June 1962	$n=5$, $m=5$	$R_m=20$

Numbers of Living *E. advena*

Mar. 1962	$n=5$, $m=5$	$R_m=26$	June 1962	$n=5$, $m=5$	$R_m=25$

TABLE 6.—*Wilcoxon test on number of living* E. advena *in* E. advena *zone.*

June 1961	$m=8$	$R_m=48$*	Jan. 1962	$m=8$	$R_m=93$
Oct. 1961 †	$n=8$		Mar. 1962	$n=10$	
June 1961	$n=8$	$R_m=58$	Jan. 1962	$m=8$	$R_m=82$
Jan. 1962	$m=8$		June 1962	$n=10$	
June 1961	$m=8$	$R_m=68$	Jan. 1962 †	$n=8$	$R_m=36$*
Mar. 1962	$n=10$		Sept. 1962	$m=7$	
June 1961	$m=8$	$R_m=65$	Jan. 1962 †	$n=8$	$R_m=34$*
June 1962	$n=10$		Nov. 1962	$m=7$	
June 1961	$n=8$	$R_m=59$	Mar. 1962	$n=10$	$R_m=87$
Sept. 1962	$m=7$		June 1962	$m=10$	
June 1961	$n=8$	$R_m=63$	Mar. 1962	$n=10$	$R_m=45$
Nov. 1962	$m=7$		Sept. 1962	$m=7$	
Oct. 1961	$n=8$	$R_m=85$	Mar. 1962 †	$n=10$	$R_m=41$*
Jan. 1962	$m=8$		Nov. 1962	$m=7$	
Oct. 1961 †	$m=8$	$R_m=110$*	June 1962 †	$n=10$	$R_m=38$*
Mar. 1962	$n=10$		Sept. 1962	$m=7$	
Oct. 1961 †	$m=8$	$R_m=102$*	June 1962 †	$n=10$	$R_m=32$*
June 1962	$n=10$		Nov. 1962	$m=7$	
Oct. 1961 †	$n=8$	$R_m=30$*	Sept. 1962	$n=7$	$R_m=52$
Sept. 1962	$m=7$		Nov. 1962	$m=7$	
Oct. 1961 †	$n=8$	$R_m=28$*			
Nov. 1962	$m=7$				

* Significant at the 95 percent level.
† Greater number of living individuals.

TABLE 7.—*Wilcoxon test on numbers of living* E. clavatum *in* E. advena *zone.*

June 1962 †	$n=10$	$R_m=32$*	June 1962 †	$n=10$	$R_m=66$*
Sept. 1962	$m=7$		Mar. 1962	$m=10$	
June 1962 †	$n=10$	$R_m=39$*	Nov. 1962	$m=7$	$R_m=64$
Nov. 1962	$m=7$		Jan. 1962	$n=8$	

* Significant at the 95 percent level.
† Greater number of living individuals.

TABLE 8.—*Wilcoxon test on numbers of living* B. frigida *in* E. advena *zone.*

June 1961	$n=8$	$R_m=61$	June 1962 †	$n=10$	$R_m=40$*
Oct. 1961	$m=8$		Sept. 1962	$m=10$	
June 1961	$n=8$	$R_m=55$	June 1962	$n=10$	$R_m=97$
Jan. 1962	$m=8$		Mar. 1962	$m=10$	
June 1961	$m=8$	$R_m=73$	June 1962	$n=10$	$R_m=62$
Mar. 1962	$n=10$		Jan. 1962	$m=8$	
June 1961	$m=8$	$R_m=64$	June 1962	$n=10$	$R_m=57$
June 1962	$n=10$		Oct. 1961	$m=8$	
June 1961	$n=8$	$R_m=52$	June 1962 †	$n=10$	$R_m=42$*
Sept. 1962	$m=7$		Nov. 1962	$m=7$	

* Significant at the 95 percent level.
† Greater number of living individuals.

TABLE 9.—*Wilcoxon test on numbers of living individuals of all species in the* E. advena *zone.*

June 1961	$n=8$	$R_m=60$	Oct. 1961	$m=8$	$R_m=81$
Jan. 1962	$m=8$		June 1962	$n=10$	
June 1961	$m=8$	$R_m=69$	June 1961	$m=8$	$R_m=60$
March 1962	$n=10$		June 1962	$n=10$	
June 1961	$n=8$	$R_m=53$	June 1962 †	$n=10$	$R_m=73$*
Sept. 1962	$m=7$		March 1962	$m=10$	
June 1961	$m=8$	$R_m=53$	June 1962 †	$n=10$	$R_m=32$*
Oct. 1961	$n=8$		Sept. 1962	$m=7$	
Oct. 1961 †	$n=8$	$R_m=51$*	June 1962	$n=10$	$R_m=54$
Jan. 1962	$m=8$		Jan. 1962	$m=8$	

* Significant at the 95 percent level.
† Greater number of living individuals.

TABLE 10.—*Numbers of individuals in samples from short cores.*

TRAVERSE	3																																							
STATIONS	74		74a		101		101a		101b		103		103a		103b		103c		107		107a		107b		107c		109		109a		109b		109c							
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Ammonia beccarii																1																								
Ammoscalaria cf. fluvialis																																								
Bolivina variabilis			1	1																																				
Buccella frigida	40	113	95	202	6	65	1	70	6	71	7	56	12	111	7	51	7	41		34	5	41	2	45	2	45	1	21	1	12	1	16	4	16						
Cornuspira planorbis																																								
Eggerella advena	8	17	6	9				11			20	27	5	8		1	1	2	7	10	13	18	1	2	2	2	49	53	36	39	34	44	28	37						
Elphidium clavatum	16	248	60	421	9	398	11	525	21	415	6	90	3	113	7	125	5	121	2	86	2	71	3	140	2	132	2	37	2	33	3	36	2	22						
E. pauciloculum	3	5	1	20		10		6		4			2	8	1	13	1	5		2	3	4		4	1	7		8	1	3		3		3						
E. tisburyensis		1																																						
E. varium	10	41	3	44	1	15		31	2	23	1	12	1	20		8		3		5	1	6		3		3		5			1	3		1						
Fissurina laevigata			2	3		1						1		3		3																								
Nonionella atlantica																																								
Poroeponides lateralis																																								
Pseudopolymorphina novangliae																																								
Quinqueloculina seminula				1																		1					1	2												
Q. seminula var. jugosa																																								
Reophax dentaliniformis		2		9		1		3				1	1	2	1	3			1	1				3		2		2						1						
R. nana																			1	1																				
Trochammina compacta																																								
T. inflata																																								
T. lobata																																								
T. squamata		1																											1	1										
Virgulina fusiformis											2	2				1			1	1	1	1			1	1														
Unknown	5	12	2	6		3	1	5	3	7	1	2	1	5	3	7	2	4		1		2		4				5		3	1	1		1						
TOTALS	82	440	170	688	16	493	13	651	32	520	37	191	25	270	19	213	16	176	11	140	25	145	6	201	8	192	53	133	41	91	40	103	34	81						
DEPTH IN METERS	15		15		16		16		16		21		21		21		21		35		35		35		35		42		42		42		42							
VOL. IN ML.	13.6		14.0		18.7		17.8		11.2		18.4		17.1		18.4		18.7		13.5		14.4		19.7		18.9		16.4		18.1		18.2		19.9							

TABLE 11.—*Statistical parameters for the sediments in L.I.S.*

Station No.	Mdφ	Mφ	σφ	αφ	Niggli's classification
1a	0.8	0.8	0.5	0.00	sand
96a	1.5	2.6	1.8	0.61	silty sand
95a	1.4	3.4	3.0	0.66	sand
4a	5.2	5.3	3.3	0.03	clayey sand
5a	6.6	5.6	3.0	—0.33	clayey silt
6a	6.8	6.7	1.9	—0.05	clayey silt
7a	6.7	6.6	2.0	0.00	clayey silt
8a	5.9	6.1	2.5	0.08	clayey silt
9a	6.6	6.6	2.0	0.00	clayey silt
10a	6.7	6.5	2.1	—0.09	clayey silt
11a	6.5	6.4	2.2	—0.04	silt
12a	6.4	6.3	2.3	—0.04	clayey silt
13a	0.8	0.3	1.1	—0.45	sand
34a	5.9	6.4	2.2	0.23	silt
35a	4.4	5.1	2.2	0.32	silty sand
36a	4.9	5.9	2.1	0.48	silt
37a	4.8	6.0	2.2	0.54	silt
38a	4.4	5.9	2.4	0.62	silty sand
39a	4.3	5.6	2.4	0.54	silty sand
40a	4.1	5.2	2.0	0.55	silty sand
41a	4.3	5.4	2.4	0.46	silty sand
42a	3.9	5.2	2.0	0.65	silty sand
44a	4.8	5.4	2.2	0.27	silty sand
45a	4.3	5.6	2.4	0.54	silty sand
46a	5.3	6.0	2.6	0.27	silty sand
47a	5.0	6.1	2.4	0.46	silty sand
48a	5.3	6.3	2.3	0.44	silty sand
51a	—0.1	—0.1	0.9	0.00	sand
54a	0.6	—0.1	1.4	—0.50	sand
55a	3.3	3.6	3.2	0.09	silty sand
56	0.6	—0.6	2.0	—0.60	pebble sand
57	4.8	4.9	3.6	0.03	silty sand
58	1.5	1.6	0.4	0.25	sand
114a	7.2	6.9	1.8	—0.17	clayey silt
116a	2.3	4.4	2.8	0.75	silty sand
117a	2.4	5.0	3.2	0.81	silty sand
118a	2.4	5.0	3.2	0.81	silty sand
119a	7.2	6.4	2.2	—0.36	clayey silt
120a	6.6	6.3	2.5	—0.12	clayey silt
121a	6.8	5.6	3.2	—0.38	clayey silt
122a	6.9	6.7	2.1	—0.10	clayey silt
123a	3.2	5.1	3.2	0.59	silty sand
124a	6.0	6.0	2.8	0.00	clayey silt

TABLE 11—(continued)

Station No.	Mdϕ	Mϕ	$\sigma\phi$	$\alpha\phi$	Niggli's classification
110a	1.9	4.1	3.9	0.56	silty sand
111a	1.3	2.4	1.8	0.61	sand
97a	5.0	5.4	2.8	0.14	silty sand
80a	0.9	1.9	2.7	0.37	sand
14a	1.0	0.8	2.0	—0.10	sand
15a	6.8	6.9	1.7	0.06	clayey silt
16a	2.6	3.8	2.4	0.50	silty sand
18a	4.0	1.8	4.2	—0.50	silty sand
19a	0.7	—0.4	2.8	—0.39	pebble sand
20a	3.5	3.0	5.2	—0.10	silty sand
50a	2.2	2.0	1.2	—0.17	sand
59a	5.8	6.5	2.1	0.33	silt
98	6.2	6.2	2.3	0.00	silt
112a	6.3	5.6	3.0	—0.23	clayey sand
113a	7.0	5.7	3.0	—0.43	clayey silt
125a	—1.8	—2.2	2.6	—0.15	pebble sand

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EXPLANATION OF PLATES

Plate 1

Fig. 1. *Reophax dentaliniformis* Brady. U.S.N.M. 641393. ×65
Fig. 2. *Reophax nana* Rhumbler. U.S.N.M. 641394. ×215.
Fig. 3. *Ammoscalaria* cf. *fluvialis* Parker. U.S.N.M. 641395. ×65.
Fig. 4. *Eggerella advena* (Cushman). U.S.N.M. 641396. ×150.
Fig. 5. *Eggerella advena* (Cushman). U.S.N.M. 641397. ×150.
Fig. 6. *Quinqueloculina seminulum* (Linné). U.S.N.M. 641398. ×150.
Fig. 7. *Quinqueloculina seminulum* var. *jugosa Cushman*. U.S.N.M. 641399. ×93.
Fig. 8. *Cornuspira planorbis* Schultze. U.S.N.M. 641400. ×150.
Fig. 9. *Trochammina inflata* (Montagu). U.S.N.M. 641401. a, Dorsal view; b, ventral view. ×150.
Fig. 10. *Trochammina lobata* Cushman. U.S.N.M. 641402. Dorsal view. ×280.

Plate 2

Fig. 1. *Trochammina lobata* Cushman. U.S.N.M. 641402. Ventral view. ×280.
Fig. 2. *Trochammina squamata* Parker and Jones. U.S.N.M. 641403. a, Dorsal view; b, ventral view. ×150.
Fig. 3. *Fissurina laevigata* Reuss. U.S.N.M. 641404. ×150.
Fig. 4. *Pseudopolymorphina novangliae* (Cushman). U.S.N.M. 641405. ×33.
Fig. 5. *Nonionella atlantica* Cushman. U.S.N.M. 641406. a, Dorsal view; b, ventral view. ×150.
Fig. 6. *Elphidium clavatum* Cushman. U.S.N.M. 641407. ×150.
Fig. 7. *Elphidium clavatum* Cushman. U.S.N.M. 641408. ×150.

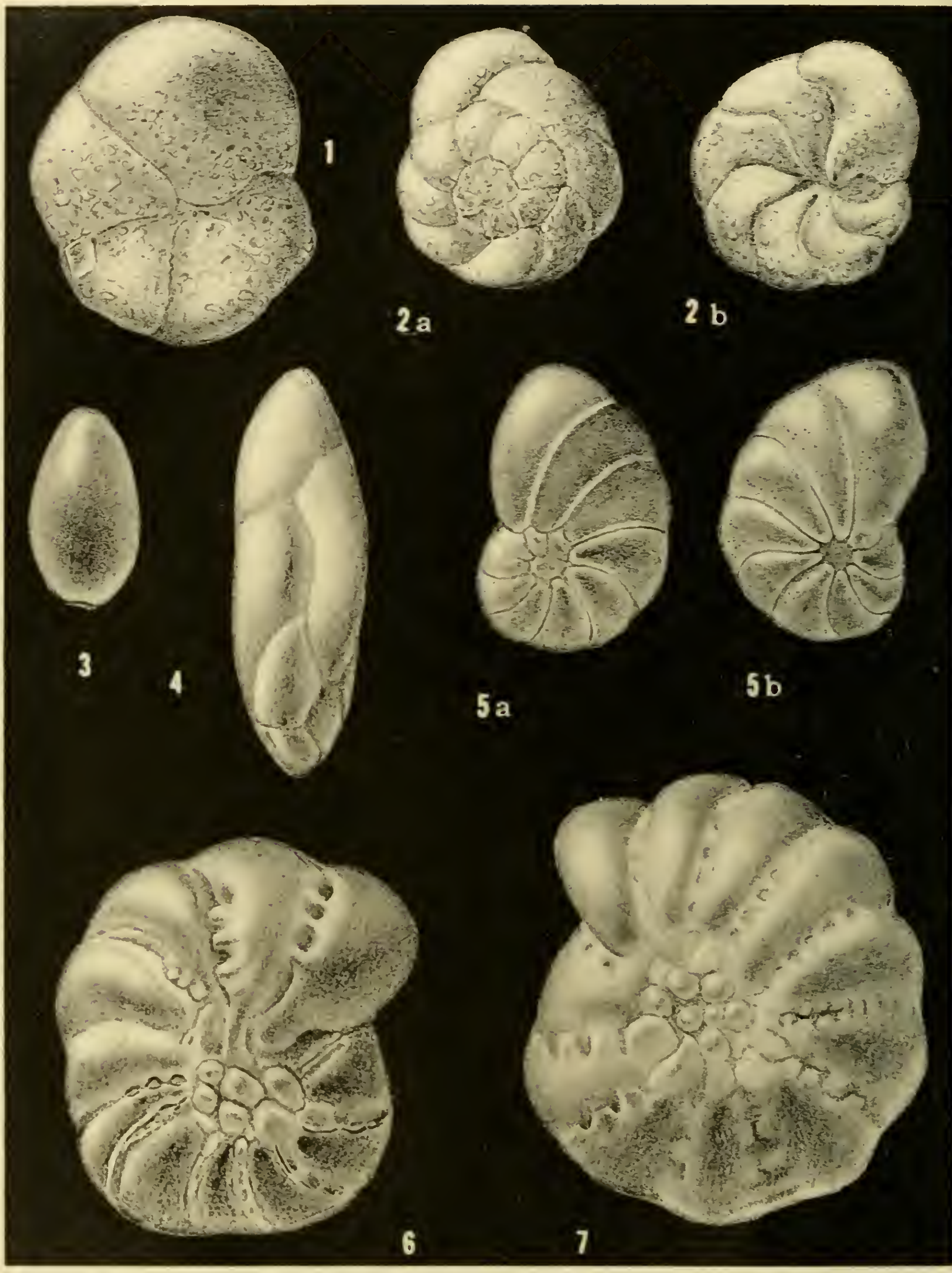
Plate 3

Fig. 1. *Elphidium clavatum* Cushman. U.S.N.M. 641409. ×150.
Fig. 2. *Elphidium clavatum* Cushman. U.S.N.M. 641410. ×150.
Fig. 3. *Elphidium pauciloculum* (Cushman). U.S.N.M. 641411. ×150.
Fig. 4. *Elphidium tisburyense* (Butcher). U.S.N.M. 641412. ×150.
Fig. 5. *Elphidium varium* Buzas. U.S.N.M. 641413. ×93.
Fig. 6. *Bolivina variabilis* (Williamson). U.S.N.M. 641414. ×280.
Fig. 7. *Virgulina fusiformis* (Williamson). U.S.N.M. 641415. ×214.

Plate 4

Fig. 1. *Ammonia beccarii* (Linné). U.S.N.M. 641416. a, Dorsal view; b, ventral view. ×150.
Fig. 2. *Buccella frigida* (Cushman). U.S.N.M. 641417. a, Dorsal view; b, ventral view. ×150.
Fig. 3. *Buccella frigida* (Cushman). U.S.N.M. 641418. a, Dorsal view; b, ventral view. ×150.
Fig. 4. *Poroeponides lateralis* (Terquem). U.S.N.M. 641419. ×93.

FORAMINIFERA FROM LONG ISLAND SOUND
(SEE EXPLANATION OF PLATES AT END OF TEXT.)



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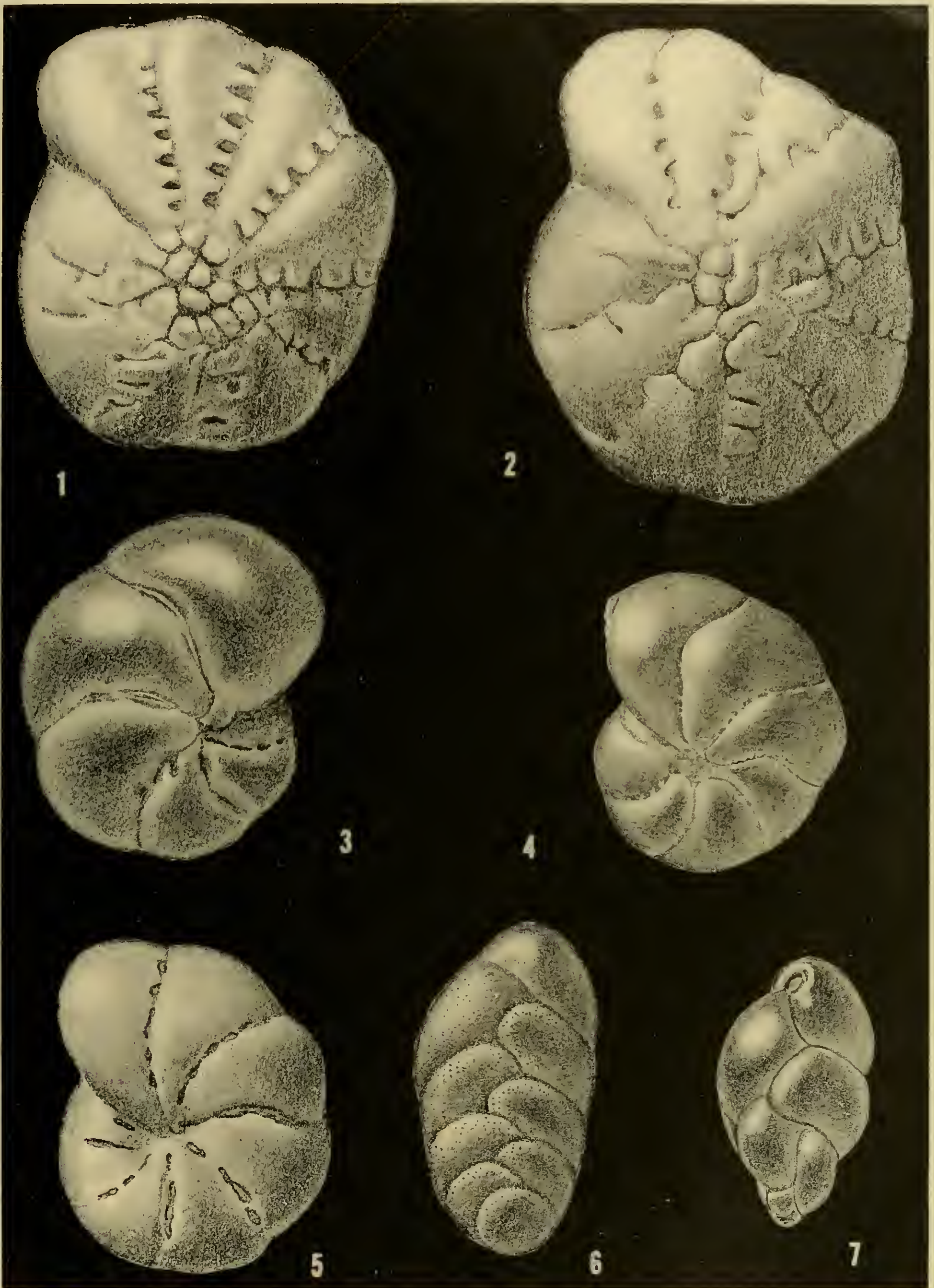

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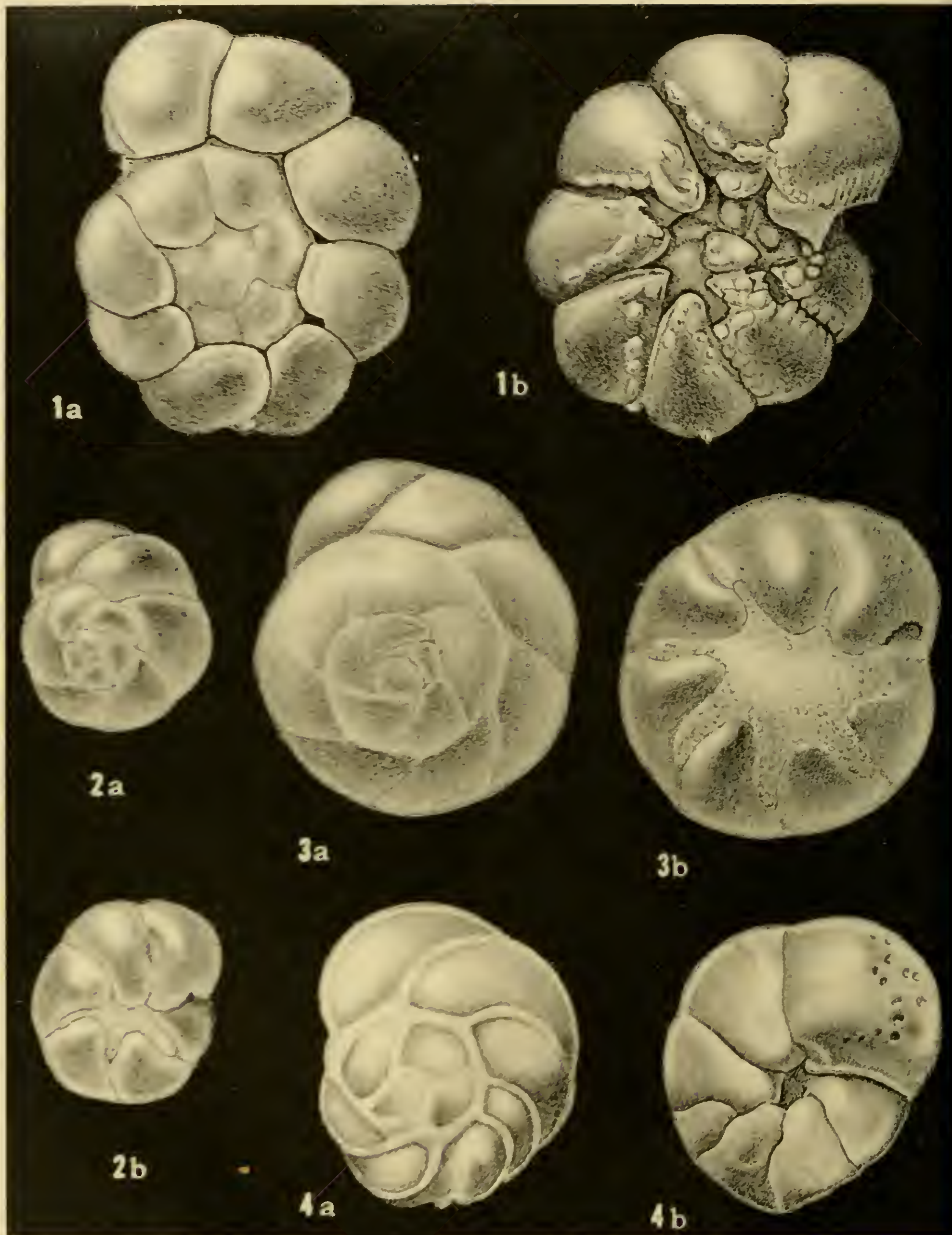

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