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VERTICAL DISTRIBUTION OF FORAMINIFERA IN THE INDIAN RIVER, FLORIDA

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ABSTRACT

In the Indian River, Florida, four cores were taken simultaneously from a subtidal flat consisting of silty sand. Each centimeter of each core was sampled to a depth of 10 cm. *Ammonia beccarii*, *Elphidium mexicanum*, and the total number of living individuals have significant differences in the mean number of individuals between depth, but not between cores. *Quinqueloculina* has a significant difference between cores, but not between depths. The data indicate abundant foraminifera occur to a depth of 6–7 cm. All species are positively correlated, and exhibit no vertical stratification.

INTRODUCTION

We have known for some time now (Richter, 1961; Buzas, 1965; Boltovskoy, 1966; Brooks, 1967; Ellison, 1972; Matera and Lee, 1972; Buzas, 1974) that foraminifera live beneath the surface of the sediment. My suggestion (Buzas, 1965) of an infaunal rather than an epifaunal (Myers, 1943) life style has been substantiated by Frankel (1972, 1975) who demonstrated reproduction and feeding beneath the surface.

While many species are clearly infaunal, the few studies conducted to date indicate differences in the details of their vertical distribution. For example, Brooks (1966) found no significant difference in the densities of *Ammonia beccarii* in the top 3 cm of the sediment he examined from Narragansett Bay, Rhode Island, but found a significant decrease in the fourth cm. In the Rappahannock River, Virginia, Ellison (1972) observed *A. beccarii* densities increased with depth in one of his two replicate cores and decreased in the other (a good reason for taking replicates). In the same cores he found abundant *Ammobaculites* to a depth of 9 cm (the length of his cores). Working in a similar environment, silty clay of Rhode River, Maryland, I (Buzas, 1974) found no significant difference in the mean number of individuals of the same species to a depth of 10 cm. On the other hand, Matera and Lee (1972, table 6) indicate foraminifera are only abundant to a depth of about 8 cm in the sands of a Long Island Sound salt marsh.

Clearly, more observations from different kinds of sediments in different environmental regimes must be made if generalizations are ever to emerge. The present study examines the vertical distribution of three species in four replicate cores from a subtidal flat in the subtropical environment of the Indian River, Florida.

METHODS

The samples were taken from a subtidal flat in about 0.5 m of water near the jetty of the Harbor Branch Foundation—Smithsonian Institution Ft. Pierce Bureau in the Indian River, Florida. Four replicate samples were taken by inserting core liners into silty sand consisting of 88% sand, 10% silt and 2% clay. Immediately upon return to the laboratory 5 ml was removed from the center of each cm of sediment to a depth of 10 cm. These 40 samples were then washed over a 63 μ sieve and stored in alcohol. The day before examination, 0.1 g of rose Bengal was added and the sample was shaken vigorously several times. On the day of examination each sample was again washed over a 63 μ

TABLE 1

Number of living individuals per 5 ml sediment. A = *Ammonia beccarii*, B = *Elphidium mexicanum*, C = *Quinqueloculina*.

Depth in cm	Core 1			Core 2			Core 3			Core 4		
	A	B	C	A	B	C	A	B	C	A	B	C
0–1	7	9	4	22	23	14	t	1	t	14	22	23
1–2	12	10	1	8	12	3	3	6	0	33	18	31
2–3	3	16	0	9	18	15	5	21	1	8	8	3
3–4	0	2	3	56	22	52	4	13	0	9	43	1
4–5	19	3	0	24	18	20	2	1	0	2	20	0
5–6	11	2	0	2	1	0	8	2	1	3	15	0
6–7	3	2	1	1	0	0	0	1	0	27	2	39
7–8	2	0	0	0	0	0	2	1	0	0	0	1
8–9	0	0	0	0	0	0	0	0	0	0	0	0
9–10	0	1	0	0	0	0	6	0	1	0	0	0

sieve, dried, and floated twice in a mixture of bromoform and acetone. The float was then portioned out into about ten or fifteen gridded petri dishes and rewetted with a mixture of water and Kodak Photo-Flo 200 solution to insure sinking of tests. All living individuals were then picked with a capillary tube and placed on micropaleontological slides for identification and enumeration.

RESULTS

Table 1 shows the number of individuals of the three most abundant taxa per 5 ml of sediment. Data of this type are most conveniently analyzed by a two-way analysis of variance (see Scheffee, 1959) where the variability between rows is due to depth and the variability between columns is due to cores. The two-way analysis of variance asks if there is a significant difference in the mean number of individuals between depths and between cores. As is customary with counts, the observations were transformed to $\ln(x + 1)$ to insure stability of variance and make the distribution more nearly Normal.

Table 2 lists the analysis of variance (ANOVA) results for *Ammonia beccarii*. Most of the sum of squares is accounted for by the difference between depths. The last column indicates the probability of obtaining the calculated F value for the given degrees of freedom. Table 2 indicates that the F value for "between depths" is highly significant. We conclude that for *A. beccarii* there is a significant difference between the mean number of individuals observed at the depth intervals, but none between cores.

Table 3 lists the ANOVA results for *Elphidium mexicanum*. For this species, as with *A. beccarii*, most of the variability is accounted for by the "between depths" sum of squares, and the F value for this hypothesis is highly significant. There is no significant difference between cores, although there is considerably more variability than with *A. beccarii*.

Table 4 lists the ANOVA results for *Quinqueloculina* most of which belong to *Quinqueloculina seminula*. Unlike the other two species, the hypothesis for "between cores" is significant at the .05 level and the hypothesis between depths is not. Table 1 indicates very low numbers of *Quinqueloculina* in cores 1 and 3 which probably accounts for the significant difference between cores and masks the fact that in core 2 all individuals

TABLE 2

Two-way analysis of variance for the number of living individuals of *Ammonia beccarii*.

Source	Sum of Squares	d.f.	F	p(F)
Between cores	1.21	3	0.39	.76
Between depths	26.35	9	2.83	.02
Residual	27.92	27		

TABLE 3

Two-way analysis of variance for the number of living individuals of *Elphidium mexicanum*.

Source	Sum of Squares	d.f.	F	p(F)
Between cores	3.20	3	2.07	.13
Between depths	44.85	9	9.67	.000002
Residual	13.91	27		

TABLE 4

Two-way analysis of variance for the number of living individuals of *Quinqueloculina*.

Source	Sum of Squares	d.f.	F	p(F)
Between cores	9.99	3	2.90	.05
Between depths	17.82	9	1.72	.13
Residual	31.01	27		

TABLE 6

Two-way analysis of variance for the number of living individuals of all species.

Source	Sum of Squares	d.f.	F	p(F)
Between cores	6.30	3	2.14	.12
Between depths	47.27	9	5.35	.0003
Residual	26.51	27		

are distributed in the top 5 cm. If more replicate samples were available, perhaps the distribution in core 2 could be shown to be the most common. At the same time, had only one core been taken, we could have been seriously mislead.

Table 5 lists the total number of living individuals observed per 5 ml of sediment. These numbers are slightly larger than the sum of the three species listed in Table 1 because rare species also are included in the counts. Table 6 lists the ANOVA results and indicates a highly significant F value for the hypothesis between depths. This might have been expected because the total number of living individuals, or standing crop, is largely dominated by the two most abundant species, *A. beccarii* and *E. mexicanum*.

Looking at Tables 1 and 5, the results of the ANOVA are readily interpretable. Below 6 or 7 cm there are very few foraminifera, and, hence, the significant hypotheses for "between depths." The four cores also show considerable variability in the densities at any depth and show no simple trend of a decrease in density with depth.

The product moment correlation coefficient was calculated for each of the three possible pairs of the taxa. The value obtained for *A. beccarii-E. mexicanum* is 0.46; for *A. beccarii-Quinqueloculina* it is 0.90; and for *E. mexicanum-Quinqueloculina* it is 0.38. At the 95% level any value larger than 0.26 can be regarded as significant. Therefore, the densities of the three taxa are highly correlated. In other words, when the density of foraminifera is high in any particular 5 ml, it is likely to be so for all the species.

TABLE 5

Total number of living individuals per 5 ml sediment.

Depth in cm	Core 1	Core 2	Core 3	Core 4
0–1	21	84	4	84
1–2	23	34	9	99
2–3	19	46	27	24
3–4	5	150	14	53
4–5	23	65	6	22
5–6	14	3	13	18
6–7	6	1	1	74
7–8	4	0	3	1
8–9	1	0	0	2
9–10	3	0	9	3

CONCLUSIONS

Matera and Lee (1972) also found abundant living foraminifera to a depth of about 8 cm in a Long Island salt marsh. This suggests that regardless of the environment, the effective living depth for foraminifera in sands is about 6 to 8 cm. In the muds of the Chesapeake estuarine system *Ammobaculites* is abundant to a depth of 10 cm (Ellison, 1972; Buzas, 1974). More research is needed in other environments to ascertain if this is peculiar to *Ammobaculites* or is a general phenomenon in muds. The depths referred to above are for abundant living foraminifera. Occasional living specimens can be found much deeper. Boltovskoy (1966) reported "penetration" to 16 cm in a sandy substrate in Deseado Creek, Argentina, and Buzas (1974) found living individuals to 15 cm in Rhode River, Maryland mud. Considering the size of individual foraminifers compared to the marine organisms with whom they share the environment, it is not surprising to find individuals transported to this depth. However, our major concern should be with the living zone where foraminifera are feeding and reproducing in abundance.

Matera and Lee (1972) found *Elphidium incertum* was most abundant in fine sand to a depth of about 3 cm and *Trochammina inflata* was most abundant in coarse sand at depths of about 3 to 6 cm. In the present study, we see no evidence of vertical stratification. Instead, there is a significant positive correlation between species densities indicating vertical space is not an important aspect of niche diversification for the species studied here. Further studies will be required to define

the importance of vertical stratification for individual species.

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