

Surface distribution of Foraminifera in a New England salt marsh: Plum Island, Massachusetts

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Résumé de l'article

Dans les marais salants longeant le système de fleches littoralea de Plum Island, au Massachusetts, les assemblages de foraminiferes agglutinants, les zones floristiques et les subdivisions environneroentales observees ressemblent au zonage des marais cotlers des Harlimes. Ouarante-trois echantillons de surface des slikkes, schorres, chenaux de maree et bancs de surface eleves ont livre sept especes: Trochammina macrescens, T. inflata, Miliammina fusca, Tiphotrocha comprimata, Ammotium salsum, Hapjophragmoides bonplandi et Arenoparrel1 a mexicana. Une analyse des rapports morts/vivants ne montre aucune difference notable entre les environneraents de marais salants. Une analyse des distributions totales indique des differences notables entre les assemblages de foraminiferes en fonction des environneraents de surface. La schorre se caracterise par T. macrescens, T. comprimata et deux especes moins communes. La slikke se distingue par M. fusca, T. infjata et A. salsum. Lea assemblages de bordure des chenaux de marees ressemblent a la slikke bien qu' A. salsum n'y soit plus preponderant. Bien que les bancs Aleves du marais ne contiennent aucun specimen vivant, on y rencontre un assemblage de specimens morts typique de la schorre. Ces assemblages cosmopolites de foraminiferes devraient pouvoir servir d'indicateurs valides lors de la reconstitution des paleomilieus de marais salants holocenes dans plusieurs regions.

SURFACE DISTRIBUTION OF FORAMINIFERA IN A NEW ENGLAND SALT MARSH:
PLUM ISLAND, MASSACHUSETTS

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Salt marsh agglutinated foraminiferal assemblages, floristic zones and environmental subdivisions along the Plum Island barrier island system in Massachusetts resemble the zonation pattern for coastal marshes in the Maritime Provinces of Canada. Forty-three surface samples from high marsh, low marsh, tidal channel margin and elevated surface environments yielded seven species: *Trochammina macrescens*, *Tr. inflata*, *Miliammina fusca*, *Tiphotrocha comprimata*, *Annotium salsum*, *Haplophragmoides bonplandi*, and *Arenoparrella mexicana*. Analysis of the dead to living ratios does not show a significant preservational difference among the salt marsh environments. Analysis of the total distributions indicates significant differences among the foraminiferal assemblages as a function of surface environments. The high marsh is characterized by *Trochammina macrescens*, *Tiphotrocha comprimata* and two of the less common species. The low marsh is characterized by *Miliammina fusca*, *Trochammina inflata*, and *Annotium salsum*. The tidal channel margin assemblage is similar to that of the low marsh except that *Annotium salsum* is no longer significant. Although the elevated marsh surfaces contained no living specimens, a high marsh type assemblage of dead specimens was present. These cosmopolitan foraminiferal assemblages should be valid discriminators for the reconstruction of Holocene salt marsh paleoenvironments in many regions.

Dans les marais salants longeant le système de flèches littorales de Plum Island, au Massachusetts, les assemblages de foraminifères agglutinants, les zones floristiques et les subdivisions environnementales observées ressemblent au zonage des marais côtiers des Maritimes. Quarante-trois échantillons de surface des slikkes, schorres, chenaux de marée et bancs de surface élevés ont livré sept espèces: *Trochammina macrescens*, *T. inflata*, *Miliammina fusca*, *Tiphotrocha comprimata*, *Annotium salsum*, *Haplophragmoides bonplandi* et *Arenoparrella mexicana*. Une analyse des rapports morts/vivants ne montre aucune différence notable entre les environnements de marais salants. Une analyse des distributions totales indique des différences notables entre les assemblages de foraminifères en fonction des environnements de surface. La schorre se caractérise par *T. macrescens*, *T. comprimata* et deux espèces moins communes. La slikke se distingue par *M. fusca*, *T. inflata* et *A. salsum*. Les assemblages de bordure des chenaux de marées ressemblent à la slikke bien qu' *A. salsum* n'y soit plus prépondérant. Bien que les bancs élevés du marais ne contiennent aucun spécimen vivant, on y rencontre un assemblage de spécimens morts typique de la schorre. Ces assemblages cosmopolites de foraminifères devraient pouvoir servir d'indicateurs valides lors de la reconstitution des paléomilieux de marais salants holocènes dans plusieurs régions.

[Traduit par le journal]

INTRODUCTION

Marsh Foraminifera are becoming recognized as valuable paleoenvironmental indicators for Holocene salt marsh environments and sea-level changes (Fig. 1), especially in the Maritime Provinces of Canada (Scott and Medioli, 1978, 1980a, 1982; Scott *et al.*, 1984; Deonarine, 1979; Smith *et al.*, 1984). However, few studies have compared both living and dead foraminiferal assemblages in the same salt marsh sites for evaluating paleoenvironmental analyses (Murray, 1976; Scott and Medioli, 1980b). The purpose of this paper is to evaluate the distributional relationships of the living salt marsh Foraminifera on the Plum Island barrier island system of northeastern Massachusetts (Fig. 2) in order to determine their potential use as indicators of Holocene salt marsh environments.

Marsh Foraminifera are dominated by agglutinated forms which are sensitive to changes in environmental conditions (Phleger and Bradshaw, 1966; Scott and Medioli, 1978, 1980a; Deonarine, 1979) and are more likely to be preserved in acidic marsh sediments than calcareous species (Poag,

1978). A close correlation exists between salt marsh floral zones and foraminiferal distributions (Phleger, 1965; Scott, 1976; Scott and Medioli, 1978, 1980a; Deonarine, 1979; Poag, 1981). Marsh organisms must be able to tolerate highly variable environmental conditions (Murray, 1976). Some foraminiferal species are endemic to restricted coastal environments (Phleger, 1970; Scott and Medioli, 1980a), and some appear to have a somewhat cosmopolitan distribution (Phleger, 1960, 1970; Scott *et al.*, 1983). Restricted coastal waters are dominated by a few foraminiferal taxa (Poag, 1981), with diversity being lowest in the high marsh (Phleger, 1970).

Although Scott and Medioli and their associates have conducted extensive investigations of Nova Scotian, New Brunswick and Prince Edward Island salt marsh surface Foraminifera as well as salt marsh subsurface Foraminifera (Scott and Medioli, 1980a; Scott *et al.*, 1981), there have been few studies of the Foraminifera living within New England salt marshes. Phleger and Walton (1950), Parker and Athearn (1959), and Phleger (1960) described the occurrence of some salt marsh

| Tidal Stage | Faunal Zones | Foraminifera | Floral Zones |
|-------------|--------------|--|--------------|
| HHW | | No Forams | |
| | 1A | <i>Trochammina macrescens</i> | High Marsh |
| | 1B | <i>Tiphotrocha comprimata</i> <i>Trochammina macrescens</i> | Middle Marsh |
| MHHW | | <i>Trochammina inflata</i> | Low Marsh A |
| MLHW | | <i>Miliammina fusca</i> | |
| | 2B | <i>Ammotium salsum</i> | Low Marsh B |
| | | <i>Miliammina fusca</i> | |
| MSL | | | Lowest Marsh |

Fig. 1. Zonation of the most diagnostic foraminiferal species with respect to tide level in a Nova Scotian salt marsh (modified from Scott and Medioli, 1980a). (MSL, mean sea level; MLHW, mean lower high water; MHHW, mean higher high water; HHW, higher high water.)

Foraminifera on Cape Cod, Massachusetts. Jones and Cameron (1983) and Hossley *et al.* (1985) conducted subsurface reconnaissance studies of the foraminiferal content of the Plum Island salt marsh. Hossley's (1986) more detailed study of Plum Island subsurface marsh Foraminifera included only a few surface samples in which the number of live specimens was too low for analysis. These studies suggest, however, that New England marsh

species distributions may be similar to those found in other regions such as Texas (Phleger, 1965; Murray, 1976) and California and Nova Scotia (Scott and Medioli, 1980a).

PLUM ISLAND STUDY AREA

Plum Island is about 65 kms northeast of Boston. It is 13 kms in length and varies in width from 0.8 to 1.2 kms. It is a segment of the barrier island system found in the Merrimack River Embayment (Fig. 2). The tidal range for the area is approximately 2.7 m, but major coastal storms frequently increase the average high tide by at least 1 m. The three major geomorphic environments found on mesotidal barrier islands are well-developed. These are: (1) an oceanward sandy beach, (2) a belt of vegetated dunes behind the beach, and (3) a salt marsh developed on the lagoonal side of the island (Fig. 3). The marine fauna and flora of the marsh are included in the Cape Cod to Nova Scotia marine biotic province.

There has been much speculation and controversy over the origin of Holocene barrier islands in general (Fisher, 1968; Hoyt, 1968; Schwartz, 1971, 1973; Leatherman, 1979) and, in particular, over the origin and development of Plum Island. In addition, little is known about the overall geologic development and biological responses of back-barrier salt marshes (Frey and Basan, 1978). McIntire and Morgan (1963), Rhodes (1973) and Hine (1979) attributed the origin of Plum Island to beach-ridge embayment associated with sea-level rise, whereas Jones and Cameron (1977, 1979) and Jones (1984) presented an alternative view that the island formed through a series of southwardly accreting spits behind which the salt marsh developed.

BACK-BARRIER SALT MARSH

The Plum Island salt marsh is a new England type salt marsh. New England type salt marshes are mesotidal, divisible into low and high marsh zones on the basis of floral assemblages and extend from the coast of New Jersey to that of Maine (Chapman, 1960). Plum Island is one of the best examples in the northeast coastal region of the United States (U.S. Fish and Wildlife Service, 1983). The Marsh represents 42% of the 14.4 square km area of Plum Island and is found along almost the entire length of the western margin of the island. Its floral zonation is different enough from other salt marsh areas where recent Foraminifera have been studied, such as Nova Scotia, to warrant a short review.

This back-barrier marsh is broadly subdivided into low marsh and high marsh vegetational zones that are dominated by the salt tolerant grasses *Spartina alterniflora* and *S. patens*, respectively. The western section of the low marsh proximal to the estuary (Fig. 3) is characterized by the brown alga *Fucus vesiculosus* and the taller form of *Spartina alterniflora*. The higher section of the low marsh environment is characterized by the shorter form of *S. alterniflora* (McDonnell, 1979).

The high marsh environment is a relatively narrow zone (Fig. 3) that occurs above the mean high-water neap tide level and is dominated by *Spartina patens*. However, *S. alterniflora* is observed along tidal creeks incised into the high marsh, and it

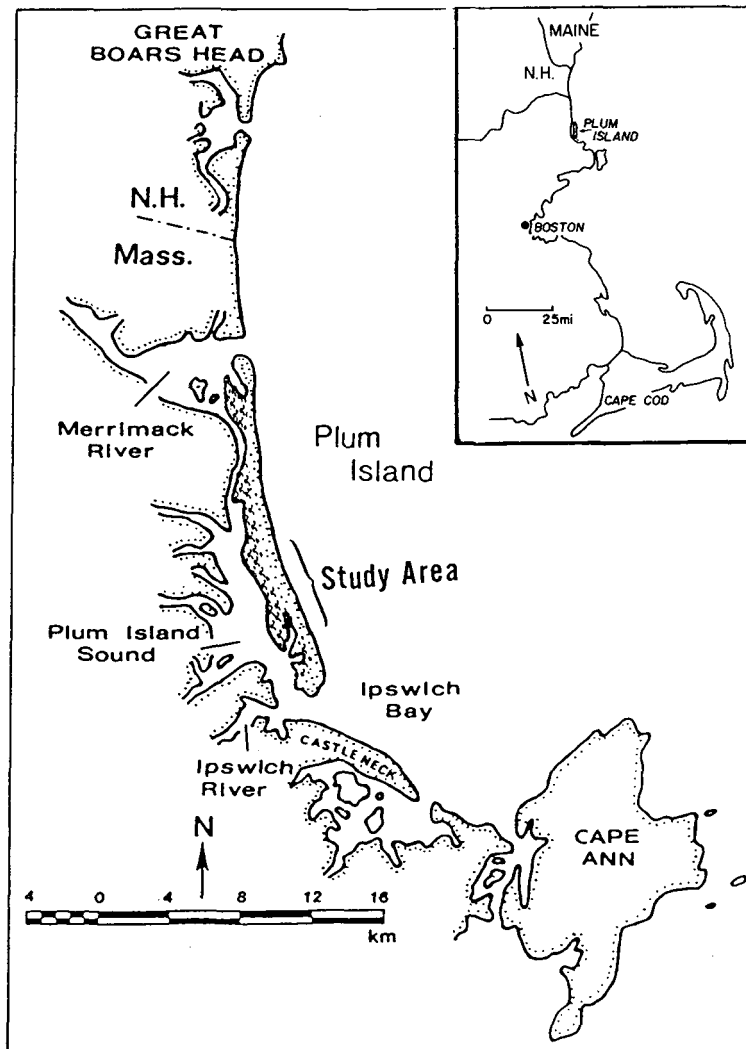


Fig. 2. Location of the Plum Island barrier island system of the Merrimack River Embayment in northeastern Massachusetts. Arrow and bracket denote detailed study area that is illustrated in greater detail in Fig. 3. (Mass., Massachusetts; N.H., New Hampshire.)

also occurs in some depressions. The grass *Juncus gerardii* is also found along the edges of and on elevated surfaces of the high marsh. Other plant taxa occurring in the high marsh zone include the grass *Distichlis* and the succulent *Salicornia* (Redfield, 1972; McDonnell, 1979). Salt panne depressions in the high marsh are unable to support vascular plants. Quartzose algal mats, produced by photosynthetic sulphur bacteria and cyanobacteria, occur around some of these pannes and along parts of the upper (eastern) fringe of the high marsh (Cameron *et al.*, 1985).

The stratigraphy of the salt marsh consists of low organic content peat horizons (Jones and Cameron, in press), sand lenses and underlying basal sands. The basal sands are found at depths that vary from 0.3 to 5.0 m (Jones, 1984). The salt marsh sediment is composed of silty-clay units that contain some sand. Salt marsh vegetation comprises from 1 to 60% of the marsh sediment by volume.

METHODOLOGY

Forty-three surface samples were collected by standard procedures (Scott and Medioli, 1980a, p. 7) from high marsh, low marsh, tidal creek banks, and elevated marsh surfaces, such as washover fans (Fig. 3). The delineation of these surface environments was determined in the field on the basis of geomorphology and/or botanical assemblages. A 5% tincture of rose bengal was added to the sample container in order to differentially stain live specimens. The samples were washed through sieves down to 63 microns, devegetated manually and viewed under a 60X binocular dissecting microscope. When abundances permitted, the first 250 specimens encountered were removed for study. Over 7,200 specimens were counted (Table 1), all identified specimens were attributable to one of the following species: *Trochammina macrescens* Brady, *Trochammina inflata* (Montagu), *Miliammina fusca* (Brady), *Tiphotrecha*

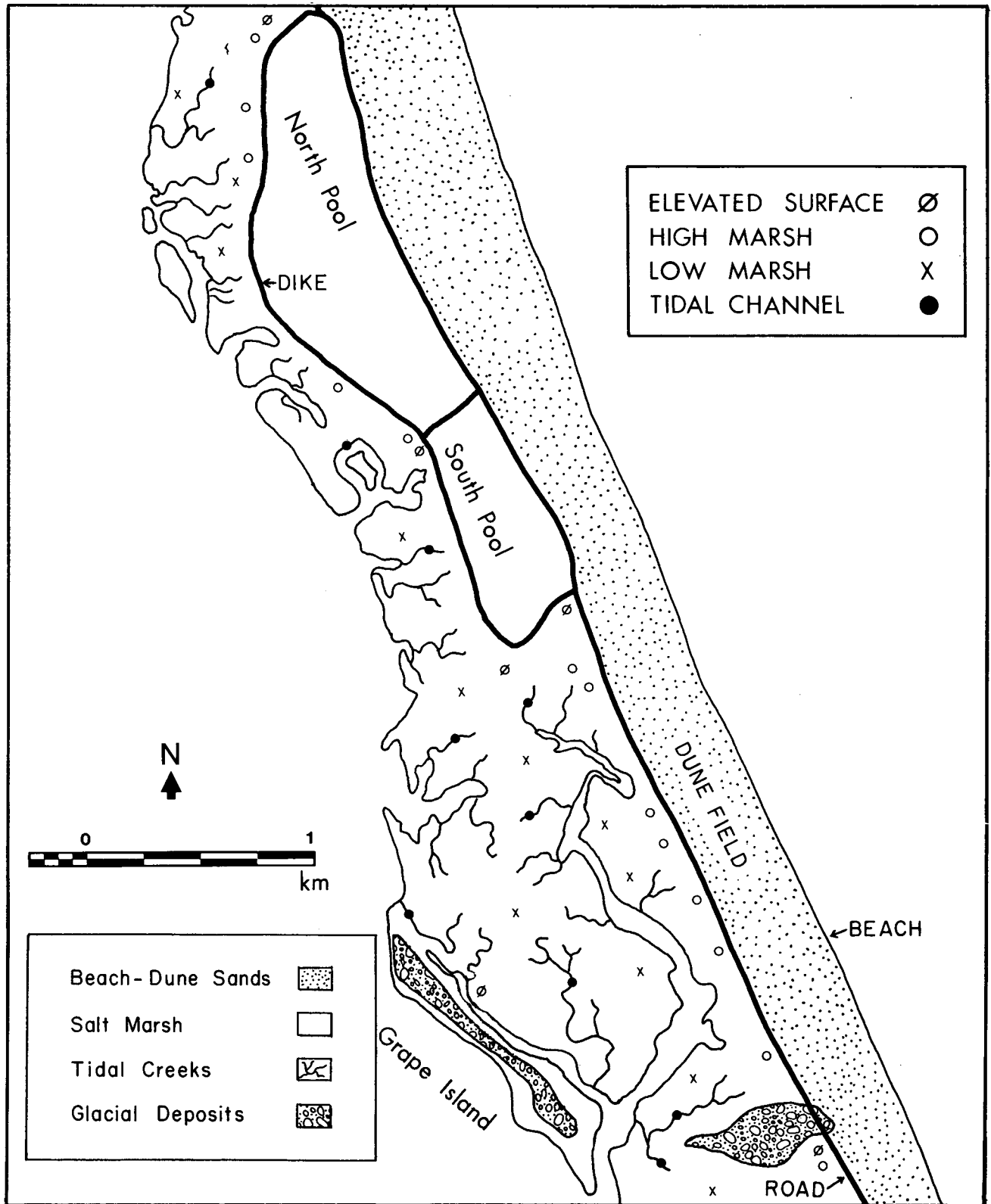


Fig. 3. Sample location map for central Plum Island, Massachusetts (see Fig. 2). Note the narrowness of the high marsh zone and the much broader low marsh zone as indicated by their respective sample symbols. Most of the elevated surface samples occur along the margins of the backdune area, dikes and glacial deposits. The beach along the oceanward side of the island is too narrow to illustrate to scale. The approximate center of the sampling area is at $42^{\circ} 40' 00''$ North, $70^{\circ} 47' 30''$ West.

Table 1. Distribution of total foraminiferal specimens in the salt marsh surface environments of Plum Island, Massachusetts*

| Species | High Marsh (13) | Low Marsh (14) | Tidal Channel (10) | Elevated (6)** |
|--------------------------------------|--------------------|-------------------|-----------------------|-------------------|
| 1. <i>Trochammina inflata</i> | 226 | 573 | 431 | 147 |
| 2. <i>Trochammina macrescens</i> | 771 | 485 | 325 | 216 |
| 3. <i>Tiphotrocha comprimata</i> | 576 | 448 | 303 | 113 |
| 4. <i>Miliammina fusca</i> | 382 | 736 | 369 | 15 |
| 5. <i>Ammotium salsum</i> | 123 | 342 | 97 | 0 |
| 6. <i>Haplophragmoides bonplandi</i> | 259 | 92 | 46 | 29 |
| 7. <i>Arenoparella mexicana</i> | 57 | 24 | 17 | 0 |

*Includes live and dead specimens

**Numbers in parentheses refer to the number of samples from each environment.

comprimata (Cushman and Bronnimann), *Ammotium salsum* (Cushman and Bronnimann), *Haplophragmoides bonplandi* Todd and Bronnimann, and *Arenoparella mexicana* (Kornfield). The species nomenclature follows that of Scott and Mediolli (1980a), who reviewed the systematic taxonomy of marsh Foraminifera.

DISTRIBUTION OF LIVE FORAMINIFERA

All seven species of Foraminifera were represented by live specimens as indicated by the stain, but no live specimens occurred in the elevated marsh surface environments. The ratio of dead to living specimens for each species was determined to test if there is a distributional difference among the species in regard to potential

preservation within the stratigraphic record (Table 2). This analysis has direct applications to the taphonomic implications of benthic Foraminifera as potential indicators of former Holocene salt marsh environments.

The Chi square test was used to test for significant differences among the high marsh, low marsh and tidal channel margin environments on the basis of the dead to living ratios (Table 2). The elevated marsh surface samples were eliminated from this analysis because they contained no live specimens. The test results failed to identify a significant difference at the 0.05 level.

These results suggest that there is not a taphonomic overprint, i.e., an over- or under-representation of a particular species within the three environments. These species appear to have

Table 2. Distribution of ratios of dead to living specimens of Foraminifera in the salt marsh surface environments of Plum Island, Massachusetts

| Species | High Marsh (13)* | Low Marsh (14) | Tidal Channel (10) | Elevated (6) |
|--------------------------------------|---------------------|-------------------|-----------------------|-----------------|
| 1. <i>Trochammina inflata</i> | 4.0 | 5.2 | 4.9 | 147. |
| 2. <i>Trochammina macrescens</i> | 3.7 | 3.2 | 4.6 | 216. |
| 3. <i>Tiphotrocha comprimata</i> | 4.6 | 4.1 | 4.3 | 113. |
| 4. <i>Miliammina fusca</i> | 6.3 | 5.7 | 6.1 | 15. |
| 5. <i>Ammotium salsum</i> | 4.3 | 4.0 | 3.9 | 0. |
| 6. <i>Haplophragmoides bonplandi</i> | 3.6 | 4.0 | 4.2 | 29. |
| 7. <i>Arenoparella mexicana</i> | 17.3 | 16.7 | 18.4 | 0. |

*Numbers in parentheses refer to the number of samples from each environment.

reliable potential for identifying marsh paleoenvironments within the Holocene stratigraphic record.

ANALYSES OF TOTAL SPECIES DISTRIBUTIONS

The same seven species were identified from dead specimens from the high marsh, low marsh, and tidal channel margin environments. Two of the less common species (*Ammotium salsum* and *Arenoparella mexicana*), however, were absent from the six elevated surface samples (Table 1). The most abundant species are, in decreasing order, *Trochammina macrescens*, *Miliammina fusca*, *Tiphotrocha comprimata*, and *Trochammina inflata*. The less common species are *Ammotium salsum* and *Haplophragmoides bonplandi*; the least common species is *Arenoparella mexicana* (Fig. 4). Five of these species (*Trochammina macrescens*, *Tr. inflata*, *Miliammina fusca*, *Tiphotrocha comprimata*, and *Ammotium salsum*) were considered by Scott and Medioli (1980a) to be diagnostic for salt marsh zonation (Fig. 1). Most have wide geographic distributions. For example, all but *H. bonplandi*

were reported from modern tidal marshes in Galveston Bay, Texas, where there is adequate data on both living and dead foraminiferal assemblages (Murray, 1976).

Scott and Medioli (1980a) presented a generalized zonation model for the distribution of modern foraminiferal species within Nova Scotian salt marshes (Fig. 1), but their distributional pattern has yet to be tested on New England salt marshes. In an attempt to evaluate their model and to determine if a significant difference exists between the respective surface environments and the distribution of foraminiferal species at Plum Island, the Chi square test of significance was computed and a Lorenz curve was constructed from our data. Both the number of living and the number of dead specimens were combined in these analyses, as would eventually be the case with their potential fossil assemblages (Scott and Medioli, 1980b).

The six samples collected from the elevated marsh surfaces were eliminated from the Chi square analysis because these data did not meet the assumptions of the test, i.e., some species were not found in these samples (Table 1). These elevated marsh surface environments probably do not represent a normal *in vivo* environment for Foraminifera. The low occurrence of Foraminifera in these areas appears to be the result of transportation by abnormally high tides or storm activity. This interpretation is supported by the dominance of high marsh species and the absence of any living specimens in any of the six samples.

The Chi square test results demonstrate that there is a significant difference at the 0.05 level for the foraminiferal distributions from the three remaining marsh environments. Therefore, certain species prefer specific marsh habitats. The plotted relative frequencies of these seven species by marsh environment are illustrated in Fig. 4.

In order to graphically illustrate the abundance and diversity relationships among the seven foraminiferal species in these three marsh environments, a spatial Lorenz curve was constructed (Hammond and McCullagh, 1974). The spatial Lorenz curve method of comparison is frequently used in geographical studies, and it appears to have merit for our distributional study of salt marsh Foraminifera. Other indices of diversity, e.g., Williams' or Simpson's, were not used because they either depend upon a large number of species or upon the numbers of the more abundant species to produce meaningful results (Reyment, 1971). The spatial Lorenz curve measures concentration by the extent to which a given distribution differs from a hypothetical distribution. The curve is constructed by plotting for each environmental subdivision the frequency of each species as a percentage of the total frequency in the form of a cumulative frequency curve (Table 3, Fig. 5). The total frequencies represent a hypothetical distribution.

The spatial Lorenz curve for our marsh foraminiferal distributions suggests that there are distributional differences among the seven species in the salt marsh environments (Fig. 5). For example, the plotted value for *Trochammina inflata* is considerably lower for the high marsh environment when compared to the value for this species in the low marsh and tidal creek

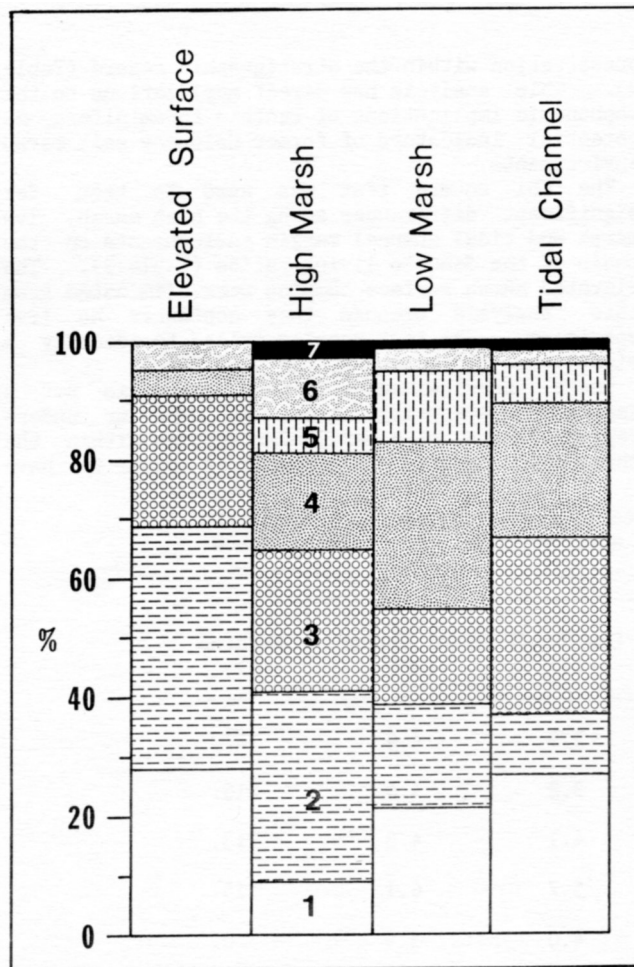


Fig. 4. Percent frequency distribution histograms for surface salt marsh Foraminifera from Plum Island, Massachusetts. 1, *Trochammina inflata*; 2, *Trochammina macrescens*; 3, *Tiphotrocha comprimata*; 4, *Miliammina fusca*; 5, *Ammotium salsum*; 6, *Haplophragmoides bonplandi*; 7, *Arenoparella mexicana*.

Table 3. Spatial Lorenz cumulative frequency percent distributions of surface salt marsh Foraminifera from Plum Island, Massachusetts

| Species | High Marsh (13)* | Low Marsh (14) | Tidal Channel (10) | Total** |
|--------------------------------------|---------------------|-------------------|-----------------------|---------|
| 1. <i>Trochammina inflata</i> | 9.4 | 21.2 | 27.1 | 18.4 |
| 2. <i>Trochammina macrescens</i> | 41.6 | 39.1 | 47.6 | 42.1 |
| 3. <i>Tiphotrecha comprimata</i> | 65.7 | 55.7 | 66.7 | 62.0 |
| 4. <i>Miliammina fusca</i> | 81.5 | 83.0 | 89.9 | 84.3 |
| 5. <i>Annotium salsum</i> | 86.6 | 95.7 | 96.0 | 92.7 |
| 6. <i>Haplophragmoides bonplandi</i> | 97.4 | 99.1 | 98.9 | 98.6 |
| 7. <i>Arenoparella mexicana</i> | 100.0 | 100.0 | 100.0 | 100.0 |

*Numbers in parentheses refer to the number of samples from each environment.

**Hypothetical distribution

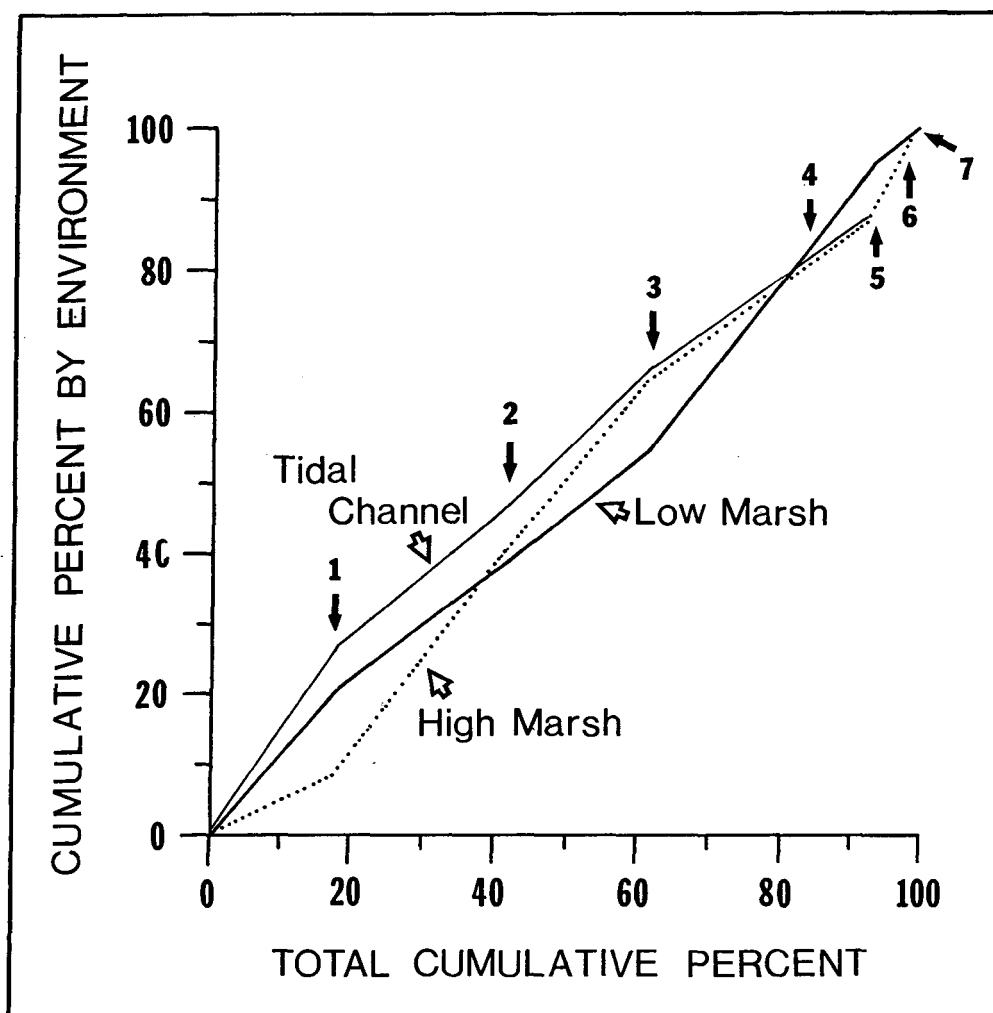


Fig. 5. Spatial Lorenz curve, based on cumulative frequency percent distributions, for surface salt marsh Foraminifera at Plum Island, Massachusetts. 1, *Trochammina inflata*; 2, *Trochammina macrescens*; 3, *Tiphotrecha comprimata*; 4, *Miliammina fusca*; 5, *Annotium salsum*; 6, *Haplophragmoides bonplandi*; 7, *Arenoparella mexicana*.

environments. The slope of the curve is also greater for *Trochammina macrescens* in the high marsh environment compared with those for the low marsh and tidal channel environments, suggesting a preferred high marsh habitat for this species. The slopes for *Miliammina fusca* and *Ammotium salsum* suggest a low marsh habitat for these two species.

In order to more quantitatively determine the most characteristic species associations within these three marsh environments, a similarity index was computed from the data prepared for the Lorenz curve (Table 4). This index is called the "Location Quotient" and is calculated by dividing the respective total frequency value for each species into its frequency value in each environmental subdivision (Hammond and McCullagh, 1974). The larger the value, the more important that particular species is to that environment, regardless of the relative percent contribution. For example, compare the first row values in Tables 3 and 4.

Analysis of the highest values of this index suggests which species are most important to each marsh environment. Examining Table 4, one can see that the high marsh is characterized by the common species *Trochammina macrescens* and *Tiphotrocha comprimata* as well as the less common species *Haplophragmoides bonplandi* and *Arenoparella mexicana*. The low marsh environment is characterized by the common species *Miliammina fusca* and *Trochammina inflata* and the less common species *Ammotium salsum*. The tidal channel margins are characterized by *Trochammina inflata* and *Miliammina fusca*.

DISCUSSION

These species assemblages correspond reasonably well with those of Scott and Medioli (1980a), even though their marsh subdivisions were somewhat different from ours (Figs. 1 and 6), i.e., we recognize two instead of three major floral subdivisions.

The more common species that characterize our high marsh environment (*Trochammina macrescens* and

Tiphotrocha comprimata) also characterize most of their high marsh and the upper part of their middle marsh subdivisions. However, we find a significant association of the less common species *Haplophragmoides bonplandi* and *Arenoparella mexicana* with our high marsh environment which they did not note for their high or middle marsh environments (Table 4; Figs. 1 and 6).

The three species characterizing our low marsh environment are also included in Scott and Medioli's list of important species in their lower middle and lower marsh zones (Figs. 1 and 6).

Our tidal channel margin subdivision may be distinct from their "2 B Low Marsh" faunal zone which is characterized by *Miliammina fusca*, *Ammotium salsum* and *Cribronionion umbilicatum*. Our channel margin environment is dominated by *Trochammina inflata*, which increases in importance from the low marsh, and *Miliammina fusca*, which becomes a less significant major contributor. *Ammotium salsum*, on the other hand, is no longer a characteristic species (Table 4; Fig. 6).

Our elevated high marsh surface may or may not be analogous to Scott and Medioli's "1 A High Marsh" faunal zone in which they found *Trochammina macrescens* dominant. Our highest marsh environment contained no live specimens and the dead specimen assemblage was dominated by *Tr. macrescens* as well as *Tr. inflata* and contained average relative contributions from *Tiphotrocha comprimata* and *Haplophragmoides bonplandi*.

CONCLUSIONS

Live Foraminifera on the surface of the modern salt marsh at Plum Island, Massachusetts, were found in only high marsh, low marsh and tidal channel margin environments. Elevated surfaces, such as former washover fans, contained only dead specimens transported primarily from the surrounding high marsh. The Chi square test indicates that there is no significant difference in the dead to live ratios among the three remaining environments. Therefore, agglutinated marsh Foraminifera appear to be potentially good

Table 4. Location Quotient index of similarity for Foraminifera from salt marsh surface environments at Plum Island, Massachusetts

| Species | High Marsh | Low Marsh | Tidal Channel |
|--------------------------------------|------------|-----------|---------------|
| 1. <i>Trochammina inflata</i> | 0.51 | 1.15* | 1.47* |
| 2. <i>Trochammina macrescens</i> | 1.36* | 0.76 | 0.87 |
| 3. <i>Tiphotrocha comprimata</i> | 1.21* | 0.83 | 0.96 |
| 4. <i>Miliammina fusca</i> | 0.72 | 1.22* | 1.04* |
| 5. <i>Ammotium salsum</i> | 0.61 | 1.51* | 0.73 |
| 6. <i>Haplophragmoides bonplandi</i> | 1.82* | 0.57 | 0.49 |
| 7. <i>Arenoparella mexicana</i> | 1.62* | 0.61 | 0.73 |

*Dominant species

| Dominant Foraminifera | Dominant Flora | Marsh Environment |
|---|---|-------------------------------|
| <i>Trochammina macrescens</i> <i>Tiphotrocha comprimata</i> <i>Arenoparella mexicana</i> <i>Haplophragmoides bonplandi</i> | <i>Juncus gerardii</i> | Elevated Surface |
| | <i>Spartina patens</i> <i>Distichlis sp.</i> <i>Salicornia sp.</i> Cyanophyte mats | High Marsh |
| <i>Ammotium salsum</i> <i>Miliammina fusca</i> <i>Trochammina inflata</i> | <i>Spartina alterniflora</i> (short form) | Low Marsh |
| <i>Miliammina fusca</i> <i>Trochammina inflata</i> | <i>Spartina alterniflora</i> (tall form) | Tidal Channel Upper Margin |

Fig. 6. Zonation of the most diagnostic salt marsh Foraminifera with respect to salt marsh flora and environmental subdivisions at Plum Island, Massachusetts.

indicators for identifying marsh paleoenvironments within the Holocene stratigraphic record.

The overall distribution of total (live plus dead) marsh Foraminifera at Plum Island is similar to that presented by Scott and Medioli (1980a) for Nova Scotian salt marshes but differs in several important ways. Although both areas contain a high marsh *Trochammina macrescens-Tiphotrocha comprimata* assemblage, our findings also indicate that the less abundant *Haplophragmoides bonplandi* and *Arenoparella mexicana* are also characteristic of the high marsh on Plum Island. The low marsh in both areas is associated with a *Miliammina fusca - Trochammina inflata - Ammotium salsum* assemblage. The lowest marsh elevation along tidal channel margins at Plum Island is associated primarily with *Trochammina inflata* and to a lesser degree with *Miliammina fusca*. This may differ from Nova Scotian lowest marsh areas which are characterized by an *Ammotium salsum-Miliammina fusca* assemblage.

Assuming that the environmental factors that control the widespread distribution of marsh Foraminifera today also affected these assemblages in a similar manner during the Holocene, a study of their distribution in marsh stratigraphic sequences in many coastal regions could provide a means of identifying former salt marsh subenvironments and associated changes resulting from sea-level fluctuations.

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