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FORAMINIFERAL ZONATION OF GREAT SIPPEWISSETT SALT MARSH (FALMOUTH, MASSACHUSETTS)

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ABSTRACT

Foraminifera of Great Sippewissett salt marsh, on the western shore of Cape Cod (Falmouth, Massachusetts), exhibit a surface zonation that corresponds with elevation (relative to mean sea level), salinity, and proximity to tidal creeks. Species zonation is similar to that described earlier for marshes of Atlantic Canada. The two most abundant foraminiferal species in Great Sippewissett—*Trochammina inflata* and two morphotypes of *Trochammina macrescens* s. l.—are abundant in assemblages in all marsh environments and at all elevations. The distribution of the two morphotypes of *T. macrescens* s. l. corresponds with salinity: *T. macrescens macrescens* is the most common morphotype in the marsh, but *T. macrescens polystoma* increases in abundance in high salinity outer marsh areas.

The surface distribution of species can be related to elevation and salinity and allows recognition of three vertical zones in the inner marsh: low marsh, transitional high marsh, and high marsh. The zones are defined by changing proportions of secondary and minor species, since *Trochammina inflata* and the two morphotypes of *Trochammina macrescens* s. l. are dominant in all zones. The low marsh zone extends from 25 cm below mean sea level to just below mean high water. It is characterized by a relatively diverse assemblage that includes abundant *Miliammina fusca, Ammotium salsum, Polysaccammina hyperhalina, Arenoparrella mexicana,* and subtidal estuarine taxa (e.g., *Trochammina squamata, Trochammina ochracea, Textularia earlandi,* and calcareous species). The transitional high marsh zone lies between the low and high marsh zones, with a lower limit slightly below mean high water and an upper limit at mean high water. It is identified by the abundance of *Tiphotrocha comprimata* with decreased proportions of low marsh species. The high marsh zone extends from mean high water to highest high water (the landward limit of tides in the marsh). It is characterized by dominance of *T. macrescens* and *T. inflata* and a decrease in abundance of low marsh and transitional marsh species. The high marsh zone provides a strandline marker with a vertical extent of 22 cm that can be combined with other sea level indicators, sediment analysis, and carbon-14 dating in order to reconstruct sea level change and marsh development from cores.

INTRODUCTION

FORAMINIFERA OF SALT MARSHES

Foraminifera of modern salt marshes have been studied since Phleger and Walton (1950) documented their distribution in Barnstable Harbor. Subsequent work has shown that foraminiferal distribution is controlled by a number of interdependent variables (Buzas, 1969). However, in the marsh, elevation relative to mean sea level can be isolated as a primary influence on assemblages (Scott and Medioli, 1978). The existence of a vertical zonation was suggested by Phleger (1965) and documented by Scott (1976a) in southern California. Scott and Medioli subsequently provided detailed description of the vertical zonation of foraminifera in marshes of other regions, including Atlantic Canada, Greece, and Italy (Scott and others, 1979; Scott and Medioli, 1980a; Petrucci and others, 1983). These studies showed that species composition of the zones varies between areas with different salinity, substrate, tidal range, and climate, but the vertical extent of the zones is similar, especially in the high marsh (Scott and Medioli, 1986).

The surface zonation is useful for interpreting ancient assemblages and accurately locating former sea level limit because the vertical range of high marsh foraminifera is very narrow and because most of the species are well preserved in subsurface peat. The presence of high marsh foraminifera in a core marks the former strandline with a small error in elevation and provides clues to former marsh surface conditions (Scott and Medioli, 1978, 1980a). The vertical zonation has been used to calibrate the magnitude and rate of late Holocene sea level changes in Atlantic Canada and the expansion of tidal range in the Bay of Fundy (e.g., Scott and others, 1981; Scott and Greenberg, 1983; Smith and others, 1984; Brookes and others, 1985; Scott and Medioli, 1986).

Before foraminifera can be used as accurate indicators of sea level in a region, the vertical zonation must be defined at the surface in local marshes (Scott and Medioli, 1986). In the present study, one of the first to document the vertical zonation of foraminifera in a southern New England marsh, the surface distribution of foraminifera is defined in Great Sippewissett salt marsh on the western shore of Cape Cod (Massachusetts) (Figs. 1, 2a). The results will be useful for interpreting buried peat deposits of southern New England, particularly for reconstructing rates of regional sea level rise during the latest Holocene (ca. 3,000–4,000 years B.P. to present), when most marshes have been forming in this area (Redfield and Rubin, 1962; Bloom and Stuiver, 1963; McIntyre and Morgan, 1963; Bloom, 1964; Keene, 1971; Redfield, 1972; Rampino and Sanders, 1981).

MATERIALS AND METHODS

In this study, outer marsh is defined as western marsh areas that are close to Buzzards Bay, the inlet, the outer sandy tidal channels, and the barrier dunes (Fig. 2a). Central marsh consists of areas in the middle, near Quahog Pond. Inner marsh includes eastern marsh areas that are near uplands and inner, muddy creeks.

Collection of surface foraminifera, measurement of elevation, and site description were made across two transects (Fig. 2b). Sample sites were chosen in a variety of environments that cross the full extent of elevation from upland edge down to tidal creek beds (Table 1). Elevation was measured with a plane table and alidade beginning at a U.S. Coast and Geodetic Survey bench mark located at the edge of an upland in the inner marsh (Fig. 2a).

Four replicate samples of marsh peat were collected for foraminifera at each site with a copper tube (2 cm diameter, 2 cm depth), producing samples approximately 6 cm^3 in volume. In the field, samples were placed in buffered formalin with the protein stain rose Bengal added to identify organisms living at the time of collection (Walton, 1952). The samples were washed over 500-μm and 63-μm sieves, and the residue from the 63–500 μm size fraction was stored in 95% ethanol until it could be examined under the microscope. The fine mesh sieve is used in order to retain all the developmental stages of foraminifera and provide the most complete representation of assemblages (Leckie, 1987; Schroeder and others, 1987).

Foraminiferal distribution at the marsh surface is patchy (Scott and Medioli, 1980b), so at least two replicate samples were counted for each site. Each sample was split in a microsplitter that produces population counts with small error in reproducibility (Clark, 1974). Splits were examined wet under a binocular microscope and at least 250 to 300 foraminifera per replicate were counted (where available). Ostracodes, thecamoebians, diatoms, and other components were also noted. After splitting, coarse-grained samples that contained too few specimens (such as channel sand) were floated in tetrachloroethylene to concentrate foraminiferal tests. This method yielded a large number of specimens.

Total foraminiferal population (living plus dead) was used for the faunal analysis because it integrates seasonal and temporal fluctuations in populations and most accurately represents the fossilizable assemblage (Albani and Johnson, 1975; Scott and Medioli, 1980b). The number of living (stained) specimens was also noted in order to provide a complete representation of the populations at the time of sampling, but their distribution was not analyzed because no seasonal measurements were made. The protein stain rose Bengal was used despite problems reported by several authors (Walker and others, 1974; Boltovskoy and Wright, 1976) because it is still the most commonly used stain (Corliss, 1985) and is fairly reliable if used carefully. In this study, the number of living individuals is considered a minimum estimate because staining was done on the entire sample, and not just the washed fraction, so that some tests might have been left unstained (D.B. Scott, written communication, 1989). However, the estimate is considered reliable for several reasons: First, individuals were counted as living only if they were stained deep pink, as described by Walton (1952). Second, problematic tests were broken open to verify the presence of stained protoplasm. Third, the samples were examined in water so that stained protoplasm would be easier to see. Fourth, the stain was strong, so that individuals properly exposed to the stain had a good chance of being stained (most samples released excess stain into the ethanol after sieving). The numbers represent a minimum, since unstained living individuals are not detected, but overestimation of living populations is prevented because few falsely stained tests are counted.

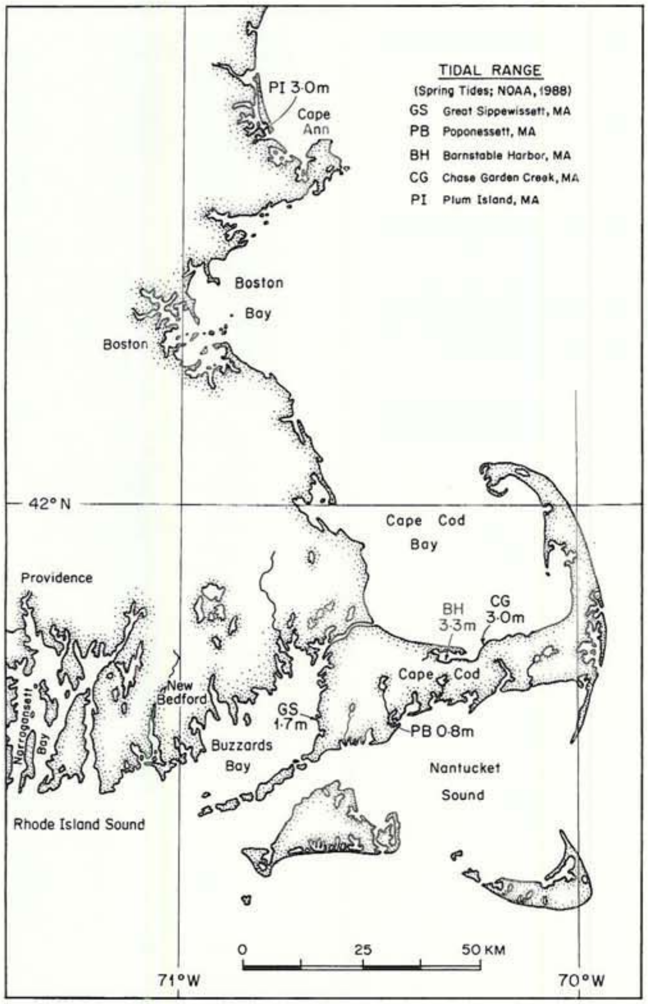

FIGURE 1. Map of Massachusetts coast showing tidal ranges for the other salt marshes discussed in this paper.

Salinity measurements were taken with an American Optical salinity refractometer and a YSI Model 33 salinity-conductivity-temperature meter at low tide in order to record extreme values due to subaerial exposure and groundwater flow. The measurements were made in a variety of marsh environments and represent trends vertically (from low marsh to high marsh) and laterally (from inner to outer marsh). Measurements were not made at individual sample sites because salinity varies hourly, daily, and seasonally.

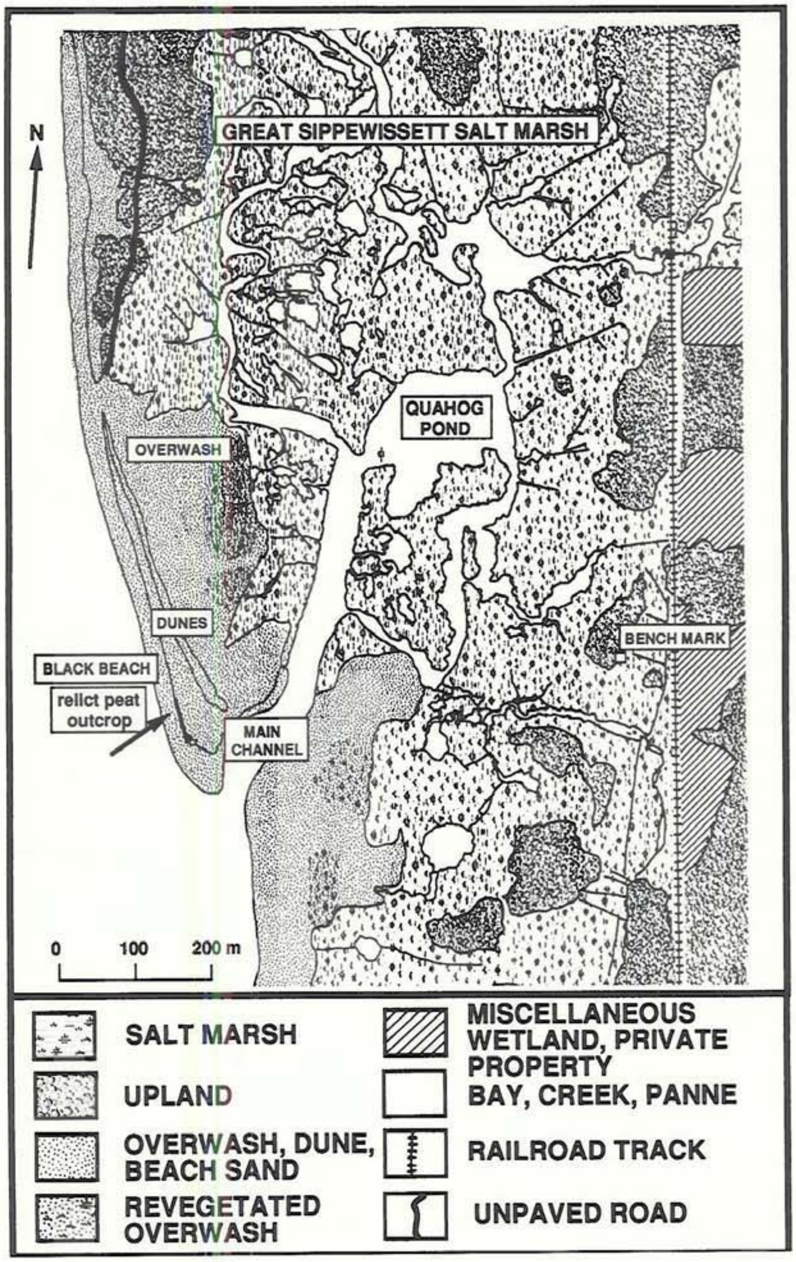

FIGURE 2a. Main features and environments of Great Sippewissett salt marsh.

ENVIRONMENTAL SETTING OF GREAT SIPPEWISSETT

PHYSICAL ENVIRONMENT

Great Sippewissett salt marsh is located on the eastern shore of Buzzards Bay and occupies a north-south trending depression bounded on its northern, eastern, and southern edges by Buzzards Bay moraine and outwash. It is fronted on the west by Black Beach, which consists of dune, beach, and relict peat deposits separating the marsh from Buzzards Bay (Fig. 2a; Oldale and Barlow, 1986). The marsh overlies the irregular surface of the Buzzards Bay outwash plain, which was deposited by the retreating Buzzards Bay lobe of the Wisconsinan ice sheet (Oldale and O'Hara, 1984).

Great Sippewissett, like other peat marshes of New England, is physically divided into low marsh and high marsh, and has subenvironments similar to those in the other marshes (Tiner, 1988; Fig. 3). In this study, only vegetated intertidal flats are considered true marsh environment because the presence of vegetation creates unique conditions not found in estuarine environments (e.g., unvegetated intertidal flats and tidal creeks) (Frey and Basan, 1985). The marsh basin covers 483,500 m^2, most of which consists of low marsh (44%) below mean high water that is flooded by almost all tides. High marsh (18%) occurs above mean high water and is restricted to a narrow fringe around the uplands that is flooded less frequently (Valiela and Teal, 1979). The rest of the area consists of microbial mats (3%);

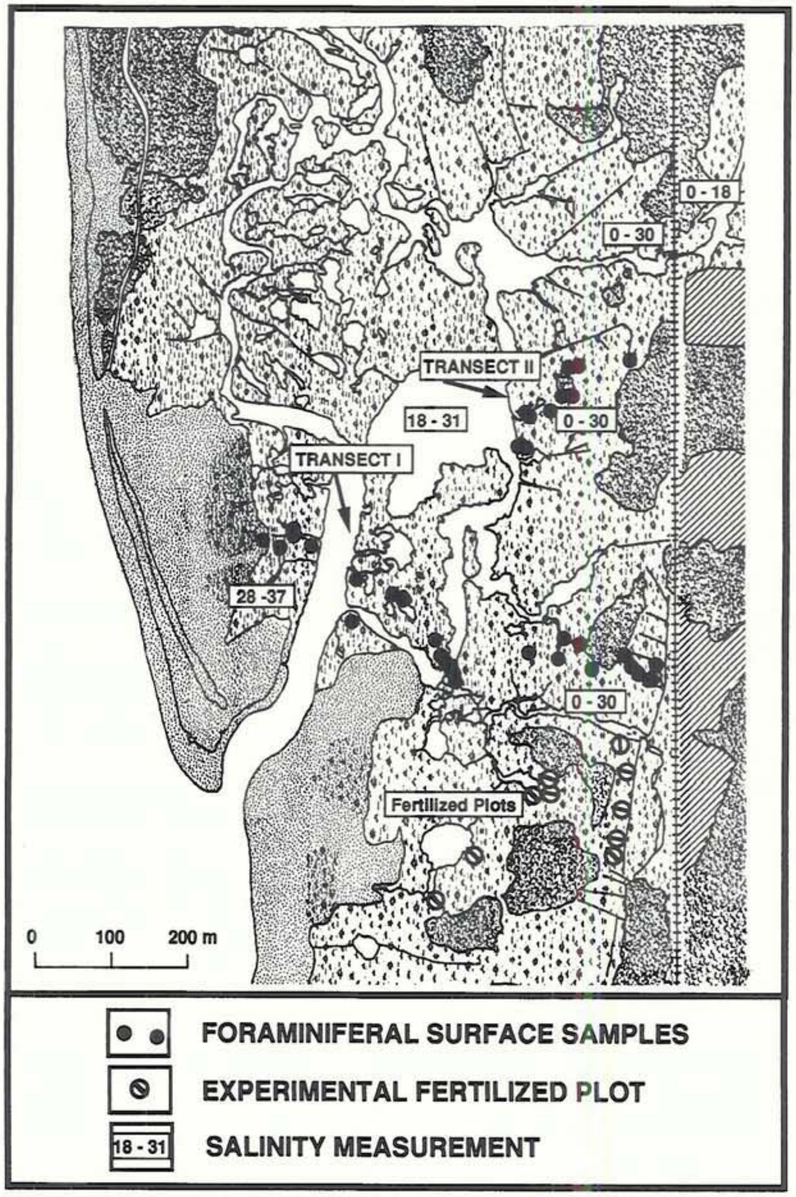

FIGURE 2b. Map showing location of transects, salinity measurements, and experimental fertilized plots in Great Sippewissett salt marsh.

sandy creeks (12%); and muddy creeks (21%); along with pannes, uplands within the marsh, and other areas (<2%) (Valiela and Teal, 1979). The upper border of the marsh is at highest high water, the limit of the tides. Wooded uplands are found above highest high water in the inner marsh, while dunes form the highlands of the western marsh. The marsh surface is interrupted by numerous pannes, most of which are filled with saline water at low tide. Mosquito ditches cut in the marsh act as tidal creeks.

The tide in Great Sippewissett is semi-diurnal and has an approximate spring range of 1.7 m and neap range of 0.9 m (NOAA, 1988). Tidal currents enter the marsh from Buzzards Bay through a single inlet into a wide sandy channel. This channel divides near the mouth into two creeks that again coalesce at mid-marsh in a broad depression called Quahog Pond (Fig. 2a). Tidal current energy is vigorous near the inlet and in deep outer tidal creeks, where tidal currents erode creek banks and transport a large volume of sand into the marsh. Tidal current energy is low in inner creeks and mosquito ditches. It is also low on most areas of the marsh surface because currents are slowed by dense stands of grass on creek banks, where most of the suspended sediment load is deposited (Stumpf, 1983; Frey and Basan, 1985).

SALINITY

Great Sippewissett, like other salt marshes in the humid, temperate climate of northeastern North America, is hyposaline in landward areas where groundwater flows in from the surrounding uplands. However, there is a wide range of salinity across the

TABLE 1. Vegetation and environmental settings on transects.

TABLE 1

VEGETATION AND ENVIRONMENTAL SETTINGS ON TRANSECTS

TRANSECT I

Site	Elevation (cm MSL)	Marsh Environment	Vegetation
I-1	-13.6	Sandy marsh near dunes	Spartina alterniflora (DF) Salicornia sp.
I-2	19.7	Sandy marsh near dunes and muddy side creek	S. alterniflora (TF), Salicornia sp., Limonium carolinianum
I-3	-16.7	Side creek bank	S. alterniflora (TF) (dense stand)
I-4	-40.9	Sandy side creek bed	None
I-5	13.6	Moist central marsh surface	S. alterniflora (DF), Salicornia sp., L. carolinianum, algae
I-6	-4.5	Sandy marsh in main creek	S. alterniflora (TF)
I-7	-40.9	Muddy side creek with *Ilyannassa*	None
I-8	28.8	Moist central marsh surface	S. alterniflora (DF), Salicornia sp., L. carolinianum
I-9	-22.7	Panne full of water at low tide	Submerged aquatic
I-10	22.7	Moist central marsh surface	S. alterniflora (DF), L. carolinianum
I-11	-22.7	Ponded water marsh behind creek bank	S. alterniflora (TF) (sparse stand)
I-12	-16.7	Side creek bank (sandy)	S. alterniflora (TF) (dense stand)
I-13	-71.2	Wide, sandy creek bed	None
I-14	-10.6	Side creek bank (sandy)	S. alterniflora (TF) (dense stand)
I-15	-22.7	Ponded water marsh behind creek bank	S. alterniflora (TF) (sparse stand)
I-16	10.6	Moist central marsh surface	S. alterniflora (DF),
I-17	-10.6	Side creek (sand & mud bed)	None
I-18	28.8	Moist central marsh surface	S. alterniflora (DF), Salicornia sp., L. carolinianum, algae
I-19	-13.6	Tributary creek bank	S. alterniflora (TF) (dense stand)
I-20	22.7	Moist marsh surface near mosquito ditch	S. alterniflora (DF)
I-21	13.6	Shallow, intermittently wet, sandy panne	S. alterniflora (DF)
I-22	50	Wet marsh surface 6 meters from upland	S. alterniflora (DF), Spartina patens
I-23	50.6	Moist surface covered by dense grass	Distichlis spicata, S. patens
I-24	50.9	Damp, grassy surface near bench mark	D. spicata, Scirpus americanus, S. patens
I-25	39.3	Wet marsh surface near muddy side creek, upland, and railroad tracks	D. spicata, S. americanus, Salicornia sp.
I-26	42.7	Damp, grassy surface near railroad track	S. alterniflora (DF), Phragmites australis
I-27	54.8	Damp, grassy surface near upland	D. spicata, S. americanus, S. patens, P. australis, Salicornia sp.
I-28	67.2	Moist surface adjacent to upland	P. australis, S. patens, marginal grasses/sedges/rushes
I-29	77.5 *?HHW?*	Upland soil, slightly moist	Upland shrubs & grasses, Spartina spp.
I-30	72.7	Damp, grassy surface next to upland	D. spicata, S. patens, other marginal grasses/sedges/rushes
I-31	39.1	Wet, grassy surface near mosquito ditch	D. spicata, S. patens, P. australis

surface in different marsh environments because of variable substrate composition, amount of groundwater input, and frequency and duration of tidal flooding.

Salinity is consistently higher in the outer marsh, and lower in the inner marsh (Fig. 2b). It is high (28–37‰) in sandy outer marsh areas near tidal creeks, overwash, and dunes, possibly because of frequent tidal inundation and more rapid drainage of the sandy peat in these areas. Salinity is lowest in the inner marsh (<1–28‰) because of freshwater drainage from glacial uplands within and surrounding the marsh (Valiela and others, 1978).

At low tide, tributary creeks and mosquito ditches of the inner marsh are well drained and salinity can be less than 1‰ near springs. The outer channels are mostly empty at low tide, except for slowly moving ebb water in deep areas. We assume that creek water is well mixed by the flooding tide because the tidal asymmetry is flood-dominated and freshwater inputs are variable and dispersed (Valiela and others, 1978). At high tide, salinity in the main channel (Fig. 2b) was the same as that measured in Buzzards Bay offshore from Black Beach (30.5–31.2‰; Rosenfeld and others, 1984). Inner creeks had the lowest high tide salinity, depending on the amount of freshwater input (20–31‰).

TABLE 1. Continued.

TABLE 1

VEGETATION AND ENVIRONMENTAL SETTINGS ON TRANSECTS

TRANSECT II

Site	Elevation (cm MSL)	Marsh Environment	Vegetation
II-1	-24.2	Sandy creek bank on Quahog Pond	Spartina alterniflora (TF) (dense stand)
II-2	-25.8	Ponded water marsh behind creek bank	S. alterniflora (TF) (sparse stand)
II-3	8.8	Moist central marsh surface	S. alterniflora (DF)
II-4	1.8	Steep side creek bank	S. alterniflora (DF, TF)
II-5	-48.5	Muddy tributary creek bed	None
II-6	18.2	Moist central marsh surface	S. alterniflora (DF), Limonium carolinianum, algae
II-7	31.8	Moist high marsh surface	Spartina patens, Distichlis spicata, S. alterniflora (DF), algae
II-8	8.8	Damp marsh surface	S. patens, D. spicata, S. alterniflora (DF), Salicornia sp.
II-9	23.6	Damp marsh surface near upland, with wrack	Scirpus americanus, S. patens, marginal grasses/sedges/rushes
II-10	50	Next to a panne that is full of water at low tide	S. patens, Juncus gerardii, Salicornia sp.
II-11	60 *?HHW?*	Relatively dry surface next to upland	S. patens, J. gerardii, Salicornia sp.
II-12	62.1	Relatively dry surface next to upland	Upland shrubs & grasses
II-13	28.8	Moist marsh surface	S. patens, J. gerardii, Salicornia sp.
II-14	26.9	Moist central marsh surface	S. patens, D. spicata, S. americanus, Salicornia spp.
II-15	-10.6	Next to muddy mosquito ditch	S. alterniflora (DF)

SUBSTRATE

The marsh substrate is peat with a total organic carbon content as high as 40–60% of dry weight (Howes and others, 1981). Sand content of the peat is variable, but it is highest in the outer marsh, where storms and tidal currents deposit it on the marsh surface. Rapid flood tidal currents deposit large amounts of sand from Buzzards Bay in the main channel and far back in side creeks. Organic detritus is exported from outer channels on the ebb tide (Valiela and others, 1978), but innermost tributary creeks and mosquito ditches contain thick accumulations of this material because of low energy in these areas.

VEGETATION ZONATION

The distribution of plant species in Great Sippewissett follows elevation and is modified by salinity and substrate (Fig. 3). It is similar to that in other peat marshes of New England described by Chapman (1960) and Tiner (1988). Salt-tolerant vegetation grows over nearly 100 cm of elevation, from the base of the *Spartina alterniflora* zone (25 cm below mean sea level) to the lower limit of upland vegetation, between 62 and 68 cm above mean sea level on transect I and between 60 and 62 cm on transect II. Vegetation content of the transects is shown in Table 1, and the vegetation zones are described below.

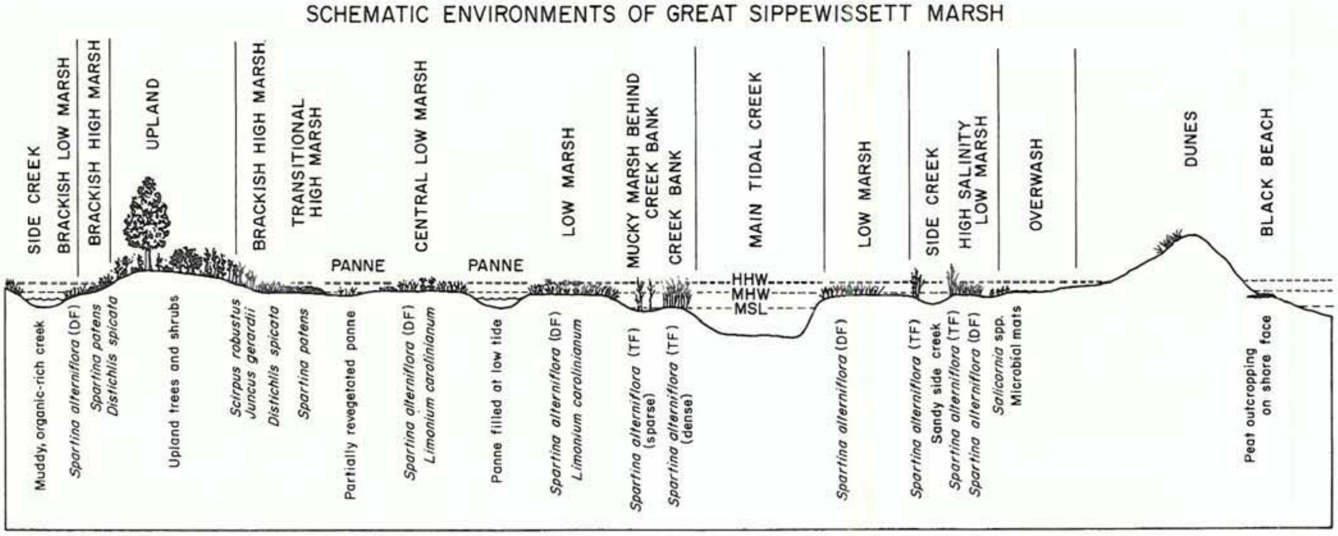

FIGURE 3. Schematic cross section of environments in Great Sippewissett salt marsh (after Tiner, 1988). The diagram is a composite of environments, not a representation of a particular transect.

Low marsh. This zone is defined by the dominance of *Spartina alterniflora.* The tall form of *S. alterniflora* grows in dense stands on creek banks and in sparse stands in ponded water depressions behind creek banks (Table 1). The short form of *S. alterniflora* vegetates wide areas of waterlogged marsh surface between creeks and uplands just below mean high water. Other species growing in this zone are *Limonium carolinianum* and several forms of *Salicornia.*

The marsh base is marked by the lowermost limit of *Spartina alterniflora* (tall), which is at 23 cm below mean sea level on transect I and at 25 below mean sea level on transect II. The highest occurrence of *S. alterniflora* (tall) is 20 cm above mean sea level, which gives the marsh base a 45-cm range, approximately the same as that reported from mesotidal (2–6 m range) marshes of Nova Scotia (Scott and Medioli, 1980a).

The low marsh zone includes all areas between the basal occurrence of *Spartina alterniflora* to the lowermost occurrence of *S. patens.* Its vertical extent is 60 cm on transect I (23 cm below mean sea level to approximately 43 cm above mean sea level) and 33 cm on transect II (25 cm below mean sea level to approximately 8 cm above mean sea level). However, the upper boundary may be gradational, ranging up to 50 cm above mean sea level on transect I and to 32 cm above mean sea level on transect II.

Middle marsh. This zone is defined by the presence of *Spartina patens* with *S. alterniflora.* In central marsh areas, *S. alterniflora, S. patens, Distichlis spicata, Salicornia* spp., *L. carolinianum,* and *Scirpus americanus* occur together in this zone. In sandy outer marsh, species of *Salicornia* and microbial mats are often the sole inhabitants of this zone.

The boundaries of the middle marsh zone overlap with low marsh and high marsh zones on both transects. On transect I, the base of this zone is found within the top 7 cm of the low marsh zone, as defined above (between 43 and 50 cm above mean sea level). The boundaries are less well defined on transect II, where the entire range lies within the low marsh zone (8 to 32 cm above mean sea level) and the upper limit is found within the base of the high marsh zone, between 23 and 32 cm above mean sea level.

High marsh. In most of Great Sippewissett, this zone forms only a narrow fringe around the uplands, although in innermost areas it is more extensive. It contains a mixture of species, including *D. spicata, Spartina patens, Scirpus robustus, S. americanus, Juncus gerardii,* and *Aster tenuifolia.* On transect I, these high marsh species grow between 50.6 cm above mean sea level and highest high water. On transect II, the lower limit of this zone overlaps with the low marsh zone, because a pure stand of high marsh vegetation was found at 23.6 cm above mean sea level. The upper limit of the high marsh zone is highest high water, which is marked by the basal occurrence of upland vegetation between 60 and 68 cm above mean sea level on transect I and between 60 and 62 cm above mean sea level on transect II (Table 1).

The vertical distribution of vegetation is modified by variations in salinity and substrate. For example, in the eastern high marsh, *Phragmites australis* grows in monospecific stands next to *Spartina alterniflora* stands in moist, brackish areas (<28‰), while *D. spicata* tolerates higher salinity nearby in drier soils of equal elevation (The Audubon Society Nature Guide, 1985). In addition, sandy peat, overwash deposits, and some pannes are populated by *Salicornia* species, *L. carolinianum,* and microbial mats, while moist, organic-rich peat at comparable elevation in the central marsh is vegetated by short *Spartina alterniflora.*

TABLE 2. List of foraminiferal species found in Great Sippewissett salt marsh.

Suborder TEXTULARIINA
- *Ammotium salsum*
- *Arenoparrella mexicana*
- *Eggerella advena*
- *Haplophragmoides manilaensis*
- *Miliammina fusca*
- *Miliammina* cf. *earlandi*
- *Polysaccammina hyperhalina*
- *Pseudothurammina limnetis*
- *Textularia earlandi*
- *Tiphotrocha comprimata*
- *Trochammina inflata*
- *Trochammina macrescens macrescens*
- *Trochammina macrescens polystoma*
- *Trochammina ochracea*
- *Trochammina squamata*

All species listed below are grouped as Calcareous Species in Appendix B

Suborder MILIOLINA
- *Cyclogyra involvens*

Suborder ROTALIINA
- *Ammonia beccarii*
- *Buccella frigida*
- *Elphidium* spp.
- *Haynesina germanica*
- *Helenina andersoni*
- *Rosalina floridana*

SURFACE FORAMINIFERAL DISTRIBUTION

GENERAL NOTES

Nineteen species of foraminifera belonging to fifteen genera were identified in Great Sippewissett (Table 2). The marsh fauna consists primarily of a low diversity group of agglutinated species typical of hyposaline marshes worldwide (Phleger, 1970; Murray, 1971a, b, 1973; Scott and others, 1983). Indigenous marsh species include *Trochammina inflata, T. macrescens* s. l., *Haplophragmoides manilaensis, Tiphotrocha comprimata, Arenoparrella mexicana, Polysaccammina hyperhalina,* and *Pseudothurammina limnetis.* Several estuarine species have the upper limit of their distribution in the low marsh. These species are included in the analyses, except for *Eggerella advena,* since fewer than five specimens were found in the samples.

The most abundant species in Great Sippewissett are *Trochammina inflata* and *T. macrescens* s. l., which includes two ecophenotypes. The ecophenotypes have been designated as *formae* based on aperture type (Scott and Medioli, 1980a). *T. macrescens macrescens* has a slit-like aperture and is associated with low salinity; *T. macrescens polystoma* (formerly *Jadammina polystoma*) has areal apertures and is associated with high salinity (Scott and Medioli, 1980a). Because their distribution corresponds with salinity, the *formae* are counted separately in this study. The *T. macrescens macrescens* form outnumbers the *T. macrescens polystoma* form in all areas of this hyposaline marsh.

Calcareous species in Great Sippewissett are rare and tend to be restricted to marsh surface near tidal creeks. They comprise primarily estuarine taxa that are common subtidally in Buzzards Bay (Murray, 1969) and reflect bay conditions more than marsh conditions (Phleger, 1970; Scott and Medioli, 1980a). They may only be seasonally abundant at the marsh surface. For example, living specimens dominated populations in a mid-July preliminary sampling of site II-3, but by August, few specimens remained and these were either badly etched or covered only by an organic lining. Since the tests dissolve in the acidic peat soon after death of the individual, calcareous species are not useful for paleoecological analysis in the marsh. However, they are included in the population counts to provide the most accurate representation of species composition at the time of sampling (August 1985).

Total population data are presented in Appendix B as relative abundance values, which represent the frequency of each species averaged among the replicates counted at a site. The absolute abundance of foraminifera (Appendix B) represents the number of individuals counted in a sample split, normalized to a standard sample size of approximately 6 cm^3. Absolute abundance ranges from a minimum of 0 to a maximum of 13,664 individuals/6 cm^3. At the time of collection, living individuals accounted for less than 20% of the population. All species had living representatives except for *Eggerella advena, Trochammina ochracea,* and *T. squamata.*

Ecologists studying Great Sippewissett since the early 1970's have added nutrients in the form of nitrogen, phosphorus, and sewage sludge to experimental plots in the southern marsh (Valiela and Teal, 1979; Fig. 2b). Nutrient enrichment of the marsh surface is apparently restricted to the plots, since visual examination shows that enhanced plant growth ends at the edge of each plot (Valiela and others, 1975). The plots retain as much as 80–94% of the nitrogen applied (Valiela and others, 1976), and much of the particulate nitrogen is exported by ebb tides (Valiela and others, 1978; Valiela and Teal, 1979). Although some of the added material may be spread to other areas of the marsh by flood tides that entrain ebb water from the previous tidal cycle, the amount is probably minor.

The present study proceeds with the assumption that marsh surface foraminiferal populations on the transects are unmodified and represent natural assemblages because of the evidence of restriction of enhanced plant growth to the plots and the export by ebb tides of nutrients released from the plots. In addition, a related study indicates that marsh foraminifera are not directly affected by nutrient enrichment, since relative and absolute abundance of foraminiferal populations in creeks draining the plots were not altered relative to those in control plots (Foreman, 1989). Secondary effects, such as changes in predator density and nature of the substrate, may be important, but they have not been quantified.

DISTRIBUTION OF KEY SPECIES

Foraminiferal distribution across the two transects results from the interaction of the influences of elevation, salinity, and proximity of tidal creeks. Species composition is not identical in samples from sites at equal elevation along the transects because of heterogeneity in environmental factors such as salinity, substrate, surface moisture, nutrients, and water energy (Buzas, 1969; Phleger, 1970; Clark, 1974), but key species of secondary and minor abundance are associated with particular limits of elevation and salinity and therefore are useful for defining a vertical zonation. The distributions of *Trochammina inflata* and *T. macrescens* s. l. do not appear to follow elevation, but they are the most abundant species at all elevations in this marsh.

To simplify data presentation, species are separated into groups, each consisting of the relative abundance of one or more species with similar or distinctive distribution and representing the average of replicate samples at each site. The average relative abundance of each group is plotted against elevation along the transects in order to define a vertical zonation and identify trends (Figs. 4, 5). Visual interpretation of the data was the most successful method for defining environmental and vertical trends because quantitative methods yielded inconclusive results. Regression analysis had weak correlation (R^2 for all samples is less than 0.4), and simple cluster analysis (Q-mode and R-mode) provided no more information than that apparent from visual representation of the data. The species groups are described below. Rare occurrences are defined as relative abundance less than 2%.

(1) *Trochammina macrescens macrescens* and *T. inflata* are the most abundant and widespread species in Great Sippewissett. Together or separately, they constitute more than 20% of the population at all sample sites. They are more abundant on transect I than on transect II (Appendix B). At a few sites, they make up more than 90% of the population, but such occurrences do not appear to follow elevation. At one site on transect I, these taxa are the major constituents, along with lesser numbers of *T. macrescens polystoma,* of an assemblage from low elevation, sandy marsh behind the dunes (site I-2; Fig. 4). However, together they dominate high marsh sites, where other species are rare, and can be used as high marsh indicators because such occurrences are considered equivalent to the Zone I assemblage of Scott and Medioli (1980a).

(2) The relative abundance of *Trochammina macrescens polystoma* increases in the high salinity outer marsh and decreases toward inner marsh and uplands. In the inner marsh, it is only common at two sites on transect II (II-11, II-13).

(3) *Miliammina fusca* and *Ammotium salsum* are most abundant in the low marsh, where surface moisture is high and salinity exceeds 28‰. Such environments include low marsh surface, creeks, and ponded water marsh. The latter environment consists of depressions behind creek banks with standing water and sparse stands of *S. alterniflora.* These species are also found in low relative abundance away from tidal creeks on wide areas of marsh vegetated by short *S. alterniflora. Ammotium salsum* is most common in ponded water depressions and in one sandy, intermittently wet panne near an upland (site I-21, 13.6 cm above mean sea level).

(4) *Trochammina squamata, T. ochracea, Textularia earlandi, Arenoparrella mexicana, Polysaccammina hyperhalina,* and a variety of calcareous species seldom individually make up more than 2% of the assemblage at any site. They are most abundant in the low marsh, where they are found with *M. fusca* and *A. salsum.* Most of these species are restricted to areas near tidal creeks because they are subtidal taxa controlled by estuarine conditions, rather than marsh surface conditions. For example, *Trochammina squamata, T. ochracea,* and *Textularia earlandi* are found only close to tidal creeks (creek banks, adjacent ponded water depressions, and pannes). *Arenoparrella mexicana* is most common on creek banks, but it is also found at several marsh surface and creek stations. Phleger (1965) suggested that this species prefers a well-drained substrate, and its abundance on sandy creek banks in Great Sippewissett supports this idea. The distribution of *A. mexicana* in this marsh may be unusual, however, since it is characteristic of brackish areas in other New England marshes (Parker and Athearn, 1959; Clark, 1974). *Polysaccammina hyperhalina* is rare and restricted to areas adjacent to creeks, and in ponded water marsh.

(5) *Tiphotrocha comprimata* is found over a wide range of elevation but is most abundant in the inner marsh just below mean high water (sites I-22, I-23, I-26, I-26, II-10), where low marsh species (e.g., *M. fusca, A. salsum, Trochammina squamata, T. ochracea,* calcareous species) decrease in abundance. *Tiphotrocha comprimata* is a good indicator of the transition between low and high marsh because its relative abundance decreases markedly above mean high water. Its distribution in Great Sippewissett is the same as that reported from marshes of Atlantic Canada, where it is a lower high marsh species (Zone I_B of Scott and Medioli, 1980a) whose abundance decreases at highest elevations.

(6) *Haplophragmoides manilaensis* reliably marks areas of marsh with brackish salinity (<1–28‰). These areas occur at low and high elevation near the inner marsh–upland border, where groundwater input increases and tidal influx decreases. In Great Sippewissett, this species is restricted to the high marsh on transect I (although it is absent from high marsh sites I-25 and I-26), where the abundance of lower marsh species (principally *T. comprimata* and *M. fusca*) decreases. However, on transect II, it occurs over a wide range of elevation and is found with abundant low marsh species. This species is common in brackish marshes (Parker and Athearn, 1959; Scott and Medioli, 1980a).

(7) *Pseudothurammina limnetis* is found at almost all stations on transect II but is only abundant at one site on the eastern end of transect I. Its distribution does not correspond with elevation or salinity measurements, but it is common in the low and transitional high marsh (e.g., at low elevation, site II-6, 18.2 cm above mean sea level, with short *S. alterniflora*). It is also abundant in one high marsh sample (I-28; 67.2 cm above mean sea level), where *Phragmites* grows

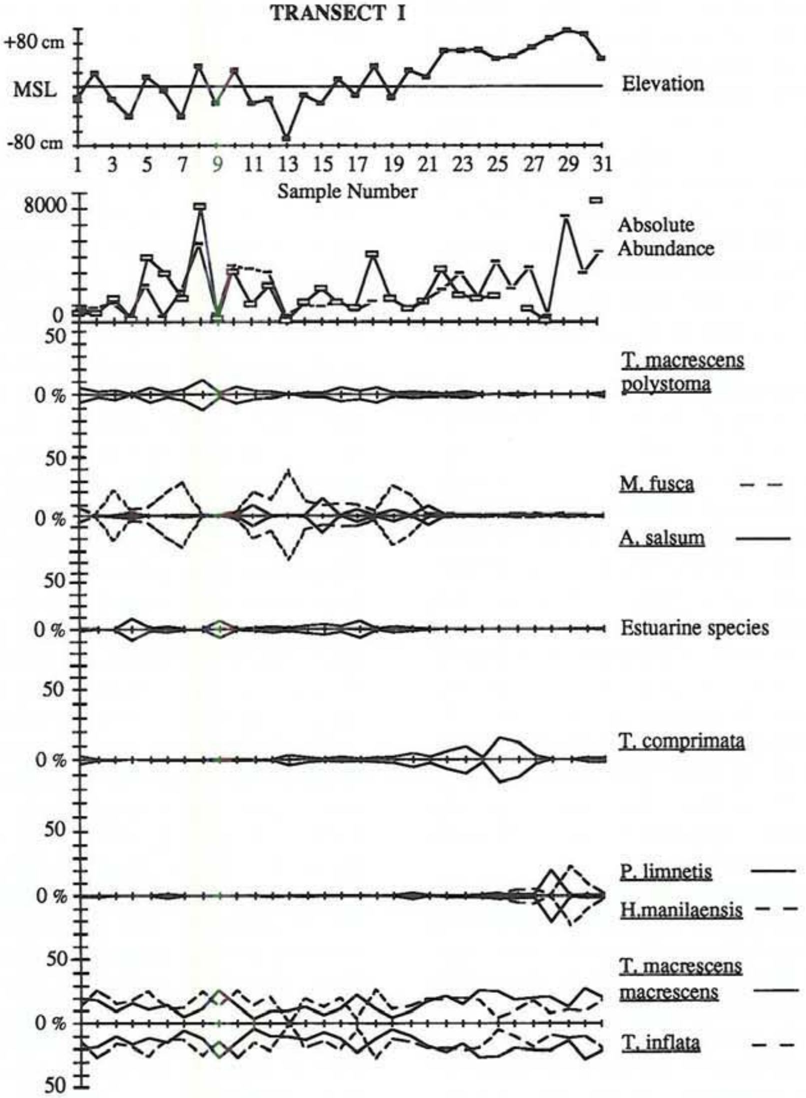

FIGURE 4. Abundance of foraminiferal species on transect I plotted against elevation of marsh surface relative to mean sea level (MSL). Relative abundance plots represent the average of two or more replicate samples counted at a site. Absolute abundance is the total number of foraminifera per 6 cc, and the lines on the graph represent separate values for each replicate.

near the railroad tracks. However, this sample contains very few foraminifera so its significance is unclear. The distribution of *P. limnetis* in Great Sippewissett is similar to that reported from Nova Scotia marshes, where it is most common at low and middle marsh elevation (Scott and Medioli, 1980a).

(8) A morphological variant of *Miliammina* with a fine-grained test is found in small numbers on both transects. It is designated *Miliammina* cf. *M. earlandi* because type specimens were not examined (Fig. 4, 5; Appendix B). It is more common on transect II in the low marsh (especially II-1, II-2, II-8) than on transect I, where it is absent except for rare occurrences in the transitional high marsh (I-23, I-27). Similar specimens are reported from low salinity, landward sites in other marshes (Clark, 1974; Ellison and Nichols, 1976). This category also includes specimens found on transect II that resemble *Miliammina* but have only an organic lining.

VERTICAL DISTRIBUTION OF SPECIES

A vertical zonation of foraminifera is defined for Great Sippewissett by comparing species distribution with elevation (Fig. 6). The distribution of secondary and minor species is the most useful criteria in defining zones because changes in the abundance of these species follows elevation. Because *Trochammina inflata* and *T. macrescens* s. l. are abundant in all environments, their distribution is only important where secondary and minor species are scarce, primarily in the highest marsh.

Low Marsh. The low marsh contains abundant *M. fusca, A. salsum,* estuarine species, *P. limnetis,* and

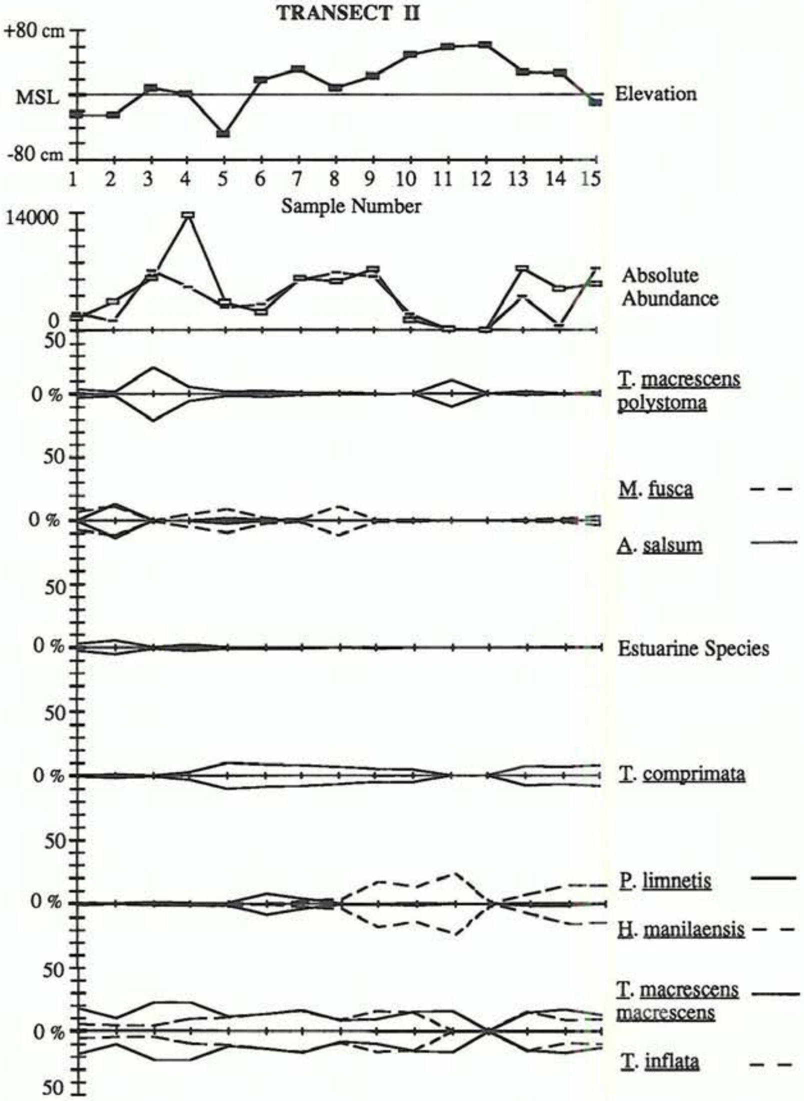

FIGURE 5. Abundance of foraminiferal species on transect II plotted against elevation of marsh surface relative to mean sea level (MSL). Relative abundance plots represent the average of two or more replicate samples counted at a site. Absolute abundance is the total number of foraminifera per 6 cc, and the lines on the graph represent separate values for each replicate.

Miliammina cf. *M. earlandi* (Figs. 4–6). This zone has the greatest vertical range, which varies between the two transects. It extends from low marsh surface to creek bottom environments. It includes all areas between the base of the *alterniflora* zone and 30 cm above mean sea level on transect I, and all areas between the marsh base and 20 cm above mean sea level on transect II.

Transitional high marsh. This zone lies just below mean high water (56 cm above mean sea level), where the relative abundance of low marsh species decreases and the relative abundance of *T. comprimata* increases. *Trochammina inflata* and *T. macrescens macrescens* are abundant on both transects. The vertical range of this zone varies between the transects. On transect I it extends from 30 to 56 cm above mean sea level, and on transect II it extends from 20 to 56 cm above mean sea level. The decrease in *T. comprimata* at mean high water marks the upper limit of this zone (Figs. 4–6).

High marsh. This zone is defined by reduced abundance of low and transitional high marsh species and persistent dominance of *Trochammina inflata* and *T. macrescens macrescens.* In low salinity areas, *Haplophragmoides manilaensis* is also common, but because this species is found over a wide range of elevation in such areas, it does not reliably mark high elevation. *Pseudothurammina limnetis* also occurs in this zone (site I-28) but is not considered an important constituent of the vertical zonation because it is rarely preserved in the subsurface.

High marsh is found in landward areas where high marsh vegetation fringes uplands (e.g., I-28, II-11). This zone has the narrowest range of those defined in Great Sippewissett, with an elevation interval of 22 cm on transect I and of less than 10 cm on transect II

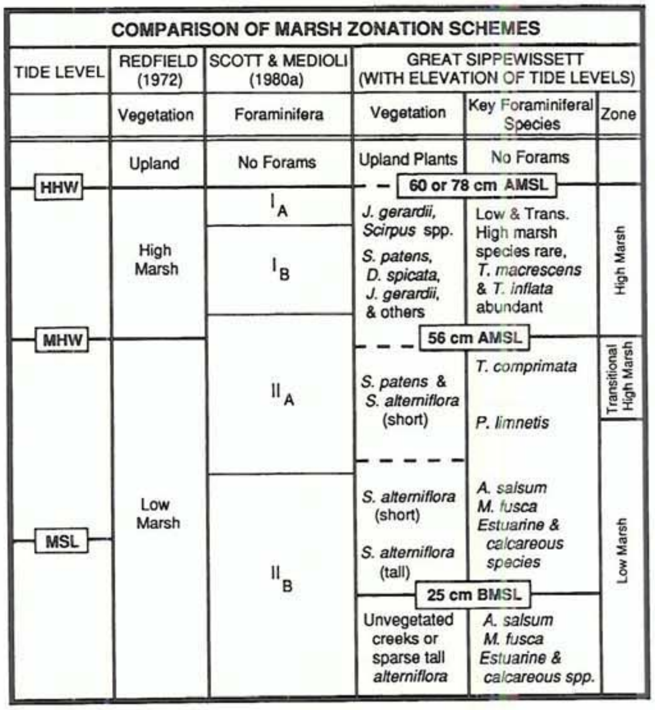

FIGURE 6. Comparison of marsh zonation scheme in Great Sippewissett with those in Barnstable Harbor (Redfield, 1972) and Chezzetcook Inlet (Scott and Medioli, 1980a). Tide levels are calculated from the bench mark in Great Sippewissett and extrapolated to the other localities. BMSL = Below mean sea level; AMSL = Above mean sea level; HHW = Highest high water. *Trochammina inflata* and *Trochammina macrescens macrescens* are dominant in all zones but are not listed for the low and transitional high marsh because they are not diagnostic of these zones.

(Fig. 6). Its lower limit is mean high water (56 cm above mean sea level) and its upper limit is highest high water, which is defined by the sharp decrease in foraminiferal numbers at the strandline. Highest high water is slightly above 77.5 cm above mean sea level on transect I (above site I-29) and at approximately 60 cm above mean sea level on transect II (Figs. 4–6).

DISCUSSION

SURFACE DISTRIBUTION OF FORAMINIFERA

The distribution of foraminiferal species in Great Sippewissett has been compared with environmental factors, including elevation, salinity, proximity to tidal creeks, and surface moisture. The correspondence between species distribution and elevation is used to define a vertical zonation that consists of low, transitional high, and high marsh zones whose species composition is somewhat modified by salinity and other factors. The narrow high marsh zone that occurs just below highest high water is considered equivalent to the Zone I assemblage of Scott and Medioli (1980a) because it is not monospecific. Only one site (II-11) contained an assemblage resembling Zone I_A of Scott and Medioli (1980a), but it is not equivalent because it contains *H. manilaensis* with *T. macrescens,* and the population is too small to be an accurate indicator (Appendix B). The absence of Zone I_A in Great Sippewissett may be an artifact of the small number of strandline samples taken (I-28, I-29, I-30; II-11) and of the lack of sampling in northernmost and southernmost areas of the inner marsh. The vertical zonation might be improved by further sampling of the marsh edge in these areas, as well as in the outer marsh near the western uplands. The greater complexity of species composition and wider vertical extent of the high marsh zone on transect I might also indicate that it could be subdivided by further sampling to locate Zone I_A. The larger vertical extent of vegetation and foraminiferal zones on transect I may also be due to decreased tidal range inward, a phenomenon reported from other marshes (Scott, 1977; Scott and Medioli, 1980a; Boon III and Byrne, 1981; Lincoln and FitzGerald, 1988).

COMPARISON WITH OTHER MARSHES

The foraminiferal fauna of Great Sippewissett is similar to that of other hyposaline marshes, in which salinity decreases with elevation because of freshwater input from adjacent uplands (Phleger, 1970; Murray, 1973; Scott and Medioli, 1980a). In Great Sippewissett, foraminiferal species typical of hyposaline marshes are found in brackish (<1–28‰) areas near uplands and springs, and include *T. comprimata* and *H. manilaensis.* By contrast, only a few species associated with normal marine and hypersaline marshes are present in Great Sippewissett. They are restricted to the outer marsh near tidal creeks and comprise small numbers of *Helenina andersoni* and the estuarine species.

Southern New England

The foraminiferal fauna of Great Sippewissett is most similar to that of other marshes in southern New England, and compares most closely with that of Poponessett Bay, on the southern shore of Cape Cod (Fig. 1). This hyposaline marsh (6–34‰; Parker and Athearn, 1959) has a microtidal range (0.9 m mean; NOAA, 1988). As in Great Sippewissett, *T. macrescens polystoma* is found in high salinity areas along with a species designated as *Reophax* sp. (which resembles *Polysaccammina hyperhalina*). *Trochammina macrescens macrescens* is more common in brackish (0.6–28.2‰) high marsh, along with *A. mexicana,* and *H. manilaensis* (erroneously identified as *H. hancocki*; D. B. Scott, oral communication, 1989).

The foraminiferal assemblages of Chase Garden Creek, a hyposaline marsh (<30‰) adjacent to Barnstable Harbor on Cape Cod Bay (Fig. 1), shares with Great Sippewissett an abundance of *T. macrescens polystoma* in high salinity (30‰) outer marsh and of *T. macrescens macrescens* in low salinity (5–30‰) areas (along with *A. mexicana, T. comprimata,* and *Reophax curtus*). However, the most widespread species are *M. fusca* and *T. inflata. Trochammina macrescens polystoma* outnumbers *Trochammina macrescens macrescens* in all environments, and *H. manilaensis* is found in areas of moderate salinity (10–30‰). Such a faunal composition may reflect differences in salinity distribution between the two marshes, since the abundance of *M. fusca, T. inflata,* and *T. macrescens polystoma* is more characteristic of normal marine and hypersaline marshes (Murray, 1973). The differences in foraminiferal distribution between Great Sippewissett and Chase Garden Creek highlight the need to define the local surface zonation before attempting to use foraminiferal assemblages to trace sea level rise.

Farther north on the Massachusetts coast, the marshes of Plum Island contain a foraminiferal distribution similar to that in Great Sippewissett despite a tidal range that is twice as large (2.7 m; NOAA, 1988) (Fig. 1). Four assemblages with basic similarities to those in Sippewissett can be related to elevation and marsh position (Jones and Cameron, 1987): (1) high marsh, containing *T. macrescens, T. comprimata, A. mexicana,* and *Haplophragmoides bonplandi* (=*H. manilaensis*; D.B. Scott, oral communication, 1989); (2) low marsh, containing *A. salsum, M. fusca* and *T. inflata*; (3) tidal channel upper margin, containing *M. fusca* and *T. inflata* and (4) elevated surfaces (overwash and *Juncus gerardii* zone) containing a mixed assemblage of dead specimens. The abundance of *Haplophragmoides bonplandi* in the high marsh indicates the presence of low salinity in the upper reaches of this marsh.

Other Regions

The foraminiferal assemblages in Great Sippewissett are also similar to those of hyposaline marshes in other temperate regions. Three Nova Scotia marshes—Chezzetcook Inlet (microtidal, 1.8 m; Atlantic coast of Nova Scotia), Chebogue Harbor (mesotidal, 2.45 m; Atlantic coast of Nova Scotia), and Wallace Basin (mixed tidal regime with range similar to Chezzetcook; Gulf of St. Lawrence)—are hyposaline marshes with vegetation and physical characteristics like those in Great Sippewissett (Scott and Medioli, 1980a). The species zonation is essentially the same as in Great Sippewissett, with calcareous taxa confined to low marsh and *H. bonplandi* to brackish areas.

The assemblages in Great Sippewissett differ from those in the hypersaline marshes of Mexico, southern California, and Italy. The species common in these marshes—including *T. macrescens polystoma, P. hyperhalina,* and calcareous taxa (Phleger and Ewing, 1962; Scott, 1976b; Petrucci and others, 1983)—are usually rare and restricted to high salinity, low elevation areas in Great Sippewissett.

The foraminiferal assemblages in Great Sippewissett are also quite different from those of Sapelo Island (Georgia). The marshes there, like others in the southeastern United States, have a much higher diversity of agglutinated and calcareous species (Goldstein and Frey, 1986). The marsh assemblages are dominated by agglutinated species that are less abundant (e.g., *A. mexicana*) in Great Sippewissett, as well as calcareous and agglutinated species (e.g., *Siphotrochammina lobata, Textularia palustris, Reophax* cf. *R. arcticus, Ammobaculites dilatatus, Ammotium pseudocassis*) not found in the New England marshes (Goldstein and Frey, 1986). The differences in species composition might be attributed to climate, higher silt and clay content of the substrate, and higher salinity in the southeastern marshes.

Summary

Assemblage composition and distribution in Great Sippewissett are most similar to marshes in temperate climates with hyposaline conditions (salinity ranging down to less than 1‰) and microtidal to mesotidal range. Such conditions are typical of New England and Atlantic Canada, and the closest parallels are with assemblages from these areas—Poponessett Bay (Parker and Athearn, 1959), on southern Cape Cod; Plum Island, north of Boston (Jones and Cameron, 1987); and marshes of Nova Scotia's Atlantic coast. In these areas, high marsh assemblages have similar, definable species composition and are effective strandline markers because their abundance can be linked to changes in elevation and salinity. It is also likely that foraminiferal faunas of Great Sippewissett are similar to those in marshes between southern Cape Cod and Long Island (southeastern Massachusetts, Rhode Island, and Connecticut).

APPLICATION TO CORES

The foraminiferal zonation in Great Sippewissett provides a tool for interpreting former sea level from cores because it divides the marsh into assemblages with defined elevation intervals. In addition, most of the key species are well preserved in the subsurface (Scott, 1989). In particular, the narrow range of the high marsh zone relative to highest high water and the low diversity of species present makes it the best strandline indicator. By contrast, the low marsh zone has a very wide range and overlaps with subtidal assemblages. The transitional high marsh zone has a narrow range but it is less easily defined than the high marsh zone. However, all zones can provide information on past environmental conditions because they are associated with particular ranges of salinity, substrate, surface moisture, and proximity to tidal creeks (e.g., to distinguish pannes from dry, sandy marsh, and creek banks from marsh surface vegetated by short *alterniflora*).

If Zone I_A of Scott and Medioli (1980a) could be identified in this marsh, the vertical width of the strandline marker could be reduced and its accuracy for estimating former sea level improved. However, in its present form, the high marsh zone allows sea level estimation with a smaller error than that made with other methods and it is reliable for distinguishing high marsh from low marsh. The abundance of *T. inflata* and *T. macrescens macrescens* and rarity of other species in a core of high marsh peat would indicate that the deposit formed within 6 to 22 cm of the former strandline, in the upper $1/7$ of the tidal range and the upper $1/4$ of the marsh.

In future studies, this zonation can be compared to that in other southern New England marshes and combined with additional sea level indicators to interpret foraminiferal occurrences in buried marsh deposits of the region. Such study will allow accurate calibration of submergence rates along this coastline during the last 2,000 years.

CONCLUSIONS

Foraminiferal distribution at the surface in Great Sippewissett is the result of interactions between many environmental variables, including elevation, salinity, surface moisture, and proximity to tidal creeks. However, elevation and salinity can be isolated as primary variables because key species are found at consistent intervals of elevation and ranges of salinity. Although the low marsh, transitional high marsh, and high marsh zones are slightly modified by salinity and other factors, they form the basis of a useful tool for tracing marsh development and sea level rise in this basin. The high marsh zone is the most accurate indicator of sea level, since it marks the strandline with an error of less than 22 cm. It will be useful for estimating sea level rise and interpreting marsh development from buried marsh deposits in this region. The vertical zonation in Great Sippewissett is similar to that defined for marshes in other regions (Scott and Medioli, 1978, 1980a), and the composition of the assemblages is most similar to that in hyposaline peat marshes of southern New England and the Atlantic coast of Nova Scotia. The assemblages in this marsh are least similar to those of the southeastern United States and Gulf of Mexico.

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APPENDIX B. CONTINUED

								RELATIVE ABUNDANCE OF FORAMINIFERA -- CENTRAL MARSH TRANSECT (II)																
24	25	26	27	28	29	30	31	Sample Site		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
50.9	39.3	42.7	54.8	67.2	77.5	72.7	39.1	Elevation (cm AMSL)		-24.2	-25.2	8.8	1.8	-48.5	18.2	31.8	8.8	23.6	50	60	62.1	28.8	26.9	-10.6
2	2	2	2	2	1	1	2	Number of Replicates		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1276	3668	1864	3248	64	6752	2888	4368	Absolute Abundance	Rep. 1	1984	1024	6992	5072	2688	3080	5920	6840	6368	1896	9	0			
1432	1548	?	760	48	No Sample		7456	(# foram/2 cc)	Rep. 2	1332	3328	6128	13664	3208	2014	6080	5696	7232	1216	32	0			
								Trochammina macrescens	L			2	0.1			0.2				10			0.4	
0.6		1.7					2.8	*polystoma*	T	6.6	3	41.4	11.6	3.4	4.5	2.4	1.3	0.4		21.1		2.7	0.8	1.9
								Miliammina	L	0.5	0.3		0.3	0.7			1.5							
1.9	0.4	2.9	2.7		2.3	0.8	0.9	*fusca*	T	15	23.2	0.5	9.3	19.5	5.1	2.2	22.9	1.4	1.6			2.1	2.6	7.1
								Ammotium	L		4.3			0.7	0.4									
								salsum	T	0.6	27.3		0.6	5.1	1.3		0.6							
								Polysaccammina	L		0.1													
								hyperhalina	T		5.6	0.1		0.5										
								Textularia	L	0.2			0.2											
								earlandi	T	0.5	2.1	0.1	1	0.1										
								Arenoparrella	L	0.7			0.2											
							0.4	*mexicana*	T	1.5	0.1		1.4	0.1										
								Trochammina	L															
								squamata/ochracea	T	1.2	2.7			0.2										
								Calcareous	L	2.1	0.1	0.4	1.2		0.7	0.1		0.1						
								species	T	2.1	0.1	0.4	1.7		0.9	0.1		0.1						
0.3	2.7	2.7	0.8	16.7	1.2		0.3	*Pseudothurammina*	L	0.1	0.2	0.5	0.2		0.5	0.6	0.1		1			0.5	0.7	
1.7	3.6	3.4	2.7	41.7	1.2	1.4	2.5	*limnetis*	T	1.6	0.8	2.6	2.3	1.4	16.6	7.9	1	1.2	1.6			2.1	1.5	
	2.8	0.5					0.1	*Tiphotrocha*	L				0.3	0.1	0.3	0.2	0.4	0.8	2.5			0.4	3.4	3.3
2.8	31.0	24.5	5.5		0.7	3.6	3.2	*comprimata*	T	0.9	3.5	0.3	5.4	20	17.7	16.8	14.3	10.5	9.4			15.6	13.7	16.7
					5.6	0.8	0.2	*Haplophragmoides*	L							3.3	0.3	0.1	3.2	20		0.1	1.5	3.2
1.3	5.0	9.8	10.9		47.5	20.7	5.1	*hancocki*	T	0.3	0.4		0.2	1.6	0.1	5.1	7.8	35.2	27.2	46.7		15.8	29.5	28.4
								Miliammina	L	0.8	0.4			0.1										
			1.6					species 1	T	22.3	2.1	0.4	0.8	2.8			18							
0.5	0.1				0.2		0.5	*Trochammina macrescens*	L	0.8	1.1	3.8	0.9		0.5	0.8		1.1	4.3			0.1	1.8	3.4
38.0	9.0	19.3	36.0	16.7	22.5	19.0	37.8	*macrescens*	T	36.6	20.5	45.9	46	23	27.2	33.3	16.4	19.3	30.6	32.2		30.2	34.3	26.3
0.8	3.7	1.3	2.3		1.9	2.5	1.2	*Trochammina*	L	0.9		0.9	0.6		1.2	1.7		1.2	4.8			1.4	1.5	2.4
52.5	51.0	38.4	40.7	41.7	25.9	54.5	42.5	*inflata*	T	10.9	8.6	8.3	19.6	22.2	26.5	32.2	17.7	31.9	29.7			31.5	17.5	19.6
1.2							4.7	Calculation error																
3	4	3	2	1	4	2	5	Number of species	L	8	7	5	9	4	6	7	4	5	5	2		5	6	4
8	5	6	6	3	6	6	8	in sample	T	13	14	10	13	13	9	8	9	8	6	3		7	7	6
									L=Living, T=Total, Rep.=Replicate															