Marsh Foraminiferal Distribution in the Minas Basin and their Occurrence in Marsh Cores from the Region

by David A. Smith

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ABSTRACT

The foraminiferal assemblages present along two Kingsport marsh surface transects were delineated into zones with respect to vertical elevation above mean sea level (a.m.s.l.), and salinities. The highest vertical zonation, Zone I, is distinguished at its upper limit, Higher High Water (HHW), by the disappearance of foraminifera in the sediments, while the zone itself is defined by the dominance of *Trochammina inflata*. The horizontal range of this zone is approximately 20 meters, while the vertical range is approximately 1 meter, from 650-750 cm above mean sea level. Zone II, the middle and lower marsh zone, is distinguished at its lower margin by the sharp decline of agglutinated species and the increase of calcareous estuarine species. This zone is defined by the dominance of both *Miliammina fusca* and *T. inflata*, with significant numbers of *Tiphotrocha comprimata* and increasing occurrences of calcareous estuarine specimens in the lower marsh.

Using $Carbon_{14}$ dating, marsh foraminiferal zonations in subsurface sediment, and tidal amplifications calculated for four sea level curves, actual relative sea level rise in the Bay of Fundy was determined. These figures range from 16 cm/100 years at Kingsport to 25.6 cm/100 years at Granville Ferry marsh.

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INTRODUCTION

Recent marsh foraminifera are commonly discussed in terms of their spatial distribution in marshes, their relationship to elevation above sea level and the salinity and vegetative regimes in which the foraminiferal assemblages occur (e.g., Scott and Medioli, 1980a). The distribution of foraminifera and flora in a marsh can be associated into vertical zones, which then can be correlated on a regional scale (Scott and Medioli, 1978, 1980a). The vertical foraminiferal zonations of a marsh are of importance to the relocation of paleo-sea levels, and their use as sea level indicators has a potential accuracy 20 times greater than any previous method, that is a $\pm$ 5cm accuracy (Scott and Medioli, 1980a). The margin of error depends on a series of factors resulting from problems involved in drilling measurements, compaction of peat in cores, or the absence of marsh sub zone 1A, which is the only zone with an accuracy of $\pm$ 5cm. The method, when properly applied, can record the small variations in relative sea level observed in the last 3,000 - 4,000 years.

Since the Bay of Fundy has the highest tides in the world, whose tidal ranges have increased through time, the effect of tidal amplification must be calculated for sea level curves and subtracted from the apparent relative sea level rise to determine the actual amount of relative sea level rise.

In this study a combination of accurate surficial assemblage information, foraminiferal assemblages in cores, $Carbon_{14}$ dates from the base of cores, and calculated tidal amplification is used to produce a precise estimate of actual relative sea level changes in the Bay of Fundy.

PREVIOUS WORK

Studies in the distribution of recent marsh foraminifera have seen a steady increase since the work of F. B Phleger (1954, 1955, 1965a,b, 1966, 1967, 1970). His work covered descriptions of marsh foraminiferal distributions from various maritime areas of the United States and Europe.

Scott (1976) illustrated the close relationship between floral and foraminiferal assemblages with sediment surface elevation in southern California marshes. Since then Scott (1977), Scott and Medioli (1978 a,b, 1980 a,b), and Scott et al. (1981), have demonstrated the relationship of marsh foraminifera to sea level in several areas of Atlantic Canada.

Deonarine (1979) reaffirmed the relationship proposed by Scott (1976), relating marsh flora to foraminiferal distribution and the actual vertical distribution of marsh foraminifera.

Scott et al. (1981) examined marshes on Prince Edward Island and found them relatively similar to Nova Scotian marshes, with respect to salinities and elevation, and they used foraminiferal zones to determine relative sea level rise.

METHODS

Two detailed surface transects were obtained from the Kingsport Marsh at low tide, collecting surficial sediment samples and other data (vegetation cover, elevation, and salinities at each station). Replicate samples of $10cm^3$ ($10cm^2$ x 1cm) were obtained at each station along the transects, using a stainless steel hand held corer (Scott, 1977).

Coring was conducted at this marsh and three other marshes in the Bay of Fundy, (Ft. Beausejour, Mary's Point and Granville Ferry, Figure 1). These cores were obtained using a Davis peat corer which was pushed down to the deepest layer of peat and a trigger was released on the corer, enabling retrieval of a small test core. The lowest level of peat usually overlaid glacial till and was located after exploratory testing to find the thickest peat sequence. A series of cores were obtained at each marsh to construct apparent relative sea level curves (Scott and Greenberg, submitted). Surficial sediment samples were wet sieved through 0.5mm and 0.063 mm sieves, the 0.5mm sieve retaining coarse organics and the 0.63mm sieve retaining the foraminifera. Organics remaining in the sample at this point were removed by decantation with water. The samples were then fixed in 10% formalin and Rose Bengal. After washing off excess formalin and Rose Bengal, the samples were placed in denatured alcohol for preservation. Many samples contained large amounts of sand, which was removed by floating the foraminifera in CCL_4. The core samples were treated in a similar manner, except no formalin or Rose Bengal was added.

The salinity at sample stations was determined at the time of sample collection, using an American Optical Salinity refractometer (compensated for temperature variance). The elevation at each station was obtained using a transit and stadial rod. These measurements were then tied into nearby bench marks. The vegetation at each station was recorded while sampling.

C_{14} dates were obtained from material in the deepest layers of peat at each core location; the dated levels overlaid noncompatible substrates to avoid autocompaction of peat (Kaye and Barghorn, 1964).

Photographs of gold-palladium coated specimens were taken, using the Cambridge (180) scanning electron microscope, with Polaroid N/P 55 film at the Bedford Institute of Oceanography, Dartmouth, N.S.

RESULTS:

Vegetation and Salinity; The plant species present at Kingsport Marsh are relatively similar in their spatial arrangement and floral content to those of Scott and Medioli (1978a, 1980a, Figure 2a & b). There is a dominance of Spartina alterniflora in the low marsh, S. alterniflora and Spartina patens in the mid marsh, but Juncus gerardii and S. patens define the high marsh floral zone, rather than Cyperaceae, which dominate other Maritime high marsh zones (Scott and Medioli, 1980a). The Kingsport marsh is dominated overall by S. patens except at the lower marsh, and J. gerardii is significant in the upper marsh as observed in Prince Edward Island marshes by Scott et al. (1981).

Salinities along Kingsport Transect I follow a relatively normal pattern (Figure 2a & b), for temperate marsh areas, with increasing salinity as elevation decreases (Scott and Medioli 1978a, 1980a). However, Kingsport Transect II has salinities that decrease with decreasing elevation. This phenomena is attributed to the lack of salinity values obtained; few samples could readily be obtained (3 out of 11 stations) due to the dryness of the marsh surface. The salinity throughout both transects is relatively high (Kingsport I, 31-38 $^{0}/00$ Kingsport II, 25-48$^{0}/00$) as compared to those observed by Scott and Medioli (1978b) in Prince Edward Island (Pisquid, 0-15$^{0}/00$, Tryon 0-23$^{0}/00$ Wolfe Inlet 0-17$^{0}/00$) and those fluctuations recorded by Scott and Medioli (1980b) at Chezzetcook Inlet, N.S.

The marsh was dry because evaporation at the time of collection was higher than precipitation or runoff, and this caused the elevated salinities. Also, the organic content of these marsh sediments is lower than other Maritime marshes, because of higher tides and more sediment input (Harrison and Bloom, 1977). This means that drainage is better here and fresh water is not retained in the sediments at low tide.

Foraminiferal Results: Each sample collected along the Kingsport transects was examined for both living and total numbers of benthonic foraminifera (See Table I and II). Total populations were used to derive assemblages rather than living populations as the total population best illustrates the prevalent marine conditions, thereby not over emphasizing any seasonal variations that may occur (Scott and Medioli, 1980b). At Kingsport this is important due to the irregularity of the living population along the transects. The 37 (x2) surface samples recorded a total of 17 species of foraminifera, with 70% of the species having living specimens.

At Kingsport, using the marsh zones standards as established by Scott and Medioli (1980a), Zone I is defined by the abundance of Trochammina inflata, the presence of Tiphotrocha comprimata and limited Trochammina macrescens forma polystoma. Zone II is also well defined by the dominance of Miliammina fusca and T. inflata (Figure 3a, b).

Although Zone I cannot be definitely broken down into subzones, Zone II can be differentiated here into two subzones, a and b. Subzone IIa is delineated by the presence of large, almost equal numbers of T. inflata and M. fusca, as well as the absence of living Trochammina macrescens forma polystoma. Subzone IIb is defined on the basis of an increased percentage of M. fusca, the increasing percentage of Haynesina orbiculare, Ammobaculities foliaceus and the occurrence of other calcareous estuarine species. The lower portion of subzone IIb is distinguished by the rapid decrease of arenaceous species and total populations.

Drill Hole Results (Table III, IV, V VI): Kingsport Marsh; Three holes were drilled at this location (see Figure 4), after exploratory work to find the deepest marsh sediments. These holes ranged in depth from 3.7 meters to 9.5 meters, and all displayed an uninterrupted sequence of marsh deposits. Twenty ml samples were removed from the C_{14} dated basal marsh sediments. All drill holes at this location were similar in their foraminiferal assemblages, with T. inflata dominating (see Figure 5). Total populations decreased towards the bottom of the cores. Tiphotrocha comprimata and Trochammina macrescens were also present but in smaller numbers. This assemblage suggests the high marsh, or Zone I. One noticeable occurrence in these cores was the decrease in total populations with increasing depth; this results as basal marsh deposits form over supra-tidal deposits with rising sea level.

Granville Ferry: Three holes were drilled at this site (Figure 6), all exhibiting a continuous sequence of marsh sediments down to basal till. Once again total populations decrease with increasing depth, representing sea level rise over a terrestrial environment. Total populations in these samples varied from 10 to 590 specimens per sample, with T. inflata dominating. The numbers of T. inflata decrease with depth, indicating a progression of marsh sediments through the upper marsh (Figure 7). T. macrescens is not prevalent in any of the holes, but T. comprimata is present in significant numbers. Unlike the Kingsport Marsh the foraminiferal assemblages vary from hole to hole. Relatively high percentages of Pseudothurammina limnetis in the upper portions of the area sampled indicate Zone Ib, putting the lowest portion of the core in Zone Ia, as defined by the dominance of T. inflata.

Mary's Point: Four holes were drilled at this location (see Figure 8), ranging in depth from 3.0 to 8.3 meters in depth, all displaying unbroken sequences of marsh deposition. All four cores are similar in their foraminiferal assemblages (see Figure 9). T. macrescens is dominant in all holes, and their total population increases towards the base, indicating a zone Ia (Scott and Medioli, 1980a) elevation range at the base.

Ft. Beausejour: This marsh was drilled 4 times with the depth of the cores ranging from 1.7 meters to 13 meters in depth (see Figure 10). At the base of the cores lower total numbers, together with the dominance of T. macrescens, indicate a Zone I fauna (see Figure 11). The presence of T. comprimata in only the upper portions of the sequence indicate the bottom of the core to be in Zone la.

C_{14} dating was used to date material from the base of the cores, (Figures 5, 7, 9, 11). The results of this dating and the production of sea level curves, (Scott and Greenberg, submitted) provided the average sea level rises for the four sampling sites.

DISCUSSION

Surface Floral Relationships: Kingsport marsh exhibits three well defined vertical plant zonations (Figures 2a & 2b). Scott and Medioli (1980a) demonstrate that the floral zonation of marshes is similar throughout Nova Scotia, although some striking individual differences are observed. The plant species that define the zones at Kingsport are no exception. The upper zone of the Kingsport marsh is defined by the dominance of elevation sensitive Juncus gerardii and Spartina patens while Scott and Medioli (1980a) record the upper zone of Chezzetcook, N.S. to be defined by Spartina cynosuroides or Cyperaceae, Chebogue, N.S. by various combinations of J. gerardi, Solidago sempervirens and Cyperaceae and Newport Landing (also in the Bay of Fundy) by J. gerardi and S. sempervirens. The Prince Edward Island marshes, as recorded by Scott et al., (1981), contained high marsh components different than those found at Kingsport. Due to the interchangeable nature of the high marsh flora in Eastern Canada paleo-sea level determination based on ancient marsh plant assemblages appear rather dubious.

The Bay of Fundy experiences tidal ranges greater than 15 meters, hence the marsh flora of Kingsport no longer extend down to mean sea level, as do marshes with normal tidal ranges (Scott & Medioli, 1980a). This high tidal range may be one reason for the elevated salinities at Kingsport (Figures 2a & 2b), and the absence of Cyperaceae and S. cynosuroides in the upper marsh.

Foraminiferal Relationships: The foraminiferal assemblages along both Kingsport transects were very similar, when differences in horizontal length, elevation and salinity were taken into account.

The fauna which occurs just below the Higher High Water (H.H.W) is very important, as it is this fauna that will delineate the H.H.W. level in a core assemblage. At Kingsport the species that defines H.H.W. is *Trochammina inflata*, in contrast to the foraminiferal species *Trochammina macrescens* found by Scott and Medioli (1978a, 1980a) and Scott et al. (1981) to define the H.H.W. in other Atlantic marshes (Zone 1A). The dominance of *T. inflata* just below the H.H.W., together with rare occurrences of *T. macrescens*, is indicative of a highly saline environment, as observed by Scott and Medioli (1980a) in the Summerville marsh, Nova Scotia. Kingsport marsh lacks any sizable *T. macrescens* population, when compared to those studies done by Scott and Medioli (1980a) in Nova Scotia and Scott et al. (1981) in Prince Edward Island. Otherwise the faunal distribution of their studies are comparable to those at Kingsport. Kingsport exhibits a pattern of population diversity with the numbers of species present decreasing at both the upper and lower portions of the marsh (Figures 3a & 3b). It also appears that Zone I cannot be subdivided into zones, as in other Nova Scotia and Prince Edward Island marshes (Scott and Medioli, 1980a, b, Scott et al., 1981, Deonarine, 1979), which reduces the absolute accuracy of these faunas as elevation indicators. The lower Zone II at Kingsport exhibits a sharp decrease in abundances of total population, with living percentages remaining relatively constant.

This represents a dilution of total foraminiferal populations as a result of sediment accumulation at the base of the marsh (Scott and Medioli, 1980a).

Sea Level Changes: All cores taken from the four sampling sites on the Bay of Fundy (Figure 1) contained continuous sequences of marsh deposits, representing a continuous sea level rise over the period of marsh deposition. According to $Carbon_{14}$ dating this has occurred for the past 3525-4400 years.

The examination of the foraminiferal assemblages classified the basal core section as to their paleo-marsh zonation. Although all cores contained different assemblages, either *T. macrescens* or *T. inflata* were dominant. This corresponds relatively well to the data gathered by Scott et al., (1981) at Orwell, Pisquid and Tryon marshes on Prince Edward Island, except these core holes exhibited only dominant *T. macrescens* as basal assemblages. The base of the core at Kingsport is defined by a dominance of *T. inflata* which indicates Zone I while other marshes in the Maritimes have a Zone I, defined by a dominance of *T. macrescens* (Scott et al, 1981, Scott and Medioli, 1980a). This reduces the accuracy of this level as a sea level indicator in the Bay of Fundy to ± 50 cm. These foraminiferal data are used to define the apparent sea level curves used by Scott and Greenberg (submitted).

The Bay of Fundy displays a phenomena known as tidal amplification, which is an expansion of the tidal range, caused by changes in water depth over Georges Bank and changes in the Bay of Fundy basin configuration (Scott & Greenberg, submitted). At the point where ocean tides contact the edge of the continental shelf, the tides have a range of one meter. This one meter range is amplified through the system with the largest amplification occurring in the upper Bay of Fundy and ranging from 6x in the central Bay of Fundy, 10x in Chignecto Bay and 12x in the Minas Basin at the head of the Bay of Fundy. Thus in order to determine the actual effects of sea level rise using H.H.W. (which are greatly affected by tidal amplification), one must be able to subtract the amount of tidal amplification. Scott and Greenberg (submitted) have made these determinations (Table VII) possible by supplying a separate curve for tidal amplifications. As indicated by Table VI, apparent sea level rises (as detected by movement of H.H.W. indicators) in the Bay of Fundy are not a direct result of relative sea level rise alone, but also tidal amplification. The subtracting of tidal amplification effects from apparent relative sea level rise reduces the actual relative sea level to 79% of apparent sea level rise.

CONCLUSIONS

1. Although the Bay of Fundy is an area of extreme tidal ranges, the salt marshes retain well defined zonations of both foraminifera and plants.

2. The relocation of the H.H.W. mark in paleo-marsh cores is possible, and provides accurate estimates of apparent sea level rises in the four sampling areas.

3. In marshes of elevated salinity, the absence of *Trochammina macrescens* is to be expected, while *Trochammina inflata* dominates Zone I. Also, there is a redistribution of marsh flora. Cyperacea do not occur in higher marsh zones on the Bay of Fundy and are replaced by *Juncus gerardii*.

4. Kingsport marsh illustrates a reduced accuracy of the H.H.W. foraminifera zone in determining paleo-sea levels.

5. Apparent sea level rise in the Bay of Fundy is a combination of tidal amplitude and relative sea level rise.

SYSTEMATIC TAXONOMY

Seventeen species have been identified as being present in the surficial sediments of Kingsport Marsh, and the cores from Kingsport, Mary's Point, Fort Beausejour and Granville Ferry. Refer to Plate 1 for electron micrographs of the species. Species are listed below in alphabetical order by genus. Some species with limited occurrences have not been listed.

Ammobaculities foliaceus (H. B. Brady)

Plate 1, Figure 8.

Haplophragmium foliaceum H. B. BRADY, 1884, p. 304, pl. 33, Figs. 20-25.

Ammobaculites C. 1. C.f. *foliaceus* (H. B. BRADY) Parker, 1952, p. 444, pl. 1, figs. 20, 21.

Ammobaculities foliaceus (Brady) SCOTT and MEDIOLI, 1980a, p. 37, pl. 1, figs. 6-8.

Cibicides lobatulus (Walker and Jacob)

Plate 1 Figure

Nautilus lobatulus WALKER and JACOB in Janmache 1798, p. 642, pl. 14, fig. 36.

Cibicides lobatula (Walker and Jacob). CUSHMAN, 1931, p. 118, pl. 21, fig. 3a-c.

Cibicides lobatulus (Walker and Jacob). NORVANG, 1945, p. 49, pl. 6, fig. 26a,b., SCOTT, MEDIOLI And SCHAFER, 1980, p. 231, pl. 4, fig. 8, 9.

Elphidium excavatum (Terquem)

Plate 1, Figure 2

Polystomella excavata TERQUEM, 1876, p. 429

Polystomella straito-punctata (Fitchel and Moll) var. selseyensis HERON-ALLEN and EARLAND, 1911, p. 448.

Cribronion excavatum (Terquem) formae, LUTZE, 1965, p. 96-101, pl 15, fig. 39; SCOTT and MEDIOLI, 1980a, p. 42, fig. 5,6.

Elphidium excavatum (Terquem) formae, FEYLING-HANSSEN, 1972, p. 337-354, pls. 1-6; MILLER and OTHERS, 1982, P. 127- pls. 1-6.

Elphidium incertum (Williamson)

Polystomella umbicatula (WALKER & JACOB) var. incerta WILLIAMSON, 1858, p. 44, pl. 3, Fig. 82a.

Elphidium incertum (Williamson) BUZAS, 1966, pg. 592-593, pl. 72, fig. 1-6.

Haplophragmoides bonplandi Todd and Bronnimann,

Plate 1, Figure 1

Haplophragmoides bonplandi, TODD and BRONNIMANN, 1957, p. 23, pl. 2, fig. 2; SCOTT and MEDIOLI, 1980a, p. 38, pl. 2, fig. 4,5.

Haynesina orbiculare (Brady)

Plate 1, Figure 5

Nonionina orbiculare BRADY, 1881, p. 415, pl. 21, fig. 5.

Nonion orbiculare (Brady). CUSHMAN, 1930, p. 12, pl. 5, figs. 1-3.

Elphidium orbiculare (Brady). HESSLAND, 1943, p. 262

Protelphidium orbiculare (Brady). TODD and LOW, 1961, p. 20. pl. 2, fig. 11; SCOTT and MEDIOLI, 1980a, p. 42, pl. 5, fig. 7.

Hemisphaerammina bradyi Loeblich and Tappan

Plate 1, Figure 9

Hemisphaerammina bradyi LOEBLICH and TAPPAN in Loeblich and Collaborators, 1957, p. 224, pl. 72, fig. 2, SCOTT and MEDIOLI, 1980a, p. 37, pl. 1, fig. 4 and 5.

Crithionina pisum Goes. GREGORY, 1970, p. 165, pl. 1, fig. 6.

Hemisphaerammina sp. COLE and FERGUSON, 1975, pl. 1 fig. 4.

Miliammina fusca (Brady)

Plate 1, Figure 3, 4.

Quniqueloculina fusca BRADY, 1870, p. 47, pl. 11, figs. 2,3.

Miliammina fusca (Brady). PHLEGER and WALTON, 1950, p. 280, pl. 1, figs. 19a, b; SCOTT and MEDIOLI, 1980a, p. 38, pl.2, figs. 1-3.

Pseudothurammina limnetis (Scott and Medioli)

Plate 1, Figure 7

Armorella sphaerica (Heron-Allen and Earland) PHLEGER and WALTON, 1950, p. 277, pl. 1, fig. 1.

Astrammina rara (Rhumbler). ELLISON and NICHOLS, 1976, p. 141.

Astrammina sphaerica (Heron-Allen and Earland). ZANINNETTI and OTHERS, 1977, p. 176, pl. 1, fig. 9.

Thurammina (?) limnetis SCOTT and MEDIOLI, 1980a, p. 43, 44, pl. 1, figs. 1-3.

Pseudothurammina limnetis (Scott and Medioli). SCOTT and OTHERS, 1981, p. 126.

Tiphotrocha comprimata (Cushman and Bronnimann)

Plate 1, Figure 13

Trochammina comprimata CUSHMAN and BRONNIMANN, 1948, p. 41, pl. 8, figs. 1-3.

Tiphotrocha comprimata (Cushman and Bronnimann). SAUNDERS, 1957, p. 11; SCOTT and MEDIOLI, 1980a, p. 42, pl. 5, figs. 1-3.

Trochammina inflata (Montagu)

Plate 1, Figures 14, 15

Natulus inflatus MONTAGU, 1808, p. 81, pl. 18, fig. 3,

Trochammina inflata (Montagu). PARKER and JONES, 1859, p. 347; SCOTT and MEDIOLI, 1980a, p. 3, pl. 3, figs. 12-14.

Trochammina macrescens Brady

Plate 1, Figure 5

Trochammina inflata (Montagu) var macrescens BRADY, 1870, p. 290, pl. 11, figs. 5a-c.

Jadammina polystoma BARTENSTEIN and BRAND, 1938, p. 381, figs. 1a-c, 2a-l.

Trochammina macrescens Brady. PHLEGER and WALTON, 1950, p. 281, pl. 2, figs, 6,7; SCOTT and MEDIOLI, 1980, p. 39, pl. 3, figs. 1-8.

Jadammina macrescens (Brady). MURRAY, 1971, p. 41, pl. 13, figs. 1-5.

Both Jadammina polystoma and Trochammina macrescens are listed in the text of this paper as separate entities, however, it is understood that there exists an intergradation of morphologic forms between these two (Scott and Medioli, 1980a).

PLATE 1

1. Haplophragmoides bonplandi Todd and Bronnimann. 1. side view, x 120.

2. Elphidium excavatum (Terquem) forma excavata, 2. side view, x 130.

3,4. Miliammina fusca (Brady) 3. side view (four chamber side) x 132, 4. side view (3 chamber side) x 132.

5. Haynesina orbiculare (Brady) 5. side view x 180.

6. Trochammina macrescens Brady forma polystoma Bartenstein and Brand dorsal view x 144.

7. Pseudothurammina limnetis (Scott and Medioli) 7. specimen with several apertures, (not visible) x 113.

8. Ammobaculites foliaceus (H. B. Brady). 8. side view of typical specimen x 96.

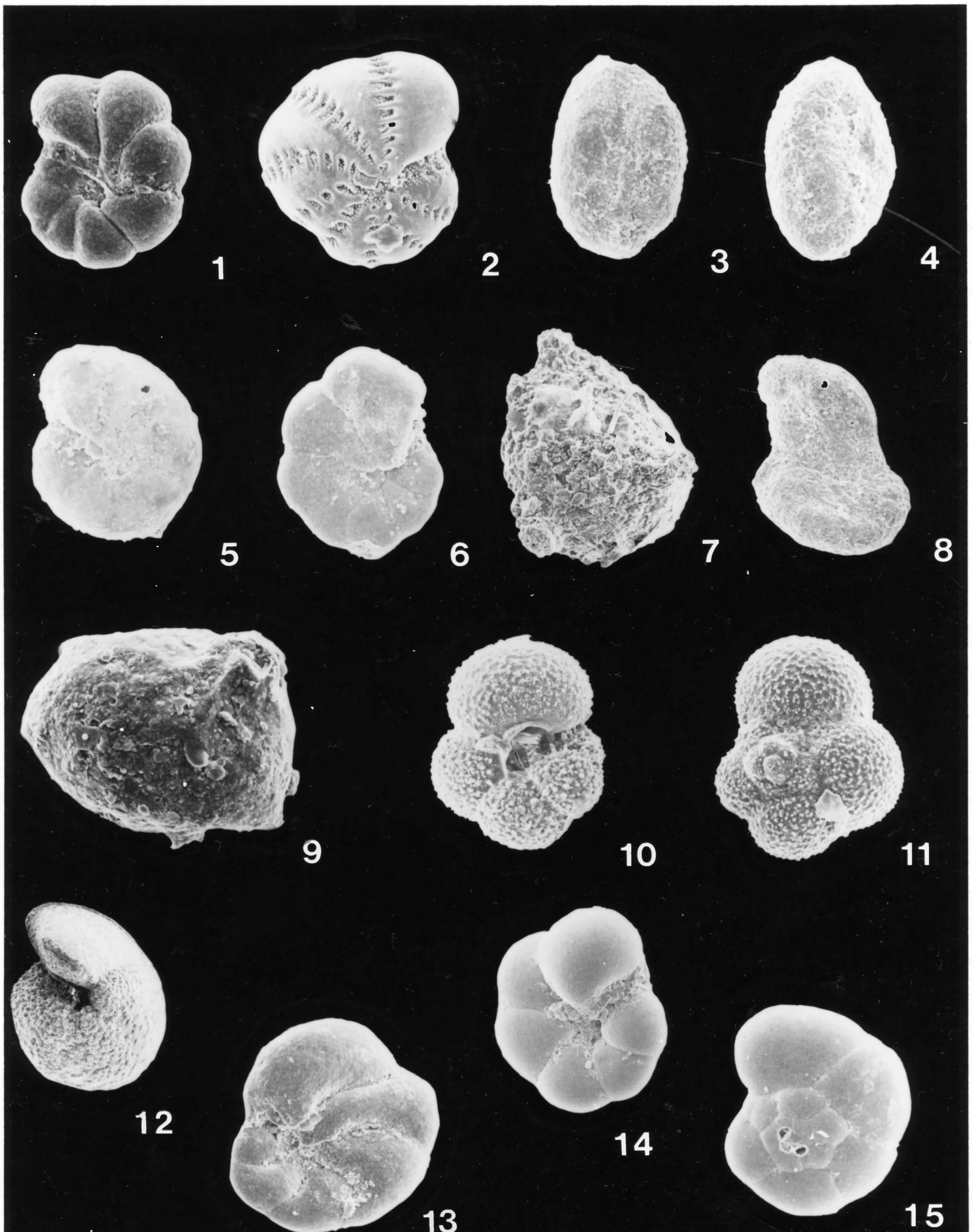
9. Hemisphaerammina bradyi Loeblich and Tappan. 9 Dorsal view of typical specimen, x 270.

10,11 Planktonics. 10 aperture view x 18, 11. Dorsal view x 195.

12. Cibicides lobatulus (Walker and Jacob) 12. Dorsal or non attached side, x 76.

13. Tiphotrocha comprimata (Cushman and Bronnimann) 13. ventral view of mature specimen with characteristic T Shaped final chamber.x 133.

14,15 Trochammina inflata (Montagu) meglaspheric form. 14. Ventral view, x 102. 15 Dorsal view, x 109.



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Appendix

LEGEND FOR FIGURES

FORAMINIFERA		VEGETATION	
SYMBOL	SPECIES NAME	SYMBOL	SPECIES NAME
A.F.	Ammobaculites foliaceus	A.P.	Atriplex
A.S.	Ammotium salsum	D.T.	Distichlis
C.L.	Cibicides lobatulus	J.G.	Juncus gerardii
E.B.	Elphidium bartletti	L.N.	Limonium
E.E.	Elphidium excavatum	P.O.	Plantago
E.I.	Elphidium incertum	S.C.	Spartina cynosuroides
E.W.	Elphidium williamsoni	S.N.	Salicornia
H.B.	Haplophragmoides bonplandi	S.S.	Solidago sempervirens
Hs.B.	Hemisphaerammina bradyi	S.A.	Spartina alterniflora
H.O.	Haynesina orbiculare	S.P.	Spartina patens
M.F.	Miliammina fusca	S.D.	Suaeda
P.T.	Planktonics	T.T.	Terrestrials
P.L.	Pseudothurammina limnetis		
T.C.	Tiphotrocha comprimata		
T.I.	Trochammina inflata		
T.M.	Trochammina macrescens		
T.Mp.	Trochammina macrescens forma polystoma		

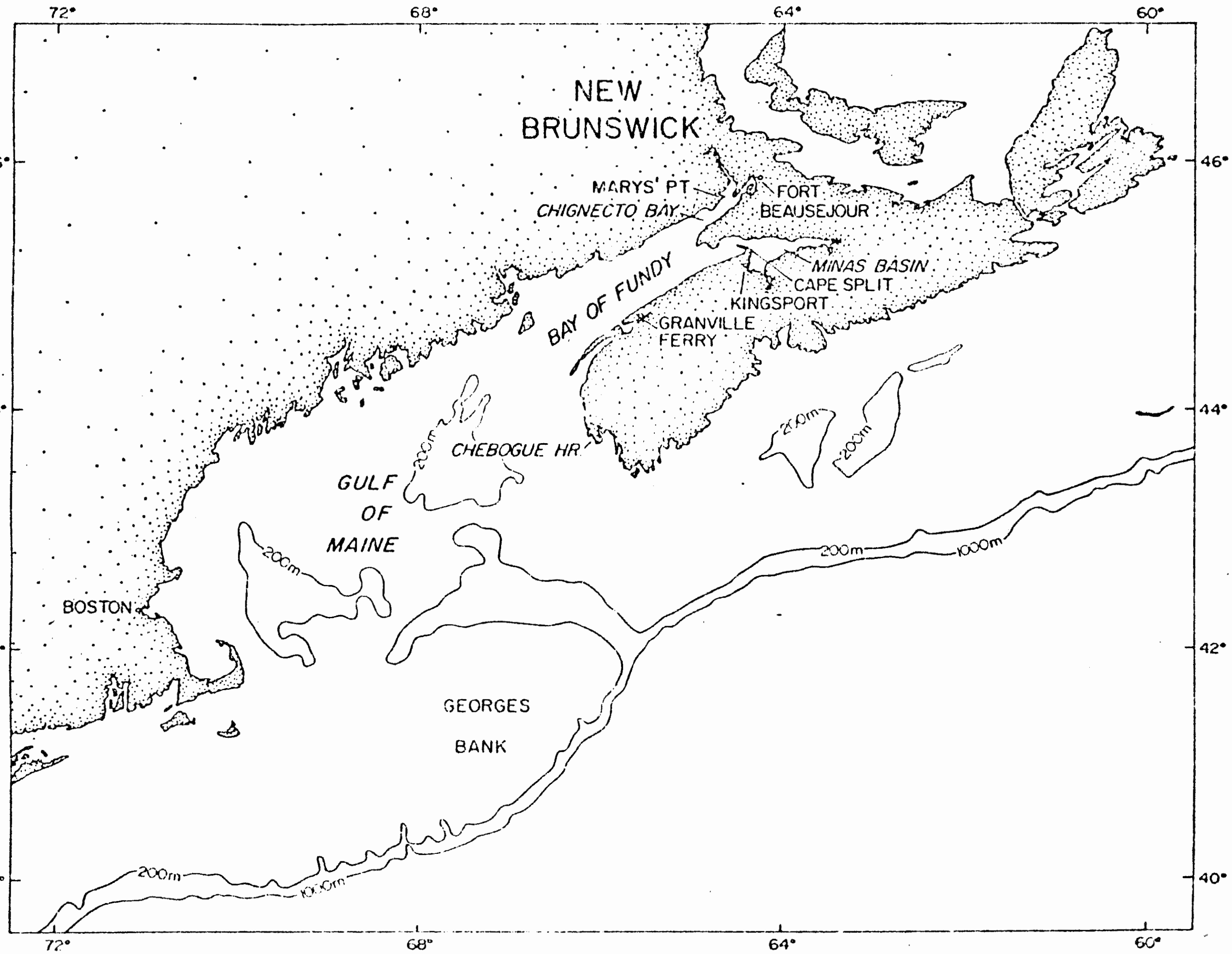

Figure 1. Regional Map Showing the Four Areas of Investigation.

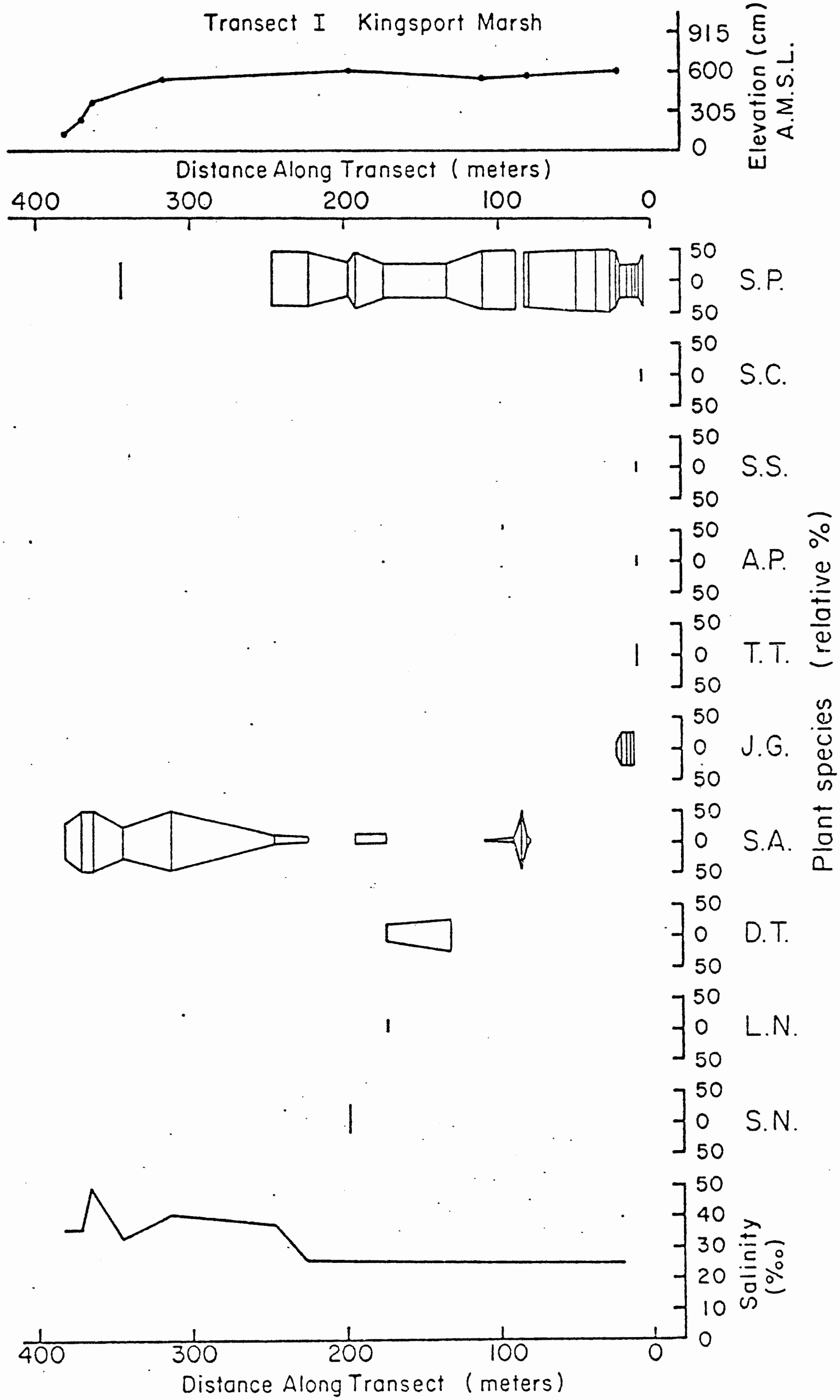

Figure 2a. Plant and Salinity Occurrences Along Transect I Kingsport Marsh

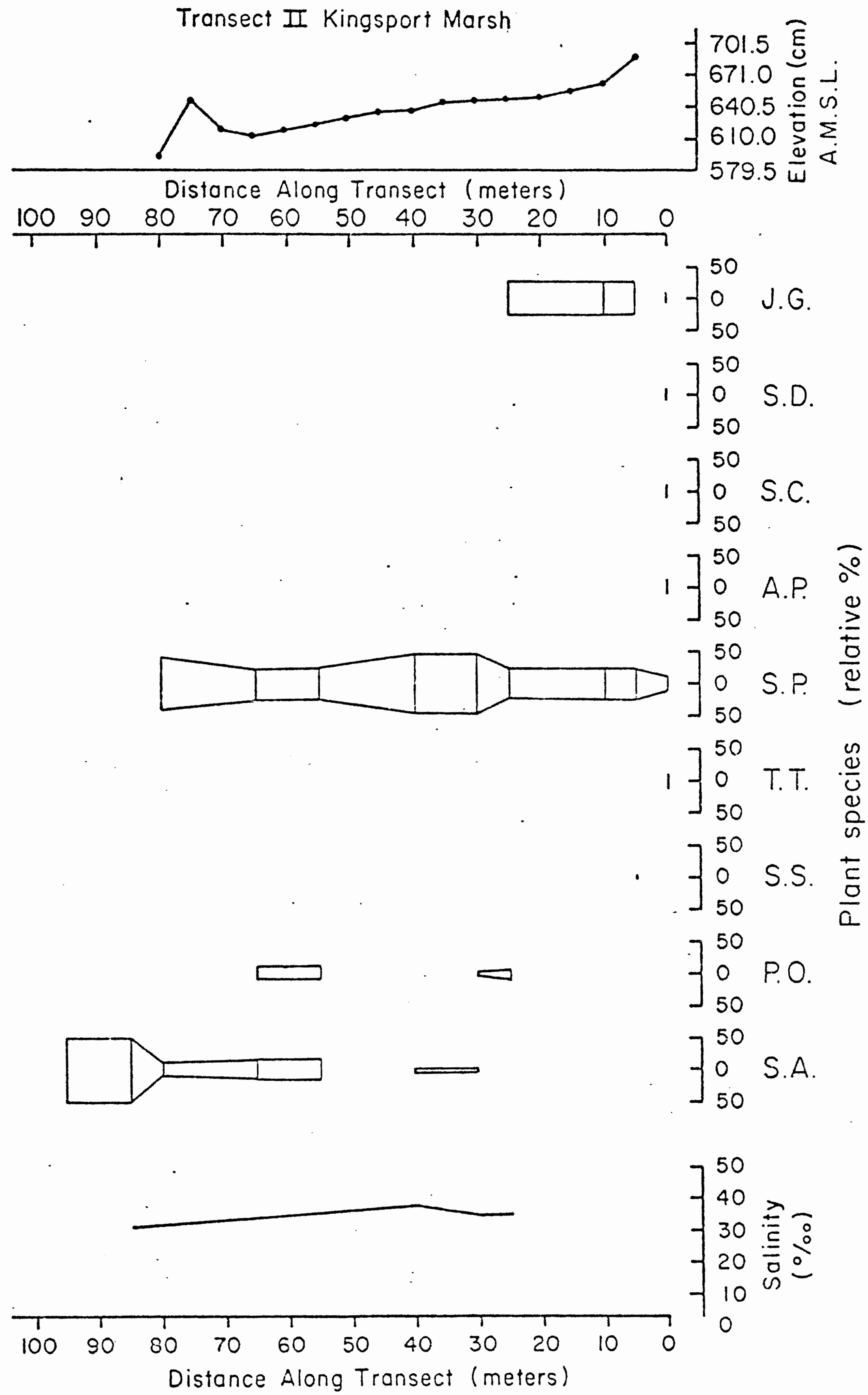

Figure 2b. Plant and Salinity Occurrences along Transect II, Kingsport Marsh

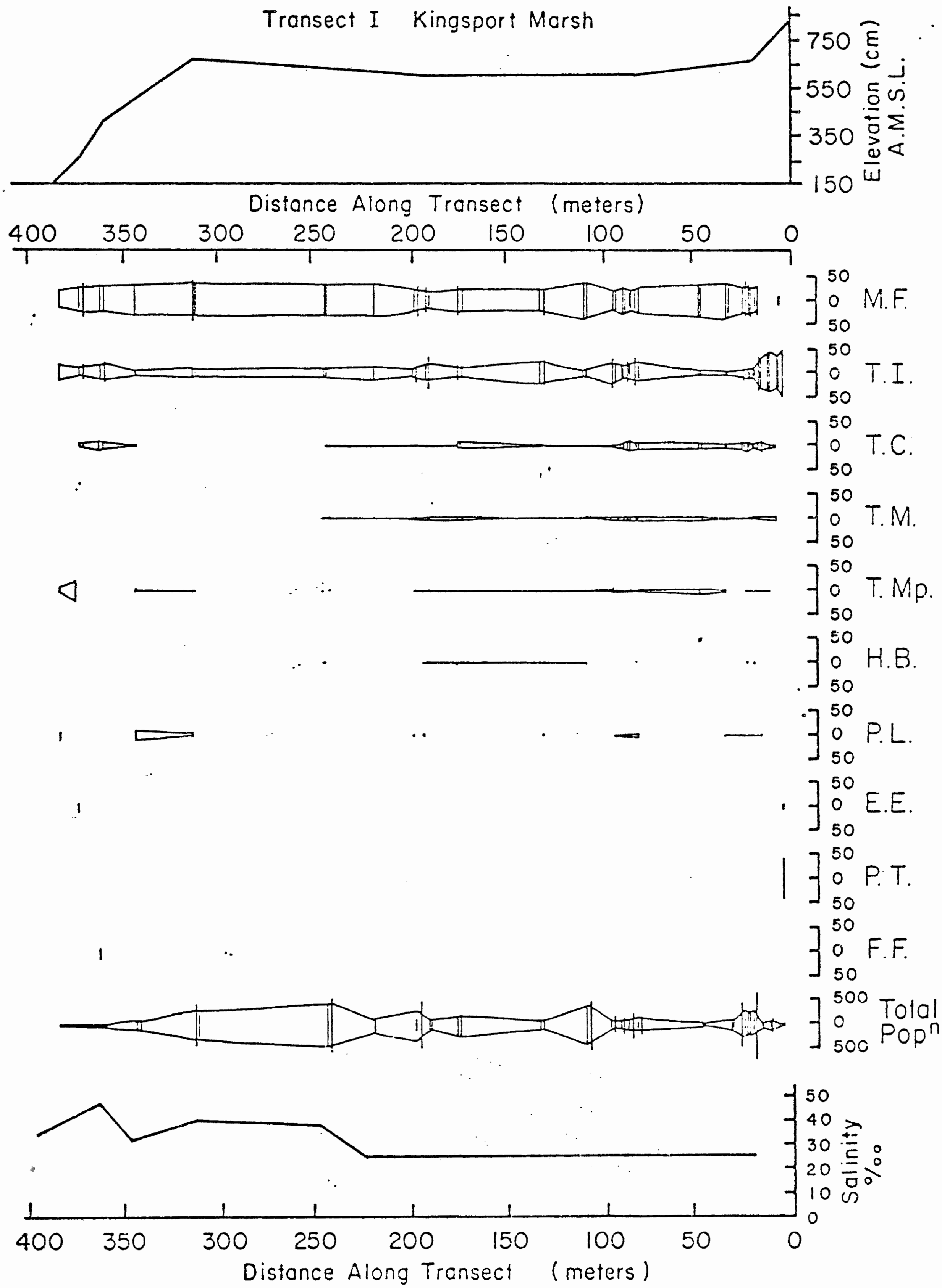

Figure 3a. Foraminiferal Distributions Along Transect I, Kingsport Marsh

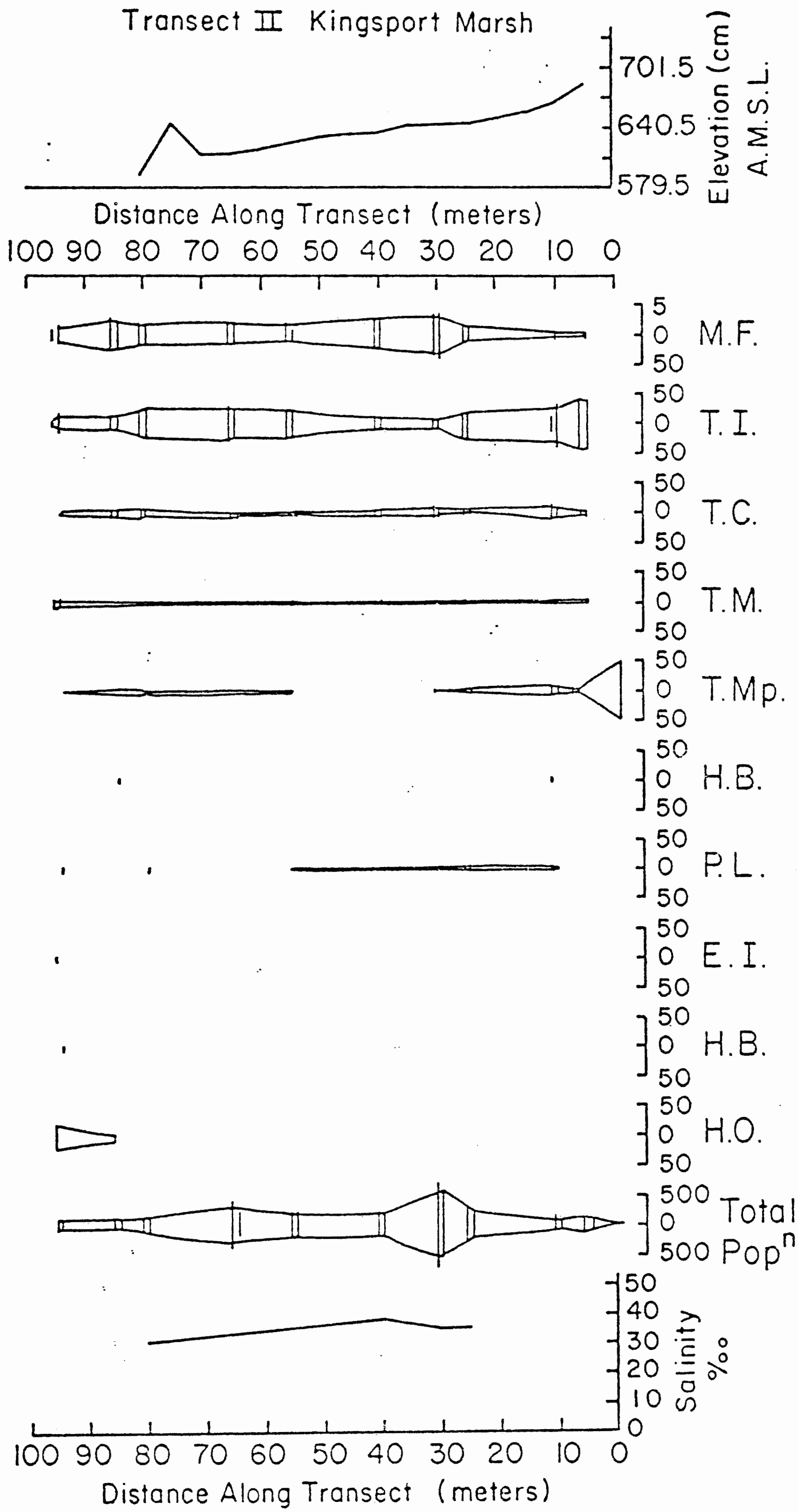

Figure 3b. Foraminiferal Distributions Along Transect II, Kingsport Marsh.

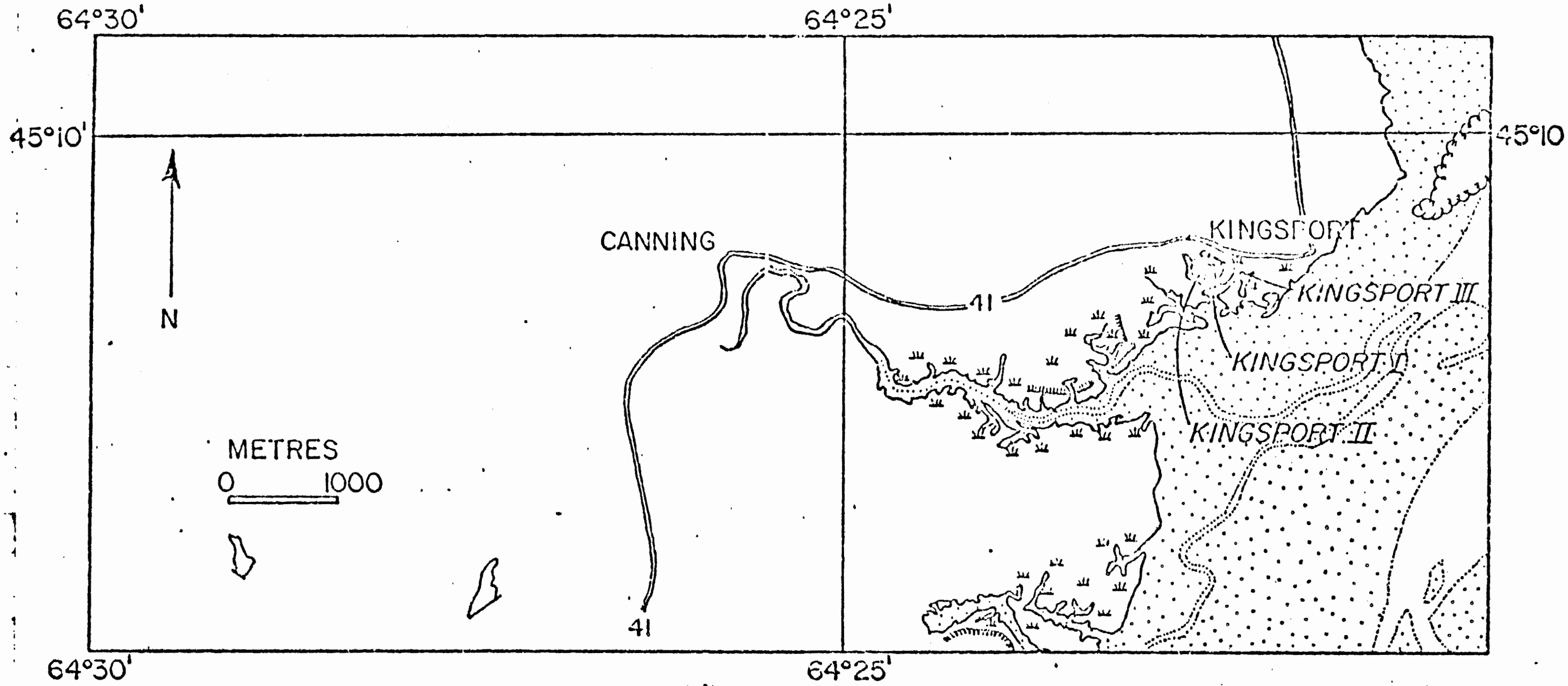

Figure 4. Core Locations, Kingsport Marsh

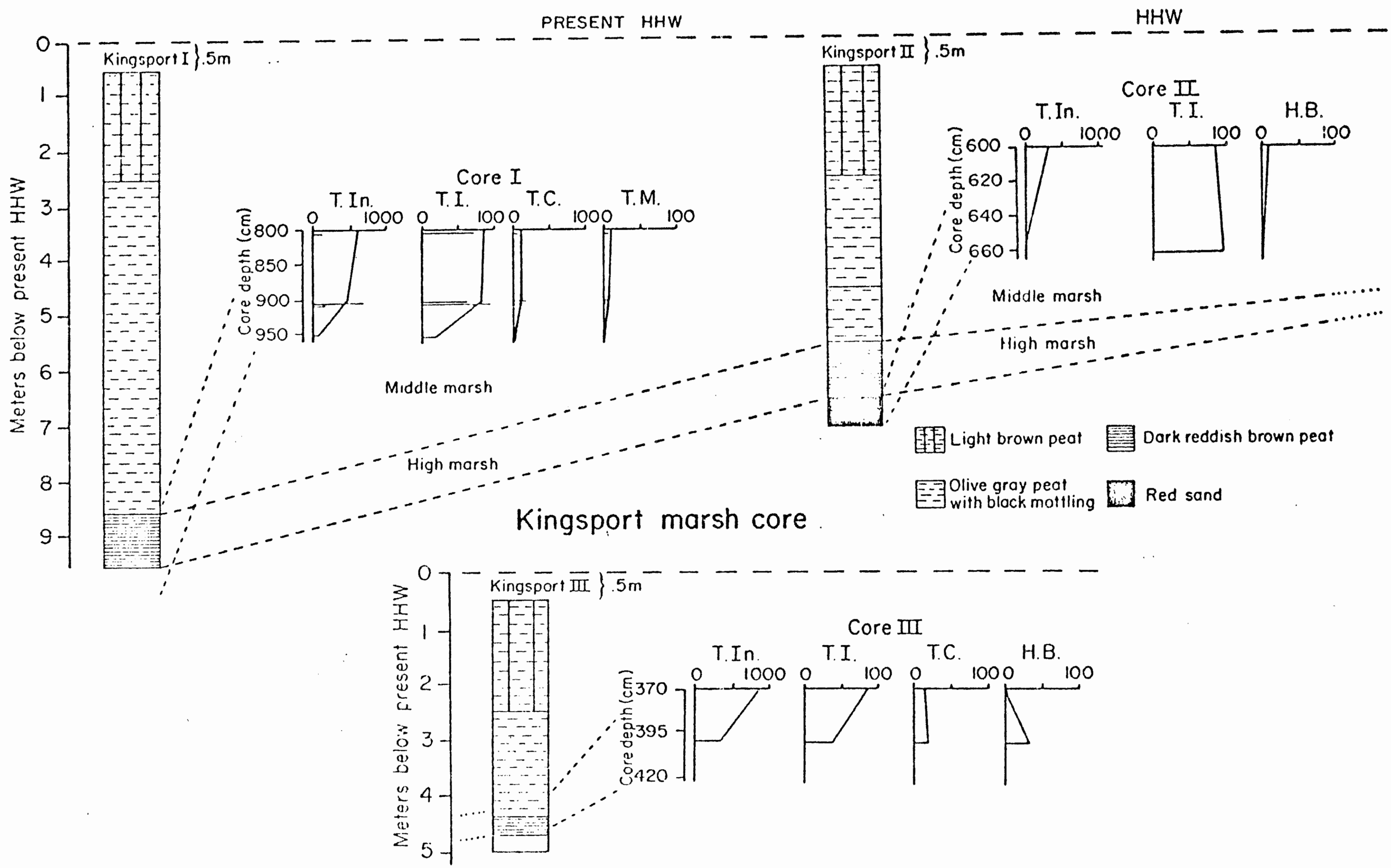

Figure 5. Litho - and Biostratigraphy of Kingsport Marsh Drill Holes.

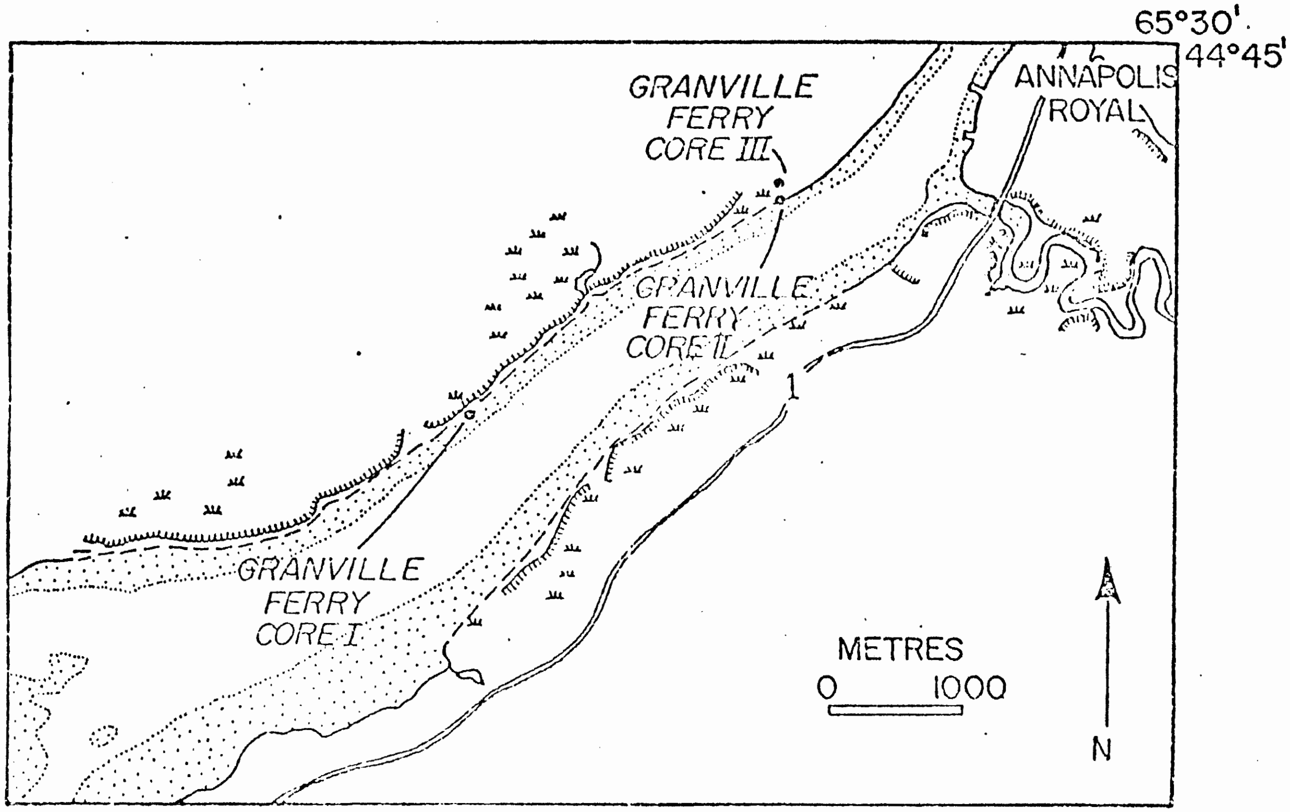

Figure 6. Core Locations, Granville Ferry.

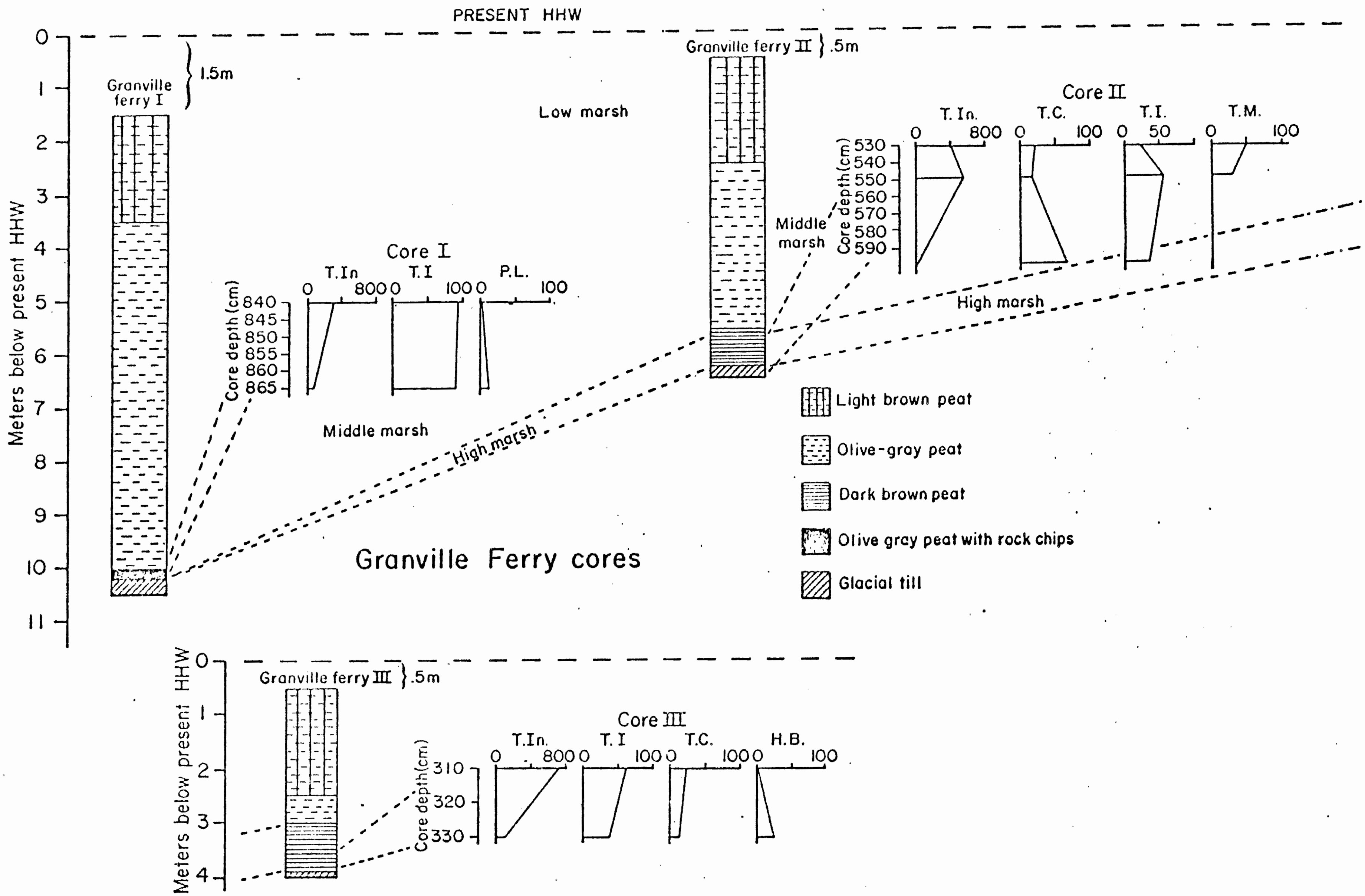

Figure 7. Litho - Biostratigraphy of Granville Ferry Marsh Drill Holes.

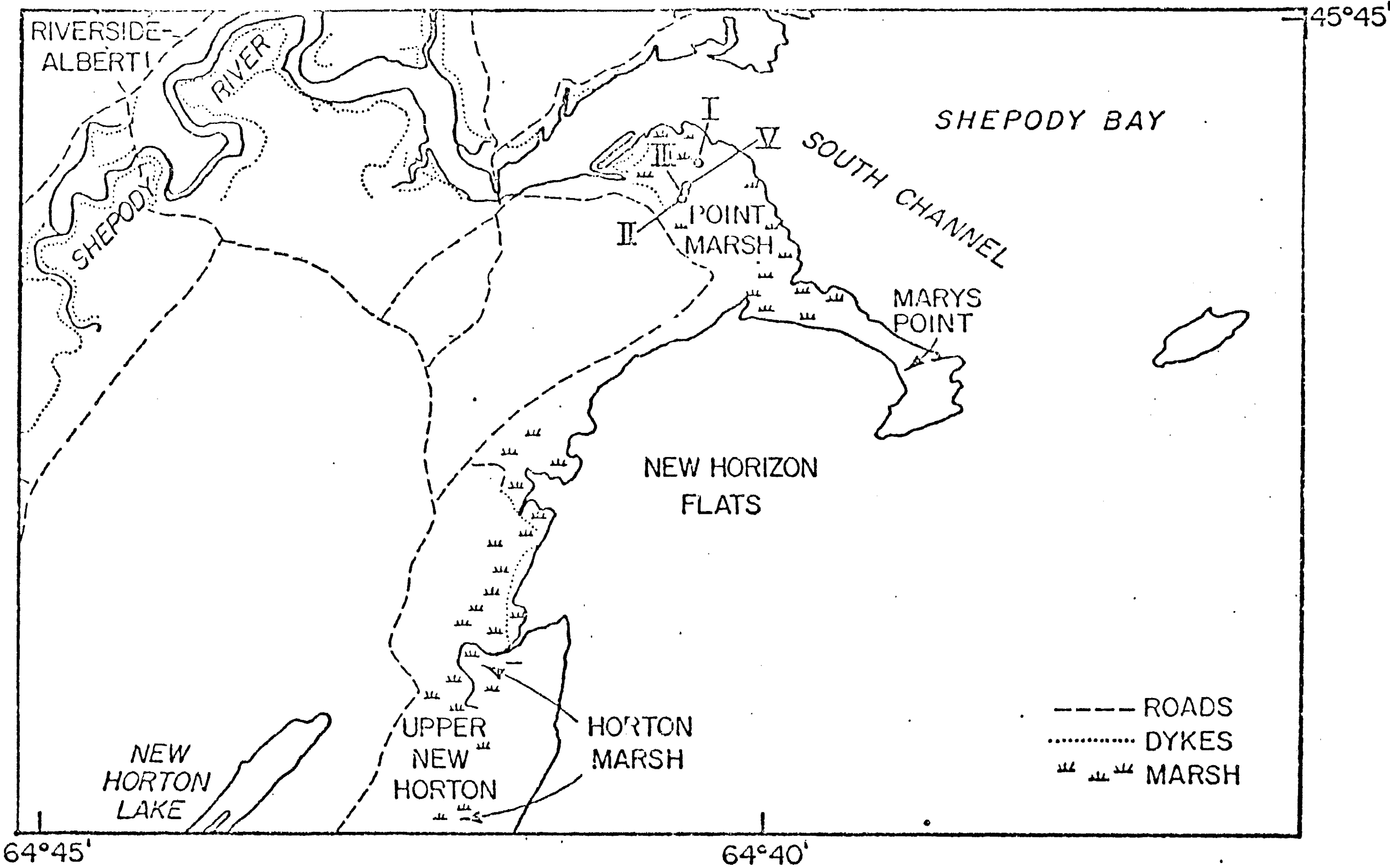

Figure 8. Core Locations, Mary's Point

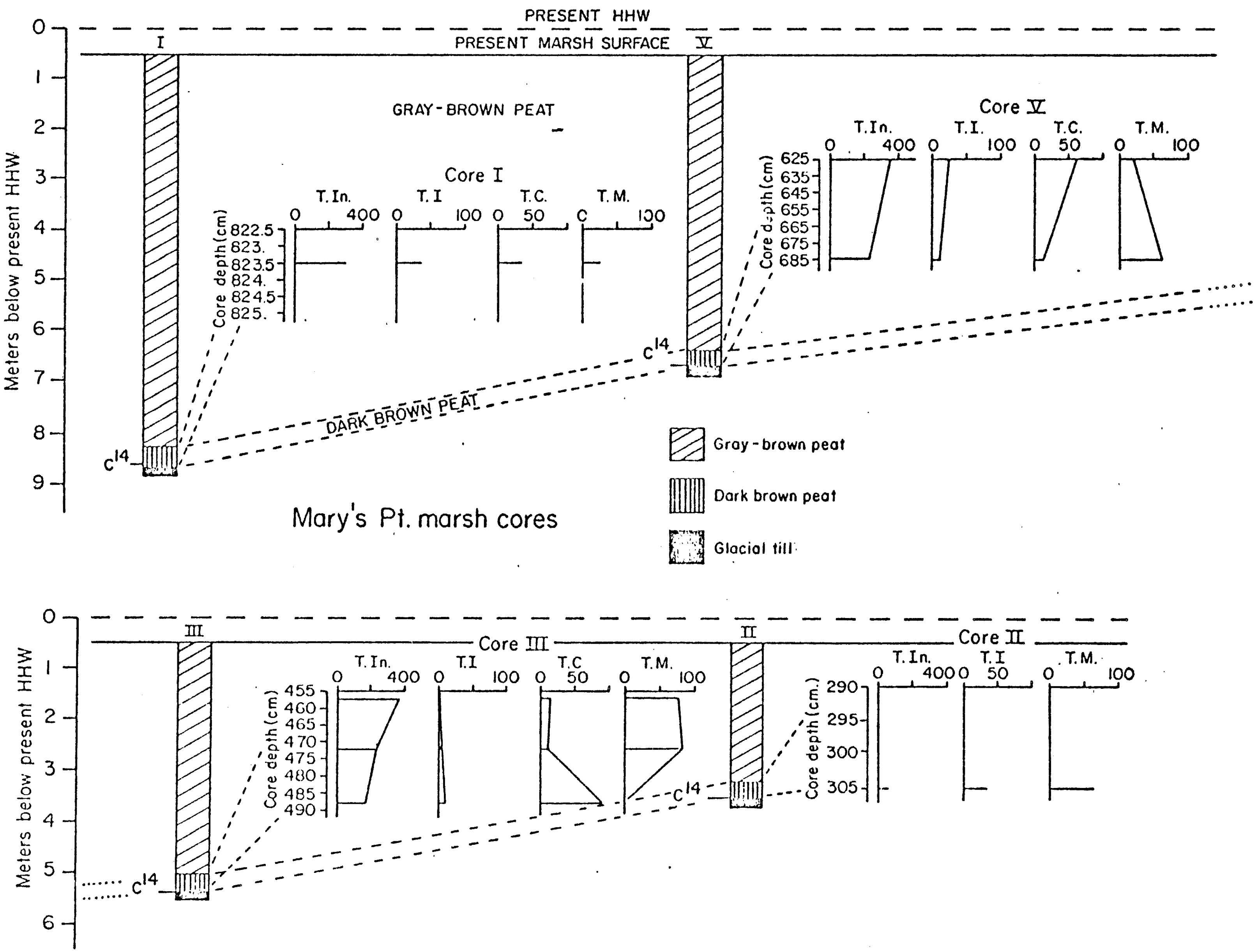

Figure 9. Litho - and Biostratigraphy of Mary's Point Drill Holes.

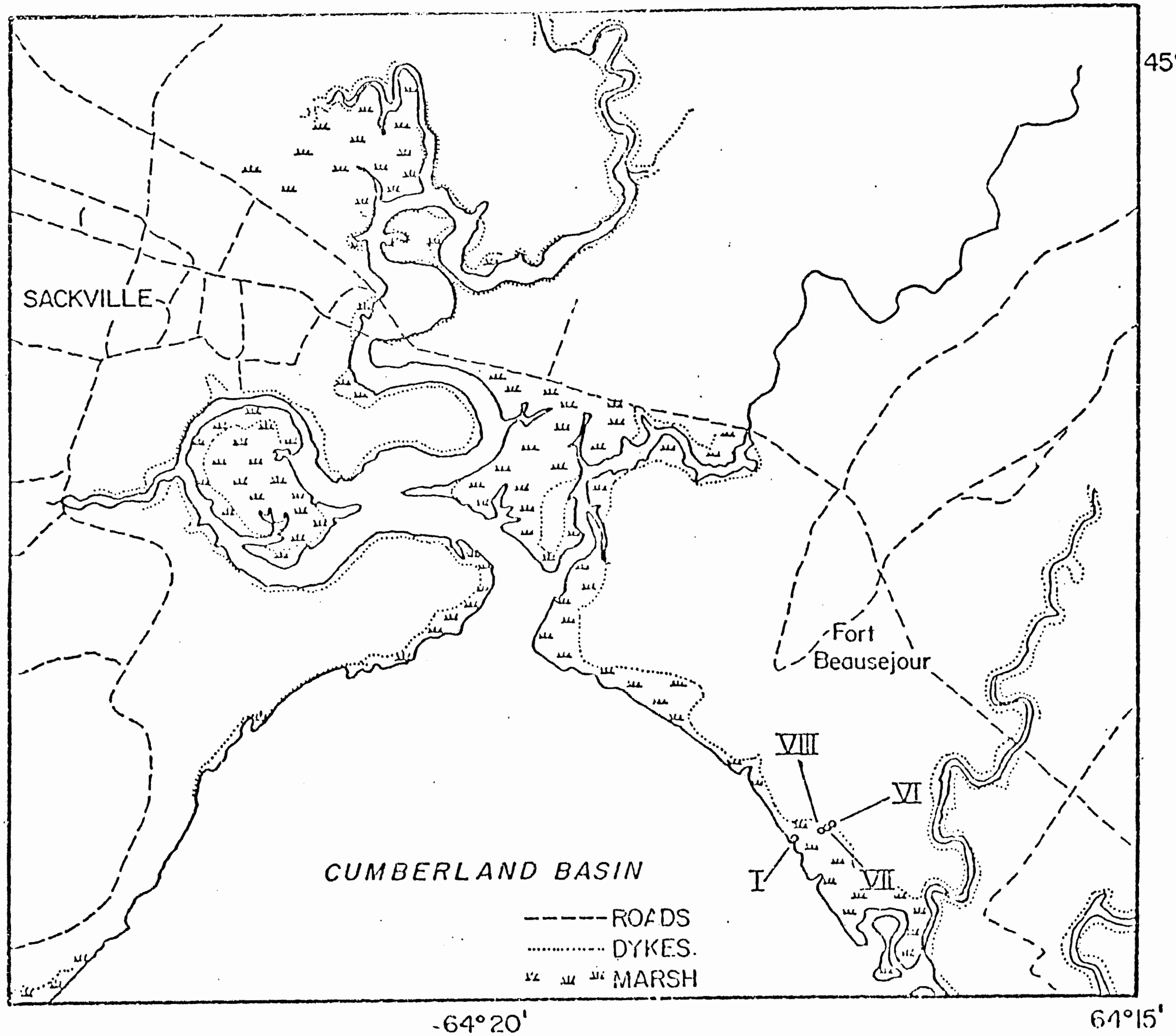

Figure 10. Core Locations, Fort Beausejour

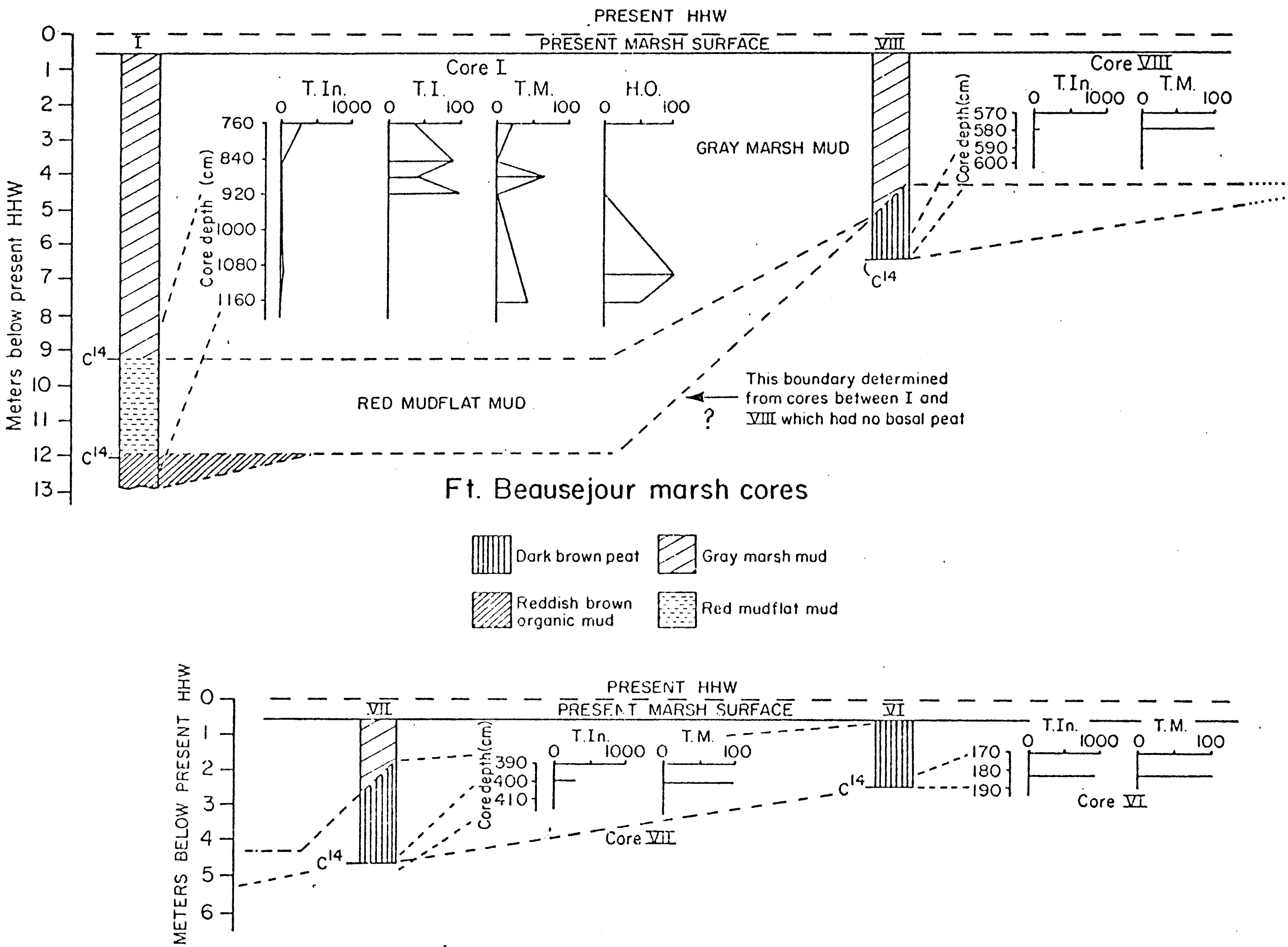

Figure 11. Litho - and Biostratigraphy of Fort Beausejour Drill Holes.

TABLE I

FORAMINIFERAL SPECIES DISTRIBUTIONS IN RELATIVE PERCENT, KINGSPORT MARSH, TRANSECT I

STATION NUMBER		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B
NO. OF SPECIES		0	0	2	1	4	3	2	4	3	4	7	5	6	7	5	5
TOTAL POP^{n} 10CM^{3}		0	0	32	4	67	69	189	322	54	52	368	1477	452	470	275	914
Total Living		0	0	0	0	0	17	12	22	20	18	60	504	84	69	33	286
Ammobaculities foliaceus	L/T L/Tp																
Cibicides lobatulus	L/T L/Tp			100 13													
Elphidium bartletti	L/T L/Tp																
E. excavatum	L/T T/Tp																
E. incertum	L/T L/Tp																
E. williamsoni	L/T L/Tp																
Haplophragmoides bonplandi	L/Tp L/Tp											100 2			100 .42		
Haynesina orbiculare	L/T L/Tp																
Hemisphaerammina bradyi	L/T L/Tp																
Jadammina polystoma	L/T L/Tp								100 1			100 1		100 2	100 .20		
Miliammina fusca	L/T L/Tp					100 24	56 26					87 46	69 69	86 55	83 71	100 59	70 81
Planktonics	L/T L/Tp			100 88													
Pseudothurammina limnetis	L/Tp L/Tp										4	100 2	100 1	57 3	100 4	100 1	100 .43
Tiphotrocha comprimata	L/T T/Tp					100 8			100 3	89 17	77 25	85 14	58 12	76 26	90 12	73 19	69 8
Trochammina inflata	L/T T/Tp				100 100	100 69	82 64	93 93	92 90	57 78	56 62	75 30	56 16	73 12	91 10	68 20	84 8
Trochammina macrescens	L/T L/Tp						86 10	100 7	100 7	67 6	86 14	88 4	76 2	83 3	89 2	92 4	86 .76

L = TOTAL LIVING (ONE SPECIES) T = TOTAL POPULATION (ONE SPECIES) Tp = TOTAL POPULATION (ENTIRE SAMPLE)

TABLE I CONTINUED

FORAMINIFERAL SPECIES DISTRIBUTIONS IN RELATIVE PERCENT, KINGSPORT MARSH, TRANSECT I

STATION NUMBER		9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16A	16B
NO. OF SPECIES		5	5	5	5	6	5	6	5	5	6	5	6	5	5	6	5
TOTAL POP^{n} 10CM^{3}		148	192	64	41	395	214	464	200	321	156	215	426	1027	810	112	313
Total Living		21	23	6	11	90	27	100	45	11	24	66	99	114	168	12	48
Ammobaculities foliaceus	L/T																
	L/Tp																
Cibicides lobatulus	L/T																
	L/Tp																
Elphidium bartletti	L/T																
	L/Tp																
E. excavatum	L/T																
	T/Tp																
Elphidium incertum	L/T																
	L/Tp																
Elphidium williamsoni	L/T																
	L/Tp																
Haplophragmoides bonplandi	L/T			100	0		100									100	
	L/Tp			3	7		0.9									2	
Haynesina orbiculare	L/T																
	L/Tp																
Hemisphaerammina bradyi	L/T																
	L/Tp																
Jadammina polystoma	L/T		100	100		100		100	100	100	100	59	75	100		100	
	L/Tp		2	5		2		0.4	1	0.9	1	8	2	2		5	
Miliammina fusca	L/T	89	89	91	72	78	100	84	69	100	98	78	84	88	78	100	84
	L/Tp	77	82	72	71	53	34	38	58	63	65	33	50	84	80	25	38
Planktonics	L/T																
	L/Tp																
Pseudothurammina limnetis	L/T	70				100		100			82		100		96		89
	L/Tp	7				1		0.4			7		0.9		4		3
Tiphotrocha comprimata	L/T	64	75	80	100	67	88	74	88	78	82	76	83	100	73	100	73
	T/Tp	9	8	16	5	17	7	22	.17	6	7	10	6	2	1	10	4
Trochammina inflata	L/T	100	100	100	100	80	80	75	91	94	96	63	78	95	83	81	87
	T/Tp	3	4	5	10	25	56	39	22	29	16	45	63	14	14	55	53
Trochammina macrescens	L/T	100	83		100	64	80	100	80	66	100	80	88	100	75	100	75
	L/Tp	.67	3		7	3	4	0.4	3	0.9	4	5	2	0.2	0.5	4	3

L = TOTAL LIVING (ONE SPECIES) T = TOTAL POPULATION (ONE SPECIES) Tp = TOTAL POPULATION (ENTIRE SAMPLE)

TABLE I CONTINUED

FORAMINIFERAL SPECIES DISTRIBUTIONS IN RELATIVE PERCENT, KINGSPORT MARSH, TRANSECT I

STATION NUMBER NO. OF SPECIES		17A 7	17B 5	18A 7	18B 5	19A 6	19B 5	20A 4	20B	21A 6	21B 7
TOTAL POP^{n} 10CM^{3}		439	394	222	197	1006	280	298		1173	915
Total Living		29	2	38	43	72	29	77		197	94
Ammobaculities foliaceus	L/T L/Tp	100 0.5									
Cibicides lobatulus	L/T L/Tp										
Elphidium bartletti	L/T L/Tp										
E. Excavatum	L/T T/Tp										
E. incertum	L/T L/Tp										
E. williamsoni	L/T L/Tp										
Haplophrag-moides bonplandi	L/T L/Tp	100 0.4		100 0.9							100 0.8
Haynesina orbiculare	L/T L/Tp										
Hemisphaeram-mina bradyi	L/T L/Tp										
Jadammina polystoma	L/T L/Tp	100 1	100 2	100 0.9	100 0.5	100 0.2	100 4			100 0.5	100 0.6
Miliammina fusca	L/T L/Tp	100 49	100 61	76 52	100 26	93 64	90 58	79 68		86 75	91 75
Planktonics	L/T L/Tp										
Pseudothuram-mina limnetis	L/T L/Tp			100 .3		100 1				100 2	100 1
Tiphotrocha comprimata	L/T T/Tp	60 9	95 11		100 1	45 3	80 4	75 1		58 2	100 1
Trochammina inflata	L/T T/Tp	93 36	100 20	88 39	63 68	96 20	89 34	64 31		75 21	84 21
Trochammina macrescens	L/T L/Tp	92 3	100 7	100 5	100 5	100 1	100 1	100 0.3		100 0.5	100 0.1

L = TOTAL LIVING (ONE SPECIES) T = TOTAL POPULATION (ONE SPECIES)
Tp = TOTAL POPULATION (ENTIRE SAMPLE)

TABLE I CONTINUED

FORAMINIFERAL SPECIES DISTRIBUTIONS IN RELATIVE PERCENT, KINGSPORT MARSH, TRANSECT I

STATION NUMBER NO. OF SPECIES		22A 5	22B 5	23A 5	23B	24A 3	24B 4	25A 4	25B 4	26A 4	26B	MEAN %
TOTAL POPn 10CM^3		494	889	201		16	27	24	44	20		
Total Living		77	135	4		2	1	0	7	0	0	
Ammobaculities foliaceous	L/T L/Tp	100 0.8				0 20						4.08 0.43
Ammotium salsum	L/T L/Tp			100 0.4		100 20						4.08 0.82
Cibicides lobatulus	L/T L/Tp											2.04 0.26
Elphidium bartletti	L/T L/Tp											
E. excavatum	L/T T/Tp								0 16			0 0.32
E. incertum	L/T L/Tp											
E. williamsoni	L/T L/Tp											
Haplophrag- moides bonplandi	L/T L/Tp											16.32 0.35
Haynesina orbiculare	L/T L/Tp											
Hemisphaerammina bradyi	L/T L/Tp											
Jadammina polystoma	L/T L/Tp	100 2	100 0.7	100 6				100 42		100 15		56.2 2.2
Miliammina fusca	L/T L/Tp	83 67	85 88	98 61		100 6	100 56	100 75	100 39	100 40		73.8 47.2
Planktonics	L/T L/Tp											2.04 1.78
Pseudothurammina limnetis	L/T L/Tp	100 8	100 0.4	96 23						100 20		40.60 1.95
Tiphotrocha comprimata	L/T T/Tp			100 .49		100 19	100 4	100 8	100 11			65.9 7.50
Trochammina inflata	L/T T/Tp	91 22	83 11	100 10		100 36	91 41	100 13	100 32	100 25		80.6 33.0
Trochammina macrescens	L/T L/Tp	100 0.2								100 2		68.1 2.5

L = TOTAL LIVING (ONE SPECIES) T = TOTAL POPULATION (ONE SPECIES)
Tp = TOTAL POPULATION (ENTIRE SAMPLE)

TABLE II
FORAMINIFERAL SPECIES DISTRIBUTIONS IN RELATIVE PERCENT, KINGSPORT MARSH, TRANSECT II

STATION NUMBER NO. OF SPECIES		1A 1	1B –	2A 4	2B 4	3A 6	3B 6	4A 6	4B 6	5A 6	5B 5	6A 3	6B 5	7A 5	7B 6	8A 3	8B 5	9A 5	9B 5	10A 7	10B 9	11A 7	11B 6	MEAN %
TOTAL POP^{n} 10CM^{3}		2	–	249	370	76	297	406	680	1109	1442	393	296	509	362	571	862	240	279	95	206	44	101	
Total Living		0	0	19	35	34	53	70	180	171	395	58	87	105	75	235	123	34	41	52	31	11	0	
Ammonia beccari	L/T L/Tp																			0 1				0 0.05
Ammotium salsum	L/T L/Tp																				100 0.5			100 0.02
Arenoparrella mexicana	L/T L/Tp																				100 0.9			4.5 0.04
Elphidium excavatum	L/T L/Tp																			50 2				2.3 0.1
E. incertum	L/T L/Tp																					100 2		4.5 0.1
E. williamsoni	L/T L/Tp																					29 16		1.3 0.7
Haplophragmoides bonplandi	L/T L/Tp					50 11															40 2			4.1 0.6
Haynesina orbiculare	L/T L/Tp																			50 4		42 43		4.2 2.2
Hemisphaerammina bradyi	L/T L/Tp																					100 5		4.5 0.2
Jadammina polystoma	L/T L/Tp	100 100			100 0.5	75 21	100 5	100 3	76 4	100 0.2				100 2	100 0.3		100 0.4	100 0.4			94 9		100 2	56.6 6.7
Miliammina fusca	L/T L/Tp			100 2			100 9	85 34	64 34	90 63	71 79	87 59	72 63	87 42	81 43	55 33	90 41	86 41	80 35	32 63	88 55	100 21	100 38	66.7 34.2
Pseudothurammina limnetis	L/T L/Tp					100 5	100 0.7	100 1	100 2	100 1	100 2		100 2	100 0.4	100 0.3				100 3				100 5	49.1 1.0
Tiphotrocha comprimata	L/T T/Tp			100 8	82 6	60 26	59 15	59 11	42 11	70 23	74 10	23 8	76 15		88 4	100 4	68 6	77 11	83 9	80 5	91 5		100 12	60.5 8.6
Trochammina inflata	L/T T/Tp			92 88	91 90	33 32	80 67	85 50	65 48	86 11	79 9	96 34	60 20	72 54	77 50	57 60	84 52	87 45	89 51	73 23	86 24	100 5	100 38	73.3 33.6
Trochammina macrescens	L/T L/Tp			86 3	85 4	50 5	100 2	100 2	100 2	76 2	100 0.3		100 0.7	80 2	67 2	84 3	88 0.9	100 3	88 3		100 2	100 9	100 6	72.9 2.4

Table III. Foraminiferal Species Distribution in Relative Percent, Kingsport Marsh Cores.

	CORE I						CORE II		CORE III		
DEPTH IN CM	800	800	900	900	950	950	600	660	370	400	420
NO. OF SPECIES	3	5	6	2	3	1	5	1	3	6	–
NO. OF INDIVIDUALS (Tp)	17	560	404	242	28	27	299	1	886	355	–
Haplophragmoides bonplanii	2	7				6			34		
Miliammina fusca		0.7	9							2	
Pseudothurammina limnetis			1				1			0	
Tiphotrocha comprimata	6	10	14	5	21		7		15	20	
Trochammina inflata	76	87	63	95	75	100	85	100	83	40	
Trochammina macrescens	18	0.3	6		4		1		2	4	

Table IV. Foraminiferal Species Distribution in Relative Percent, Granville Ferry Cores.

	CORE I		CORE II			CORE III	
DEPTH IN CM	840	365	530	550	600	310	330
NO. OF SPECIES	4	3	6	6	2	6	5
NO. OF INDIVIDUALS (20ml)	302	78	419	590	3	630	96
Haplophraymoides bonplandi			4	4		9	29
Miliammina fusca	3	4	9	1		3	5
Pseudothurammina limnetis	1	14	3	0		0	
Tiphotrocha comprimata	12		22	14	67	21	13
Trochammina inflata	84	82	14	52	33	58	44
Trochammina macrescens			48	29		9	9

Table V. Foraminiferal Species Distributions in Relative Percent, Mary's Point Cores.

	CORE I	CORE II		CORE III			CORE V	
DEPTH IN CM	823.5	289.5	305	457.5	472.75	488	625	685
NO. OF SPECIES	5	0	2	6	5	3	4	6
NO. OF INDIVIDUALS 10cm) (Tp)	297	0	49	366	249	162	348	228
Haplophragmoides bonplanii	14			2	4			11
Jadammina polystoma								24
Miliammina fusca	1			16	3			
Pseudothurammina limnetis	8			2			9	1
Tiphotrocha comprimata	101			66	21	3	191	28
Trochammina inflata	110		16	1	1	1	82	26
Trochammina macrescens	63		33	279	211	158	66	138

Table VI. .Foraminiferal Species Distribution in Relative Percent, Fort Beausejour Cores.

	CORE # I						CORE # II		CORE # III	CORE # IV	CORE # VI	CORE # VII	CORE # VIII
DEPTH IN CM	762.4	884.5	854	915	1098	1165.5	716.5	762.5	701.5	701.5	183	396.5	579.5
NO. OF SPECIES	4	2	2	1	1	2	3	2	2	0	1	3	2
NO. OF INDIVIDUALS 10cm^3) (Tp)	254	3	20	17	67	25	534	3	9	0	868	274	59
Haplophragmoides bonplandi													
Haynesina orbiculare					100	52							
Jadammina polystoma													
Miliammina fusca			10									4	
Pseudothurammina limnetis	1												
Tiphotrocha comprimata	42						13		11				
Trochammina inflata	37	33	90	100			27	66	89			1	2
Trochammina macrescens	20	67				48	60	34			100	95	98

Table VII. Calculations of Actual Sea Level Rises, for Sampling Localities in the Bay of Fundy.

Core Sites	Apparent Sea Level Rise	Apparent Sea Level Rise/100 Years	Tidal Amplification	Avg Sea Level Rise - Tidal Amplification = Actual Sea Level Rise	Actual Sea Level Rise/ 100 years
Kingsport Marsh	9.35m/ 4400 years	21.25cm / 100 years	2.32m/ 4400 years	7.03m / 4400 years	16cm/100 years
Granville Ferry Marsh	9.9m/ 3525 years	28.10cm / 100 years	0.89m/ 3525 years	9.01m / 3525 years	25.6cm/100 years
Mary's Point Marsh	9.7m/ 3500 years	27.32cm / 100 years	1.43m/ 3550 years	8.27m / 3550 years	23.3cm/100 years
Ft. Beausejour Marsh	11.4m/ 3850 years	29.61cm / 100 years	1.7m / 3850 years	9.70m / 3850 years	25.2cm/100 years

The following is a breakdown of the approximate time spent in the preparation of this thesis.

ITEM	TIME SPENT (HRS.)
Foraminiferal Identification and Counting	135
Sample Preparation	10
Tables and Diagrams	45
Photographic Plate Preparation	7
Research and Writing	45
Total Time	242

Frank Thomas did the S.E.M. photography at B.I.O.

Map figures within this thesis were obtained from David Scott. All other figures were designed by the author and drafted professionally.

All tables contained in this thesis were prepared by the author but were drafted professionally on a word processor.

Photographic plates were compiled by the author but reproduced professionally.

David Smith