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Studies of Benthonic Foraminifera in the Restigouche Estuary: 1. Faunal Distribution Patterns near Pollution Sources*

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Introduction

The Restigouche River, flowing into the Bay of Chaleur at its head, forms an estuary about 100 miles long between Gaspé Peninsula, Quebec and northern New Brunswick (Fig. 1). In addition to its many inherent environmental features, the Restigouche estuary is especially well suited for the study of the local effects of industrial and municipal sewage discharges on the physical and chemical characteristics of the nearshore water and sediment, and on the local distribution of benthonic foraminiferal populations. This unique setting has evolved because most large scale industrial and urban development has been confined to the New Brunswick coast. Comparative areas that appear to be relatively unpolluted are available for study along most of the Quebec shore.

The aims of this report are: 1) to describe the local physical and chemical characteristics of water and sediment near effluent sources during the summer of 1970 and to compare these values with those collected in other nearshore areas of the estuary; and 2) to determine the local distribution of benthonic foraminifera in areas immediately adjacent to various municipal and industrial outfalls and to distinguish those species that may be potentially useful as pollution indicators. The long range goals of this investigation are to determine seasonal and spatial variations in species distributions and Foraminiferal Number in the upper three centimetres of bottom sediment and to apply this information to a study of the Late Quaternary history of the estuary through micropaleontological analysis of core samples.

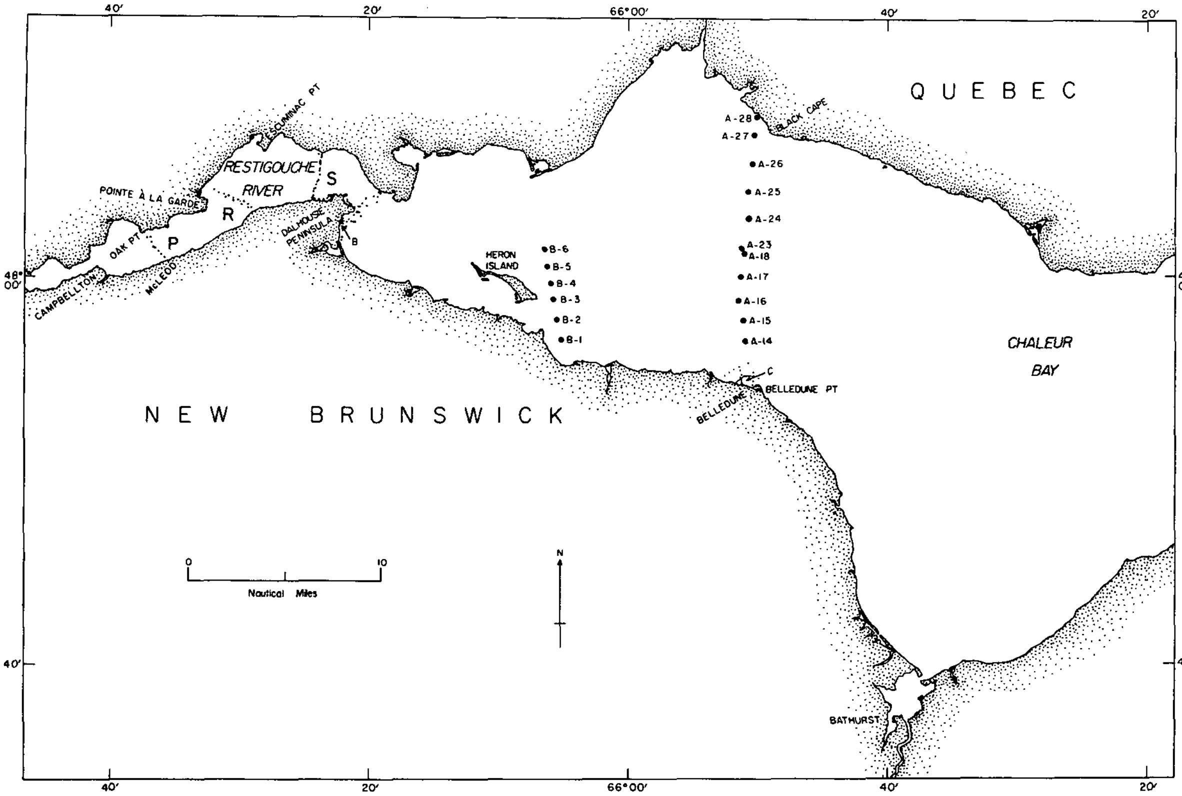

Figure 1. Station locations in the Restigouche Estuary. C and B denote the location of "Belledune Basin" and the "Dalhousie Power Station" respectively. Traverses S, R and P are located west of Dalhousie, New Brunswick.

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Field and Laboratory Procedures

All stations were located by triangulation using a Heath and Co. horizontal sextant to measure angles between known visible locations along the coasts of the estuary. Sediment samples were collected with an 18 x 18 cm modified Ekman dredge. The pH of the upper layer of each sediment sample, as well as a split of each water sample, was measured using a Metrohm E 280A pH metre. Part of the upper layer of sediment was then removed and preserved in a 50-50 solution of isopropyl alcohol and distilled water. The remainder of the sample was retained for grain size analysis. Bottom water samples were collected with a five-litre P.V.C. water sampler. A part of each sample was transferred to a BOD bottle and fixed with $MnSO_4$ and NaOH-KI solutions (Strickland and Parsons, 1968). A second split was collected and frozen for subsequent phosphate analysis. Portions of the remaining sample were retained for salinity and pH determinations.

In the laboratory, the preserved sediment sample was flushed into a 100 ml cylinder for determination of wet volume. The sample was then washed through a number 230 sieve (0.063 mm openings), dried at 60°C and floated in a solution of bromoform and acetone (Gibson and Walker, 1967; Sen Gupta and McMullen, 1969). The floats were dried at room temperature and foraminifera species were identified and counted on a standard Curtin 14401 slide. Seventy-nine stations were occupied during Phase I of this study which was initiated during August and September, 1970.

Physical and Chemical Characteristics of Bottom Water and Sediment

Before discussing the differences between the observed physical and chemical parameters in the greater part of the estuary, compared with certain locally-polluted nearshore areas, it is useful to relate briefly the significance of these parameters to the observed distributions of benthonic foraminifera. In most situations the temporal variations in concentration and distribution of water-borne effluents are far more frequent than variations in sediment and invertebrate faunal characteristics that develop in response to pollution influx. Intermittent measurement of various water-related parameters serve only to establish the existence of possible barriers that may influence the local distribution of the benthos. However, since the configuration and extent of these barriers is usually variable, the resulting faunal distribution will generally reflect the averaged environmental conditions that have persisted over long periods (i.e. months). This situation develops because many invertebrates are slow to respond and, in certain instances, possess an ability to isolate themselves from short-term unfavorable conditions. Conversely, the occurrence of intense conditions of pollution during a reproductive period can cause distributional changes that may be evident for many months because of the relatively greater sensitivity of juvenile specimens and pelagic larvae compared with adult forms (Mileikovsky, 1970). The parameters discussed below are useful therefore in describing the nature of possible physical and chemical barriers. However the factors in the waste discharge which influence, directly or indirectly, the changes in the benthic community are presently not well understood (see: Reish, 1970b).

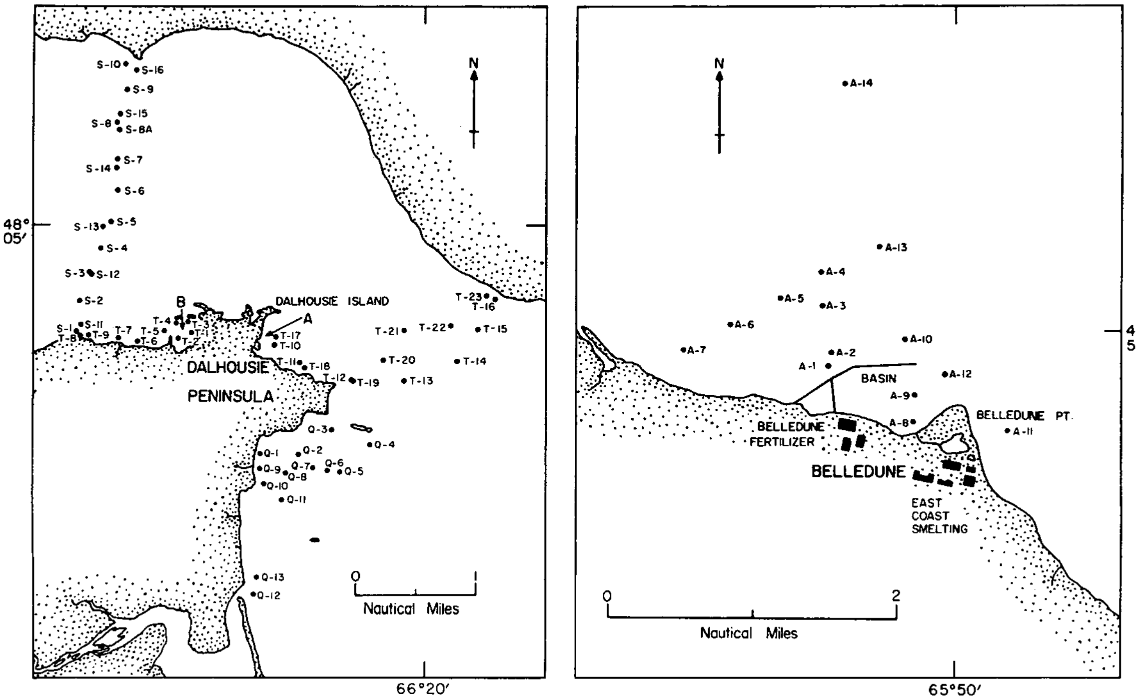

Figure 2. Station locations near industrial and urban sites. A and B denote "embayments" referred to in the text. Dalhousie Island has been permanently joined to the mainland.

(A) Temperature:

Near the Belledune wharf, water temperatures varied from 11.9 to 13.4°C (Figs. 1-C, 2). The highest temperature in this area was recorded adjacent to the Belledune Fertilizer Co. outfall, however it was only about one degree higher than adjacent waters and is not considered significant in terms of influencing the local distribution of the eurythermal nearshore foraminiferal fauna. North of Belledune bottom water temperatures decreased markedly in the deeper offshore parts of the estuary. The lowest value recorded during the August-September field season was 7.4°C at station A-17 in the central part of the Bay. Bottom waters were generally cooler in the southern half of the Bay (See: Appendix I) and showed the greatest decrease in temperature between 16 and 29 metres. Immediately east of Heron Island temperatures were all above 10°C and values slightly higher than 13°C were recorded in the shoal areas along the south shore of the Bay.

Near the Dalhousie power plant outfall (Fig. 1-B), water temperatures reached a high of 19.3°C but decreased abruptly away from the outfall to an average of about 13°C during August and September. Temperatures in this area were generally about 1°C higher than those of adjacent waters to the north. During the summer season the relatively high water temperature in this area is related to a combination of shallow water depths (less than 5.5 m) and proximity to the heated effluent discharge of the power station. Isotherms drawn in this area suggest that the heated effluent tends to flow parallel to the shoreline during calm days. Assuming that all other water quality criteria can be made acceptable, the relatively higher water temperatures, gentle slope of the seabed, undeveloped shoreline, and protective highlands to the north and west renders this area ideally suited for the development of a summer recreational site.

West of Dalhousie bottom water temperatures were all greater than 10°C and the 12°C isotherm paralleled approximately the nine-metre depth contour. Wide shoal areas and heated effluents discharged by industries and municipalities situated along the southern shore probably give rise to slightly warmer bottom temperatures (about 0.5°C) in the subtidal zone during August and September. Bottom water temperatures increased gradually west of Escuminac Point and values greater than 15°C were recorded across much of the south side of the river channel near McLeod, N.B. Temperatures continued to increase up estuary (westward) and were relatively higher in the southern half of the channel especially in water less than nine metres deep.

(B) Salinity:

Salinities averaged about 28.0^{o}/oo in the Belledune basin (Fig. 2), and were about 1.0^{o}/oo less at the western end of the wharf. Values increased to about 28.9^{o}/oo in the central parts of the Bay just north of Belledune and then decreased about 4.0^{o}/oo towards the coast near Black Cape, Quebec. Southwest of Black Cape at the eastern end of Heron Island nearshore values ranged from 25.3^{o}/oo to 26.0^{o}/oo compared with offshore values of 26.5 to 28.3^{o}/oo. Near Dalhousie a vertical gradient of about 2 to 4^{o}/oo developed as mixed river water passed over the Bay water. West of Dalhousie salinities ranged between 23.7 and 26.9^{o}/oo and once again showed a slight decrease in shoreward directions. At Pointe à la Garde, Quebec, this shoreward decrease was also evident along with a pronounced decrease in salinity compared with areas near Dalhousie (Range 14.5 to 22.7^{o}/oo). At the westernmost traverse near Oak Point, New Brunswick, relatively higher salinities characterized the deeper north channel (21.5^{o}/oo), while low saline water (6.3^{o}/oo) flowed in the southern half of the channel. The distribution of bottom-water salinity values suggests that salt water incursions are confined to the deeper north channel between Dalhousie and Oak Point during the greater part of the tidal cycle.

(C) pH:

The pH of bottom water averaged about 7.5 near the Belledune wharf. There was a slight decrease (7.2) near the East Coast Smelting Co. outfall and a sharp decrease (6.0) adjacent to the Belledune Fertilizer Co. outfall. Bottom sediment pH conforms to about the same pattern, however the average value was somewhat lower than that of the water. The most acidic pH was measured in sediment adjacent to the Belledune Fertilizer Co. outfall (4.4) and no specimens of foraminifera were observed in the sediment sample collected from that area. At station A-2 (Fig. 2) the pH of the sediment increased to 6.7 and six species of living foraminifera were noted of which 93 per cent were calcareous hyaline types belonging to the genus *Elphidium*. The sediment pH data noted here and elsewhere (Bartlett, 1964) suggests that the minimum pH that will permit establishment of these forms in this area is probably close to 6.7.

In the Bay area north of Belledune, water pH averaged about 7.6 over the entire cross-section. The pH of sediments was slightly lower in the deeper offshore areas (Av. 6.9) compared with sediments collected from intermediate depths on either side of the channel. To the west near Heron Island, bottom water pH's increased about 0.1, whereas sediment values remained about the same as those recorded in the offshore areas north of Belledune. Sediment pH did, however, show a general decrease offshore between stations B-1 and B-6. The reason for this decrease is not yet clear.

Near Dalhousie the pH of water was similar to that measured at stations near Heron Island. Conversely, the embayment south of Dalhousie Island (Fig. 2-A) was characterized by pH values that averaged about 0.5 lower than open waters to the north. These lower values are probably related to the location of municipal and industrial sewage outfalls and landfill operations along this part of the shore. The pH of bottom waters are at normal values about 0.5 nautical miles east of the sewage outfall. Sediment pH's were correspondingly low in this area and seemed to persist in a belf of sediment about 0.1 mile wide that extends for about one mile east and south parallel to the shoreline. Values of pH were about 0.4 lower than average in this belt of sediment.

West of Dalhousie values of pH in the offshore bottom water decreased about 0.1. The embayment on the western side of Dalhousie (Fig. 2-B) was characterized by relatively lower pH values in the water (Av. 7.5) and the sediment (Av. 6.5) pH values, compared with adjacent nearshore areas. This condition may reflect the discharge of industrial effluent and landfill operations connected with the paper mill located at this site. Relatively low pH's were again traceable in the sediments over much longer distances.

West of Esuminac Point, Quebec, bottom water pH showed no change. There was, however, approximately a 0.1 decrease in the sediments in offshore areas. At Oak Point pH values of the bottom water remained about the same as those recorded to the east although the sediments showed an average decrease of 0.2.

(D) Phosphates in Bottom Water:

The highest phosphate concentrations (expressed as μg at. P/ℓ) were measured around the Belledune wharf, and ranged from 4 to 124. Typical offshore values averaged about 1.1 and decreased northward towards Black Cape, Quebec where concentrations averaged about 0.8. East of Heron Island phosphates decreased in a shoreward direction and were about the same concentration as was observed in the northern half of the Belledune traverse.

Just east of Dalhousie phosphate concentrations were again highest in the offshore water. Phosphate concentrations west of Dalhousie were also lower in the nearshore zone (e.g. 0.4-1.2) and values greater than 1.0 were confined to the central channel area. A similar geographic distribution and range of concentrations was evident at Point à la Garde and Oak Point. The consistently high relative values in the deeper parts of the channel suggest possible westward transport of phosphate-enriched waters from the eastern end of the estuary near Dalhousie. The markedly higher salinities that characterized the northern (deeper) half of the channel near Oak Point are in agreement with this conclusion.

(E) Dissolved Oxygen in Bottom Water:

Dissolved oxygen concentrations (expressed as ml O_2/l) were surprisingly uniform throughout the entire estuary. Typical values in the Bay ranged from 5.2 to 6.5 and in the river from 4.4 to 5.6. Concentrations greater than 5 were common immediately adjacent to both industrial and municipal sewage outfalls and compared favorably with typical Bay and River values. Strong winds probably induce complete mixing and aeration of nearshore shallow waters thereby maintaining reasonably normal dissolved oxygen concentrations in most of these high oxygen demand areas during this season of the year. Salinity profiles in these areas also suggest complete vertical mixing.

Anomalously low concentrations of dissolved oxygen (less than $5^{o}/oo$) were evident along the coast of New Brunswick just west of Dalhousie and along the north shore near Oak Point, Quebec. The reasons for these distributions are not readily apparent. However effluent discharges of both the Canadian Industries Ltd. (C.I.L.) Chemical Plant, the Imperial Paper Co. and municipal sewage discharges at Dalhousie may be related to the depressed values observed in this particular area.

(F) Tides and Currents:

According to Canadian Hydrographic Survey charts the average tidal variation in the estuary is about 1.6 m at Belledune, 1.9 m at Dalhousie and 2.0 m at Campbellton. The major areas of current activity are centered around and north of Dalhousie and Campbellton where the river channel is relatively constricted. At these locations the charts show tidal currents of one to two knots. These currents are undoubtedly helpful in flushing pollutants from waters adjacent to the industrialized sections of the shoreline. Unfortunately, these same currents serve to spread the pollutants throughout the entire estuary thus influencing the general degradation of its water quality.

(G) Particle Size of Bottom Sediments:

The median diameter and degree of sorting of bottom sediments in the Restigouche estuary ranges between +6.6 and -5.4 and between 0.4 and 5.9 phi units (Inman, 1952) respectively. Most of the sediments in the estuary are characterized by median diameters greater than two phi, and deviation values between one and three phi, although stations Q8 to Q11, near the Dalhousie power station, have deviation values of less than 0.7 phi (Appendix II). East and west of Dalhousie

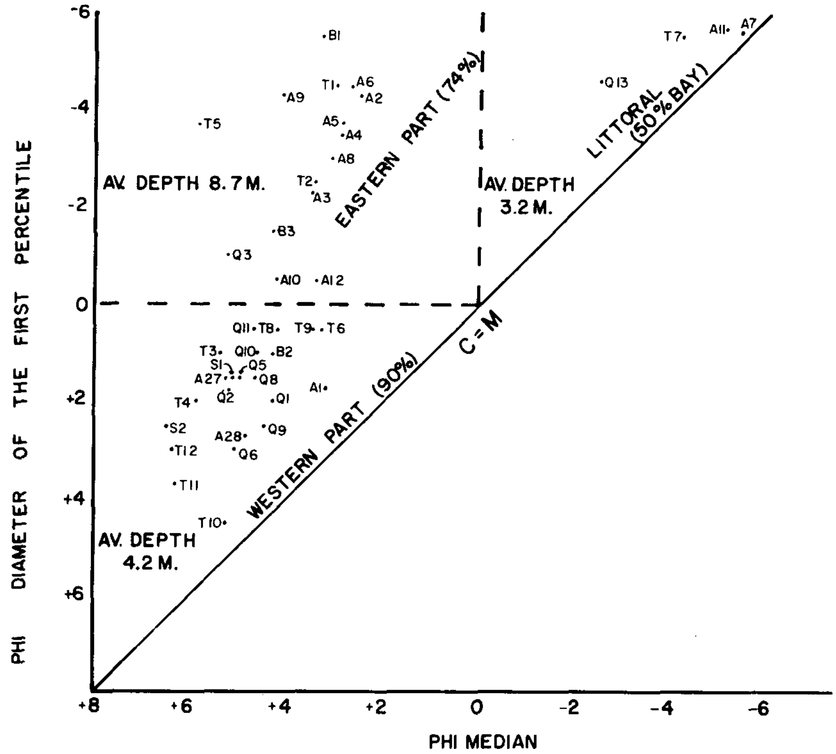

Figure 3. C/M plot of sediments in the Restigouche Estuary.

peninsula (Fig. 2-A,B) the sediments are exceptionally fine because of the influx of suspended particulate matter from several nearby municipal and industrial sewage outfalls. Throughout the remainder of the estuary phi median values increase generally in an offshore direction. A plot of the first percentile phi diameter over the phi median diameter (Passega, 1957) shows that the sediments in the estuary can be classified generally into three groups which are associated with the western, eastern and littoral parts of the estuary (Fig. 3). Bottom sediments in the western part of the estuary are composed of relatively fine particles compared to those collected east of Dalhousie Island. These sediments are deposited primarily from suspension and include a high percentage of river-associated organic detritus. Sediments in Chaleur Bay are coarser generally because this area is removed from the major source of the fines, most of which appear to be trapped in the western part of the estuary. The trapping of these fines is probably related to several factors including the circulation pattern (i.e. stratification) in the estuary which may, at times, transport material upstream. Flocculation and relatively rapid deposition of clay-sized particles may be triggered by the mixing of sediment-laden fresh water with saline estuarine water. Scour and depositional lag processes as well as freezing of the surface layer of water may also prevent resuspension and transport of fines from the western part of the estuary. Littoral and subtidal zones along the entire estuary are characterized, in general by relatively coarse pebbles and cobbles, representing deposits that have been reworked and winnowed by waves and currents (Buckley and Grant, 1964).

Foraminiferal Distribution in the Estuary

Forty-six benthonic and one planktonic species of foraminifera have been identified in sediment samples from the nearshore areas of the Restigouche estuary. Fifteen species are common to both the inner and outer estuary and about 59 and 86 percent of these were collected alive in the inner (River) and outer (Bay) areas respectively. The inner (western part) estuary is arbitrarily defined as that body of water lying west of Dalhousie Island. About 32 species appear to be restricted to the outer estuary and 32 percent of these were living at the time of collection. Species of *Reophax*, *Quinqueloculina*, *Lagena*, and *Fissurina* are especially important as outer estuary indicator forms (Table I). The writer has identified 20 of the species reported by Bartlett (1966) from the Miramichi estuary and 12 of the species noted by Hooper (1970) in the Bay of Chaleur.

TABLE I

DISTRIBUTION OF FORAMINIFERA – RESTIGOUCHE ESTUARY

COSMOPOLITAN FORMS	I	O.	OUTER ESTUARY FORMS	O
AMMODISCUS CATINUS	D	D	BUCCELLA cf. INUSITATA x	D
AMMOMARGINULINA FLUVIALIS *	L+D	L+D	BULIMINELLA ELEGANTISSIMA *	L+D
AMMOTIUM CASSIS * x	L+D	L+D	CASSIDELLA cf COMPLANATA	D
BUCCELLA FRIGIDA *	L+D	L+D	CIBICIDES LOBATULUS	D
EGGERELLA ADVENA *	L+D	L+D	CRIBROSTOMOIDES JEFFREYSI x	D
ELPHIDIUM FRIGIDUM	D	L+D	DENTALINA ITTAI	D
E. INCERTUM CLAVATUM * x	L+D	L+D	ELPHIDIUM BARTLETTI *	D
E. MARGARITACEUM *	L+D	L+D	ESOSYRINX CURTA	D
E. SUBARCTICUM *	L+D	L+D	FISSURINA LUCIDA	D
HEMISPHAERAMMINA SP. *	D	L+D	F. MARGINATA *	L+D
MILIAMMINA FUSCA *	L+D	D	GLOBIGERINA BULLOIDES (PLANKTONIC)	D
PROTELPHIDIUM ORBICULARE *	L+D	L+D	GORDIOSPIRA ARTICA	D
SACCIMMINA ATLANTICA	D	L+D	ISLANDIELLA TERETIS x	D
TROCHAMMINA INFLATA *	D	L+D	LAGENA GRACILLIMA	D
T. SQUAMATA * x	D	L+D	L. NEBULOSA	D
			L. SEMILINEATA	D
			NONIONELLA LABRADORICA *	L+D
			PATELLINA CORRUGATA	D
			PATEORIS HAUERINOIDES	L+D
			PSEUDOPOLYMORPHINA NOVANGLIAE *	L+D
			QUINQUELOCULINA AGGLUTINATA	D
			Q. SEMINULUM *	L+D
			REOPHAX ARTICA x	L+D
			R. CURTUS x	L+D
			R. NANA	D
			R NODULOSA	L+D
			R. PILULIFERA *	D
			R. SCOTTI	L+D
			SPIROPLECTAMMINA BIFORMIS * x	D
			TEXTULARIA TORQUATA x	D
			T. CF. NANA	L+D
			TROCHAMMINA OCHRACEA *	D
LIVING SPECIES	9	13		11
TOTAL SPECIES	15	15		32
PER CENT LIVING	59	86		34

L = LIVING
D = EMPTY TESTS
* = BARTLETT (1966) MIRAMICHI R.
x = HOOPER (1970) BAY OF CHALEUR

TABLE II

LOCAL FAUNAL DISTRIBUTIONS AT KEY INDUSTRIAL AND URBAN SITES

KEY INDUSTRIAL SITES	NUMBER OF LIVING SPECIES	% LIVING SPECIES / TOTAL SPECIES	FORAMINIFERAL NUMBER	TYPICAL NEAR SHORE SPECIES ABSENT NEAR OUTFALL	SPECIES LIVING NEAR OUTFALL WHO'S RELATIVE % INCREASES BAYWARD	SPECIES LIVING NEAR OUTFALL WHO'S RELATIVE % DECREASES BAYWARD	DOMINANT LIVING SPECIES AT STATION NEAREST TO OUTFALL
EAST COAST SMELTING	INCREASES BAYWARD	INCREASES BAYWARD INCREASES BAYWARD	INCREASES IN (CENTRAL PART) PROTECTED ENCLOSURE	A. CASSIS E. FRIGIDUM A. FLUVIALIS HEMISPHAERAMMINA SP P. NOVANGLIAE R. FUSIFORMIS R. NODULOSA S. ATLANTICA T. INFLATA	E. ADVENA E. FRIGIDUM A. FLUVIALIS HEMISPHAERAMMINA SP. P. NOVANGLIAE R CURTUS R. NODULOSA S. ATLANTICA T. INFLATA P. ORBICULARE	E INCERTUM/CLAVATUM B. FRIGIDA E. MARGARITACEUM A. CASSIS	E. INCERTUM/CLAVATUM
BELLEDUNE FERTILIZER	INCREASES BAYWARD	DECREASES SLIGHTLY BAYWARD INCREASES BAYWARD.	INCREASES BAYWARD	A. FLUVIALIS A. CASSIS P. ORBICULARE Q. SEMINULUM R. ARCTICA R. SCOTTI S. ATLANTICA E. INCERTUM/CLAVATUM E. MARGARITACEUM E. SUBARCTICUM E. ADVENA B. FRIGIDA	A. FLUVIALIS A. CASSIS P. ORBICULARE Q SEMINULUM R. ARCTICA R. SCOTTI S ATLANTICA	E INCERTUM/CLAVATUM E. MARGARITACEUM E. SUBARCTICUM E. ADVENA B FRIGIDA	E INCERTUM/CLAVATUM
DALHOUSIE POWER PLANT	APPROXIMATELY CONSTANT	DECREASES SLIGHTLY BAYWARD APPROXIMATELY CONSTANT	INCREASES BAYWARD	P. ORBICULARE	A. CASSIS E. ADVENA	P. ORBICULARE E. INCERTUM/CLAVATUM B. FRIGIDA E. MARARITACEUM	E. INCERTUM/CLAVATUM
DALHOUSIE PENINSULA (EAST SHORE)	INCREASES BAYWARD	CONSTANT INCREASES BAYWARD	INCREASES BAYWARD	A. CASSIS E. INCERTUM/CLAVATUM E. ADVENA P. ORBICULARE	A. CASSIS E. INCERTUM/CLAVATUM	E. ADVENA P ORBICULARE	E. INCERTUM/CLAVATUM
DALHOUSIE PENINSULA (WEST SHORE)	INCREASES BAYWARD	DECREASES BAYWARD INCREASES BAYWARD	INCREASES BAYWARD	NONE	E. INCERTUM/CLAVATUM P. ORBICULARE	E. MARGARITACEUM M. FUSCA	E MARGARITACEUM
C I L CHEMICAL	APPROXIMATELY CONSTANT	DECREASES BAYWARD INCREASES SLIGHTLY BAYWARD	INCREASES BAYWARD	A. FLUVIALIS A. CASSIS E. ADVENA B. FRIGIDA	A. FLUVIALIS A CASSIS E ADVENA B FRIGIDA M. FUSCA	E. INCERTUM/CLAVATUM P ORBICULARE E MARGARITACEUM	E. INCERTUM/CLAVATUM P. ORBICULARE
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)

Localized Distributions of Foraminifera

Faunal data gathered from selected areas are arranged into categories which the writer believes to be important in describing locally unfavorable conditions near sewage and industrial outfalls located in the estuarine zone (Table II). In the "outer" estuary the number of living species increases away from the outfalls. This trend is also evident in the "inner" estuary. It is accepted generally by most ecologists that species diversity increases under optimum conditions. This concept has been repeatedly demonstrated with respect to larger invertebrates inhabiting nearshore areas adjacent to a pollution source (e.g. Bellan et. al., 1970). It can be tentatively concluded therefore from the data in columns I and II of Table III that at East Coast Smelting, Belledune Fertilizer and Dalhousie, municipal and industrial effluents produce locally unfavorable environments for benthonic foraminifera populations.

When the percent living species increases bayward concurrently with the total number of species (Table II, Col. II) it can usually be assumed that conditions are becoming more favorable. This trend occurs only once in column II. In most instances the percent of living species decreases bayward. There are two possible explanations for this decrease: (A) deteriorating environmental conditions presently developing in offshore areas, (B) seasonal variation of species distribution and reproduction. The findings of Boltovskoy and Lena (1969), Buzas (1965) and Lee, et. al. (1969) support the latter hypothesis.

The Foraminiferal Number (defined here as the number of living specimens/cc wet sediment) increases bayward in all instances. This situation can develop through increased reproduction at the periphery of the effluent plume where organisms can survive and take advantage of the beneficial aspects (e.g. nutrients and abundant phytoplankton) of the effluent. This condition develops usually just beyond what is commonly called the "sterile" or "azoic" zone. For example, at outfalls in the Bedford Basin, Nova Scotia, abnormally large quantities of mussels, starfish and sea urchins are found living adjacent to this zone. Bellan et. al. (op. cit., p. 4) refer to this area as the "subnormal" zone which separates essentially "polluted" and "normal" enviroments. On the basis of the Foraminiferal Number, stations A-9, A-3, T-2 and Q-2 fall within this zone and their distance from the effluent source is an approximate measure of the bottom area currently being affected by the pollutants at each locality.

Columns IV and VII are interrelated with respect to the variation of the relative percentages of living species and their presence or absence near an outfall. Species present in column VII are considered facultative and are abundant at the edge of the "sterile zone". One gradational group and two species of *Elphidium*, *E. incertum/clavatum* group (See: Bartlett, 1965), *E. orbiculare* and *E. margaritaceum* fall into this category and appear to be the most pollution-tolerant forms living in the estuary. These forms define an area near sewage and industrial outfalls which is probably most analogous to the *Capitella capitata* zone noted by Reish (1970a). Bartlett (1966) found that the largest populations of *E. incertum* "complex" (=*E. incertum/clavatum* group) were associated with sediment having a high organic carbon content and that increased numbers of *E. incertum* "complex" commonly corresponded with decreased numbers of *Eggerella advena*. Along the coast of California, *E. advena* occurs in abundance in shallow water adjacent to the Orange County sewer outfall (Watkins, 1961). Although the *E. incertum* "complex" - *E. advena* relationship noted by Bartlett (op. cit.) was observed in this study in samples from the outer estuary, there was no apparent correlation between the ratio of these two forms and any of the measured physical parameters. *E. advena* appears to be associated primarily with the "subnormal" zone of Bellan et. al. (1970).

Elphidium orbiculare replaces *E. margaritaceum* in a bayward direction at East Coast Smelting, Belledune Fertilizer, the west shore of Dalhousie peninsula, and the Dalhousie power station. Bartlett (op. cit.) found a similar displacement in the Miramichi estuary suggesting that this distributional pattern is common to nearshore zones in this area and that the pattern is not usually influenced by an influx of pollutants or abnormally high water temperatures.

Generally, species listed in column VI are being displaced by those in column V. This replacement may indicate a return to normal conditions or a response to the decrease in the degree of physical variability associated with the subtidal zone.

Those parts of Table III where all of the species in column IV are represented in columns V, VI, and VII, denotes those areas in which an "azoic" condition exists at stations nearest to the outfall. This "azoic" condition was developed at Belledune Fertilizer and along the east coast of Dalhousie peninsula and is undoubtedly related to the acidic nature of sediments found immediately adjacent to the outfalls in these areas. Typical nearshore species appearing in columns IV and VII may be pollution-sensitive, and are therefore poorly represented near the outfall, or, alternatively increase naturally offshore. The potentially pollution-indicative species include *Ammomarginulina fluvialis*, *Elphidium frigidum*, *Hemisphaerammina sp.*, *Pseudopolymorphina novangliae*, *Reophax fusiformis*, *R. arctica*, *R. scotti*, *R. nodulosa*, *Saccammina atlantica*, and *Trochammina inflata* in the "outer" estuary and *Eggerella advena* in the "inner" estuary. Controlled experiments are currently being formulated in order to test the validity of these field observations in the laboratory. Nevertheless, the majority of these species are arenaceous types and it is interesting to note that Watkins (1961) observed an increase in the percentage of arenaceous specimens and species near the Orange County outfall in waters considerably shallower than those normally inhabited by these forms.

Summary

The possible pollution-sensitive characteristics of the aforementioned species have been stressed in this report in order to develop basic information for future studies in nearshore pollution and paleoecology in coastal areas of the Atlantic Provinces. Investigations of the distribution of similar forms inhabiting nearby estuaries suggest that the benthonic foraminifera in these areas are eurybathyic and that "a decrease in species indicates an increase in environmental variability" (Bartlett, 1966). In local nearshore areas of the Restigouche estuary much of this "variability" appears to be related primarily to man's activities and is reflected, among other things, by the species diversity-abundance relationships of benthonic foraminifera. Determination of the direct effect of certain effluents on living specimens of foraminifera requires further controlled laboratory experiments (e.g. Bradshaw, 1961) combined with field studies in which significant physical and chemical parameters of water and sediment are continuously monitored and compared with quantitative faunal data (e.g. Phleger and Bradshaw, 1966).

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Appendix I - Faunal Reference List

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Appendix II - Particle Size Characteristics of Bottom Sediments

Station No.	Phi Median	Phi Mean	Phi Deviation	Phi Skewness
A-1	3.24	3.61	1.12	0.32
A-2	2.52	2.46	1.19	-0.05
A-3	3.54	4.34	2.81	0.28
A-4	2.87	3.44	2.52	0.22
A-5	2.97	2.73	3.15	0.27
A-6	2.69	1.66	3.38	-0.30
A-7	-5.42	-5.42	0.11	-0.03
A-8	3.08	4.10	1.86	0.55
A-9	4.14	4.78	1.88	0.34
A-10	4.22	5.15	2.27	0.41
A-11	-5.13	-5.04	0.24	0.37
A-12	3.40	4.72	2.13	0.62
A-27	5.22	6.36	2.84	0.40
A-28	4.86	5.44	1.17	0.49
B-1	3.29	0.89	5.92	-0.41
B-2	4.30	5.20	1.84	0.49
B-3	4.33	5.16	2.02	0.41
Q-1	4.32	3.97	1.07	-0.33
Q-2	5.21	5.87	1.34	0.49
Q-3	5.25	6.23	1.81	0.55
Q-5	4.97	5.94	1.69	0.57
Q-6	5.10	5.92	1.48	0.55
Q-8	4.72	4.93	0.58	0.36
Q-9	4.46	4.33	0.54	-0.23
Q-10	4.59	4.66	0.39	0.19
Q-11	4.67	4.88	0.57	0.37
Q-13	-2.45	-2.06	1.87	0.21
S-1	5.12	5.66	2.09	0.26
S-2	6.54	7.10	2.19	0.26
T-1	3.01	3.29	1.44	0.20
T-2	3.44	4.53	1.84	0.60
T-3	5.38	6.46	1.98	0.55
T-4	5.87	6.75	1.98	0.44
T-5	5.86	6.78	2.38	0.38
T-6	3.32	4.80	2.33	0.63
T-7	-4.18	-0.47	4.59	0.81
T-8	4.18	3.81	1.03	-0.36
T-9	3.44	3.79	1.06	0.33
T-10	5.36	7.00	2.26	0.73
T-11	6.36	7.02	2.07	0.32
T-12	6.41	7.01	2.28	0.26

APPENDIX III

PHYSICAL AND CHEMICAL CHARACTERISTICS OF BOTTOM WATER AND SEDIMENTS

			WATER						SEDIMENT
STATION	LAT.	LONG.	(metres) DEPTH	TEMP °C	SAL. $^{o}/oo$	pH	OXYGEN ($m\ell O_2/\ell$)	PHOSPHATES (μg at/ℓ)	pH
P-1	48°02.18'N	66°36.28'W	6.5	14.30		7.2			7.1
P-2	48°01.95'N	66°36.03'W	1.7	15.6		7.0			6.8
P-3	48°01.70'N	66°35.86'W	1.7	14.4		7.2			6.8
P-4	48°01.52'N	66°35.50'W	2.2	14.1		7.5			7.2
P-5	48°01.31'N	66°35.27'W	1.8	15.7		6.9			6.8
P-6	48°01.16'N	66°35.13'W	1.4	15.8		6.9			6.9
P-7	48°02.43'N	66°36.52'W	1.5	12.5	13.8	7.3	4.7	0.4	
P-8	48°02.18'N	66°36.09'W	3.0	12.3	21.5	7.5	4.4	5.3	
P-9	48°01.65'W	66°35.73'W	2.0	12.3	6.3	7.5	5.3	0.5	
R-1	48°04.55'W	66°31.56'W	1.3	12.0		7.5			7.2
R-2	48°04.43'N	66°31.23'W	1.5	12.3		7.6			7.3
R-3	48°04.33'N	66°30.84'W	1.5	12.3		7.6			7.0
R-4	48°04.24'N	66°30.45'W	1.5	12.5		7.6			7.0
R-5	48°04.15'N	66°30.14'W	2.3	12.6		7.5			7.4
R-6	48°04.11'N	66°29.73'W	14.0	12.2					7.4
R-7	48°04.05'N	66°29.36'W	8.9	12.1					7.2
R-8	48°03.92'N	66°29.02'W	3.0	12.4		7.4			7.3
R-9	48°03.75'N	66°28.81'W	4.2	12.4					6.5
R-10	48°04.19'N	66°30.68'W	1.0	12.8	14.5	7.3	5.4	0.37	
R-11	48°04.05'N	66°30.10'W	13.7	11.8	22.7	7.6	5.2	1.2	
R-12	48°03.89'N	66°24.49'W	6.0	12.1	21.6	7.6	5.1	0.7	
R-13	48°03.73'N	66°28.99'W	3.0	12.1	20.4	7.4	5.0	0.4	
S-1	48°04.16'N	66°24.27'W	3.0	13.3		7.7			6.6
S-2	48°04.41'N	66°24.25'W	6.5	11.7					6.3
S-3	48°04.62'N	66°24.14'W	5.3	13.2					6.9
S-4	48°04.83'N	66°24.00'W	7.3	11.6					7.3
S-5	48°05.05'N	66°23.86'W	8.9	12.0					7.6
S-6	48°04.33'N	66°23.77'W	8.2	11.5					7.4
S-7	48°05.57'N	66°23.76'W	11.0	10.2					7.4
S-8A	48°05.86'N	66°23.73'W	14.6	10.0					
S-8	48°05.90'N	66°23.73'W	14.6	10.1					
S-9	48°06.15'N	66°23.62'W	11.0	10.5					7.1
S-10	48°06.34'N	66°23.64'W	4.0	11.3					7.2
S-11	48°04.21'N	66°24.23'W	4.0	12.2	23.7	7.5	4.9	0.9	
S-12	48°04.62'N	66°24.10'W	4.0	12.0	25.4	7.6	4.9	0.7	
S-13	48°05.03'N	66°23.98'W	7.0	11.8	26.2	7.6	5.4	0.4	
S-14	48°05.50'N	66°23.82'W	11.0	11.7	26.5	7.6	5.5	1.2	
S-15	48°05.96'N	66°23.70'W	14.6	11.6	26.9	7.6	5.6	1.1	
S-16	48°06.28'N	66°23.53'W	4.0	11.9	25.2	7.6	5.4	1.0	
T-1	48°04.08'N	66°22.85'W	0.8	12.3		7.6			6.2
T-2	48°04.06'N	66°23.04'W	1.0	12.3		7.5			6.9
T-3	48°04.22'N	66°23.94'W	1.5	12.2		7.5			6.5
T-4	48°04.23'N	66°23.07'W	2.7	12.2		7.5			6.5
T-5	48°04.12'N	66°23.31'W	2.7	12.1		7.5			6.5
T-6	48°04.09'N	66°23.56'W	2.2	12.4		7.4			6.7
T-7	48°04.08'N	66°23.80'W	2.2	12.7		7.4			6.7
T-8	48°04.10'N	66°24.25'W	1.4	12.4		7.4			6.9
T-9	48°04.10'N	66°24.20'W	1.1	12.7		7.1			7.0
T-10	48°03.97'N	66°21.88'W	1.1	12.1		7.1			6.8
T-11	48°03.86'N	66°21.49'W	2.8	11.8		7.1			6.9
T-12	48°03.68'N	66°20.88'W	5.8	11.7					6.4
T-13	48°03.72'N	66°20.17'W	19.2	11.5					

Appendix IIICont'd.

WATER

STATION	LAT.	LONG.	DEPTH	TEMP.°C	SAL. °/oo	pH	OXYGEN (mℓO$_2$/ℓ)	PHOSPHATES (µg at/ℓ)	pH
T-14	48°03.84'N	66°19.56'W	20.1	11.3					7.4
T-15	48°04.11'N	66°19.30'W	7.8	11.4					7.7
T-16	48°04.39'N	66°19.04'W	1.9	12.3					7.3
T-17	48°04.02'N	66°21.41'W	2.5	12.3	24.0	7.5	5.1	0.9	
T-18	48°03.81'N	66°21.41'W	3.0	12.1	24.3	7.7	5.4	0.2	
T-19	48°03.66'N	66°20.84'W	6.0	11.8	26.5	7.8	5.7	1.7	
T-20	48°03.87'N	66°20.45'W	16.5		27.3	7.7	5.6	1.2	
T-21	48°04.10'N	66°20.24'W	20.1	11.2	27.4	7.8	5.5	0.7	
T-22	48°04.14'N	66°19.63'W	14.6	11.9	26.3	7.8		0.7	
T-23	48°04.40'N	66°19.17'W	3.0	12.3	24.9	7.7		0.8	
Q-1	48°03.12'N	66°21.97'W	1.0	19.3		7.0			7.0
Q-2	48°03.09'N	66°21.56'W	3.1	13.2					7.2
Q-3	48°03.30'N	66°21.12'W	4.3	12.9					6.9
Q-4	48°03.17'N	66°20.62'W	7.5	13.2					7.2
Q-5	48°02.96'N	66°21.03'W	6.0	13.2					6.9
Q-6	48°02.97'N	66°21.19'W	5.6	13.0					7.2
Q-7	48°02.97'N	66°21.25'W	5.0	13.0					7.1
Q-8	48°02.95'N	66°21.61'W	3.8	13.1					7.1
Q-9	48°02.99'N	66°22.03'W	1.9	14.6					7.5
Q-10	48°02.68'N	66°21.96'W	2.5	14.6					7.3
Q-11	48°02.74'N	66°21.74'W	3.9	13.2					7.2
Q-12	48°01.97'N	66°22.12'W	1.0	13.2					
Q-13	48°02.12'N	66°22.07'W	2.2	13.4					
B-1	47°56.78'N	66°05.05'W	6.1	13.0	25.3	7.7	6.0	0.7	7.5
B-2	47°57.75'N	66°05.40'W	9.8	13.2	25.8	7.7		1.0	7.1
B-3	47°58.88'N	66°04.78'W	9.8	13.0	26.0	7.8	6.1	0.9	7.2
B-4	47°59.65'N	66°06.00'W	8.9	12.9	26.5	7.7		1.3	7.1
B-5	48°00.50'N	66°06.25'W	16.8	12.6	26.6	7.8	5.9	1.2	7.1
B-6	48°01.34'N	66°06.51'W	19.2	10.7	28.3	7.6		1.2	6.9
A-1	47°54.69'N	66°51.14'W	1.7	13.4		6.0		123.8	4.4
A-2	47°54.77'N	65°51.16'W	10.7	12.3				7.2	6.7
A-3	47°55.02'N	65°51.23'W	14.6	11.9					7.1
A-4	47°55.43'N	65°51.15'W	16.8	11.3					7.1
A-5	47°55.21'N	65°51.64'W	13.7	11.4					6.9
A-6	47°55.06'N	65°52.22'W	11.0	12.1					7.0
A-7	47°54.91'N	65°52.63'W	2.9	12.7					
A-8	47°54.36'N	65°50.29'W	5.8	12.3				5.2	7.9
A-9	47°54.48'N	65°50.33'W	8.5	12.1				7.2	7.1
A-10	47°54.83'N	65°50.32'W	13.4	12.0					7.2
A-11	47°54.33'N	65°49.67'W	5.4	12.2					
A-12	47°54.73'N	65°49.99'W	9.5	11.9					7.0
A-13	47°55.60'N	65°50.60'W	19.5	11.3					7.1
A-14	47°56.70'N	65°50.85'W	29.3	9.5					7.0
A-15	47°57.75'N	65°51.04'W	31.1	7.9					7.1
A-16	47°58.80'N	65°51.44'W	31.1	7.9					7.2
A-17	48°00.00'N	65°51.25'W	29.3	7.4					6.9
A-18	48°01.18'N	65°51.03'W	29.3	9.5					7.2
A-23	48°01.40'N	65°51.10'W	29.3	10.0	28.7	7.6	5.3	1.2	6.8
A-24	48°03.12'N	65°50.70'W	27.5	9.4	28.9	7.7	5.2	1.2	6.9
A-25	48°04.32'N	65°50.75'W	27.5	9.6	28.9	7.5	5.2	1.4	7.0
A-26	48°04.80'N	65°50.36'W	27.5	10.6	28.7	7.6	5.5	1.0	7.0
A-27	48°07.22'N	65°50.25'W	22.0	10.8	28.4	7.7	5.8	1.0	7.2
A-28	48°08.30'N	65°50.11'W	5.5	12.1	28.0	7.7	6.5	0.7	7.0

APPENDIX IV

FAUNAL DATA

STATION NUMBER	A-8	A-9	A-12	A-11	A-1	A-2	A-3	A-10	A-7	A-6	A-5	T-1	T-3	T-2	T-4	T-5	T-6	T-7	T-9	S-1	S-2	S-3	Q-1	Q-2	Q-9	Q-8	Q-3	Q-6
LIVING SPECIES	6	7	13	2	0	6	10	9	1	16	13	4	0	4	1	1	5	4	4	4	4	2	6	3	5	4	4	5
TOTAL SPECIES	20	26	33	6	0	16	29	36	3	28	31	5	1	6	2	2	9	7	5	12	7	6	11	10	9	9	9	10
N.LIVING/CC WET SED.	6.37	17.79	11.81	0.17	0.00	0.18	5.98	4.28		4.37	11.44	0.35	0.00	12.70	0.01	0.01	0.73	0.48	0.10	0.62	0.48	1.07	7.66	43.24	6.21	7.62	0.73	29.30
TOTAL N/CC WET SED.	86.10	171.74	105.9	0.60	0.00	2.12	237.4	30.8		48.11	183.5	1.61	0.02	3.06	0.03	0.04	3.74	4.68	5.35	11.48	3.08	6.72	68.74	62.10	20.91	46.41	7.90	109.6
Ammodiscus catinus		0	0				0	0		0	0										0							
		0.21	0.18				0.49	0.17		0.39	0.51										0.68							
Ammopemphix sp.								0																				
								0.09																				
Ammomarginulina fluvialis	0	4.00	4.84				3.23	7.89		0.85	8.13										39.13							
	0.16	1.04	4.50				0.16	0.35		0.23	0.91										23.71							
Ammotium cassis	0	46.01	17.74	0		0	9.68	26.32		3.39	35.71						1.41			42.31	39.13	56.41	1.49	0.99	4.44	4.64	46.71	73.71
	0.32	18.43	3.42	3.23		2.42	1.06	2.07		1.54	6.54						0.83			28.91	60.14	73.51	0.83	7.29	6.64	23.41	30.01	51.70
Buccella frigida	4.26	2.00	1.61			7.14	6.45	13.16		1.69	0.81									0	8.70	0	2.24	0.11	0.74	0	0	0.32
	4.88	6.63	2.70			5.45	3.41	4.39		1.69	1.98									0.42	1.35	1.47	4.07	1.30	4.20	4.21	5.92	1.27
B. cf. inusitata	0	0	0			0	0	0		0	0												0	0			0	0
	0.79	1.09	5.17			0.61	0.24	1.03		1.08	0.30												0.33	0.46			1.22	0.09
B. sp.		0																										
		0.62																										
Buliminella elegantissima			0				0	0		0.85	0																	
			0.18				0.16	0.09		0.08	0.10																	
Cassidella cf. complanata							0	0			0																	
							0.08	0.09			0.10																	
Cibicides lobatulus		0																										
		0.21																										
Cribrostomoides jeffreysi								0			0																	
								0.09			0.10																	
Dentalina ittai		0	0				0	0			0																	
		0.21	0.18				0.33	0.09			0.05																	
Eggerella advena	2.13	6.00	38.70	0		7.14	6.45	18.42		7.63	34.15						0			0	13.04	0	0.75	0	0.74	1.99	4.44	5.08
	2.83	12.22	34.35	6.45		6.00	48.9	29.0		44.5	72.02						0.23			0.62	12.84	1.18	0.33	0.38	3.32	4.11	3.88	25.89
Elphidium bartletti	0			0			0				0																	
	6.30			6.45			1.14				0.10																	
E. frigidum	0	0	3.23			0	0	0		0.85										0			2.24		0			
	1.57	0.08	2.34			4.24	3.78	3.96		0.62										4.15			2.08		1.33			
E. incertum	87.23	0.32	14.52	77.7		42.9	16.13	21.05	100.0	53.4	0.81	28.6		24.24	100.0	100.0	36.31	16.67	39.8	19.23		43.52	90.3	93.4	78.5	17.42	46.67	18.10
	81.40	45.54	38.13	74.19		51.52	31.67	44.71	55.55	37.18	5.68	28.68		21.76	66.6	75.01	30.61	21.79	33.76	41.08		22.83	90.11	95.40	67.03	52.27	54.89	17.06
E. margaritaceum	2.13	0	0	0		21.42	0	0	0	0.85		53.6		16.16			8.45	12.50	19.97				2.24					
	1.10	0.62	0.90	3.23		7.27	1.30	3.79	5.56	1.54		39.53		16.32			6.33	5.56	19.53				1.75					
E. subarcticum	0	0	0			7.14		2.63		0.85	0	0		0			0	4.17										
	2.20	0.62	0.52			8.48		3.62		1.39	0.30	6.20		2.09			2.48	6.41										
Esosyrinx curta			0					0																				
			0.18					0.09																				
Fissurina lucida			0																									
			0.18																									
F. marginata		0									0.81																	
		0.41									0.05																	
Gordiospira arctica	0																											
	0.16																											
Hemisphaerammina sp.	0	0.06	1.61			0	0	2.63		0.85	2.44						0	0		0	0	0		0	0	0	0	0
	0.32	2.28	0.90			4.85	0.33	0.86		0.77	0.66						3.17	0.43		0.21	0.68	0.44		0.23	1.33	0.70	1.02	0.59
Islandiella teretis			0					0															0					
			0.18					0.09															0.08					
Lagena gracillima			0					0			0																	0
			0.18					0.09			0.05																	0.05
L. nebulosa								0																				
								0.09																				
L. semilineata											0																	
											0.05																	
Miliammina fusca	0	0	0				0	0		0	0	10.71		1.01			1.41	0	1.77	7.69		0	0			0	0	
	0.47	0.21	0.36				0.08	0.26		0.67	0.15	10.85		6.69			5.51	8.97	2.55	9.13		0.59	0.08			0.30	0.82	
Nonionellina labradorica						0				0.85	0																	
						0.61				0.23	0.05																	
Patellina corrugata		0	0					0		0																		
		0.21	0.18					0.09		0.08																		
Pateoris hauerinoides	0.32		0				3.23	0		0														0			0	
	2.13		0.18				0.24	0.09		0.23														0.08			0.20	
Protelphidium orbiculare	2.13	8.00	6.45	22.22		14.29	35.41	5.26		24.6	0	7.14	0	58.59	0	0	52.11	66.61	38.94	15.38				5.51	15.56	1.49	2.22	2.86
	0.79	2.90	3.06	6.45		3.03	2.03	3.01		6.47	0.41	14.73	100.0	52.72	33.33	25.01	52.9	55.13	35.46	14.11				6.22	15.27	1.71	2.04	2.72
Pseudopolymorphina novangliae			1.61				0	0		0													0					
			0.18				0.08	0.09		0.08													0.08					
Quinqueloculina agglutinata										0																		
										0.08																		
Q. seminulum																												
Reophax arctica		0	0				9.68	0		0.85	2.44																	
		0.21	0.18				0.81	0.17		0.67	0.46																	
R. curtus		0	1.61			0	0	0		0	4.07															0		
		0.21	0.54			0.61	0.41	0.34		0.08	3.80															0.20		
R. nana										0																		
										0.08																		
R. nodulosa		0	4.84				0	0		0	4.89																	
		0.21	1.26				0.16	0.09		0.23	0.91																	
R. pilulifera			0				0	0		0	0																	
			1.80				0.08	0.09		0.08	0.30																	
R. scottii	0	0	0	0			6.45	2.63		0	1.63												0					
	0.16	0.21	0.72				0.73	0.26		0.23	0.66												0.17					
Saccammina atlantica		0	1.61				3.23	0			2.44									0								
		0.41	0.54				0.16	0.26			1.98									0.21								
Spiroplectammina biformis		0	0				0	0			0																	0
		0.21	0.18				0.33	0.17			0.10																	0.26
Textularia torquata		0					0	0			0																	
		0.21	0.18				0.08	0.09			0.05																	
Trochammina inflata	0	0	1.61			0	0	0		1.69	0			0			0	0	0	0	0			0		0		0
	1.42	0.83	1.98			3.03	0.24	0.60		0.77	0.15			0.42			0.55	1.71	0.21	0.62	0.68			0.15		0.10		0.34
T. cf. nana	0		0			0	0	0			1.63																	
	0.16		0.18			1.21	0.49	0.17			0.91																	
T. ochracea						0	0																					
						0.61	0.24																					
T. squamata			0					0		0.85	0									0					0			
			0.52					0.09		1.54	0.05									0.83					0.66			
Globigerina bulloides																				0				0	0			
																				0.21				0.08	0.22			
PLANKTONIC SPECIES																												