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OF THE LOWER ST. LAWRENCE ESTUARY -
A QUANTITATIVE STUDY.....

UNIVERSITY.....CARLETON.....

DEGREE FOR WHICH THESIS WAS PRESENTED.....M. Sc.....

YEAR THIS DEGREE GRANTED.....1976.....

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BENTHONIC FORAMINIFERAL ASSOCIATIONS OF THE LOWER
ST. LAWRENCE ESTUARY - A QUANTITATIVE STUDY

by

CYRIL GERARD RODRIGUES, B.Sc.

A thesis submitted to the Faculty of
Graduate Studies in partial fulfilment
of the requirements for the degree of
Master of Science

Carleton University

Ottawa, Ontario.

September, 1976

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The undersigned hereby recommend to the Faculty of
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Cyril Gerard Rodrigues, B.Sc., in partial fulfilment of
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ABSTRACT

Eight associations of modern benthonic foraminifera result from weighted pair group cluster analysis of live, dead and total data matrices compiled by Hooper from sixty-two bottom sediment samples of the lower St. Lawrence Estuary.

At depths less than 100 meters (-1 to 16°C , salinity less than 32.5‰) there are two associations related to distinct substrates. An association characterised by Eggerella advena-Reophax scotti-Spiroplectammina biformis-Trochammina ochracea-Ammotium cassis occurs in Sept Iles Bay between 7 and 46 meters. At 7 meters the dominant species are A. cassis, E. advena and Miliammina fusca. This fauna which reflects the influence of fresh water discharge into the Bay is replaced by Eggerella advena-Spiroplectammina biformis-Trochammina ochracea-Reophax scotti from 12 to 36 meters. R. scotti and S. biformis account for more than 75% of the fauna at 46 meters. The replacement of Eggerella advena with increasing depth occurs in more saline and cool water. The association is characterised by arenaceous species and a low species diversity.

An association of Cibicides lobatulus-Elphidium incertum 'group'-Islandiella islandica was observed between 18 and 91 meters in gravelly pelitic to pelitic sands. Calcareous species dominate this association. At 18 meters E. incertum 'group' is more abundant than C. lobatulus. With increasing depth C. lobatulus replaces E. incertum 'group' as the most abundant species and I. islandica and I. teretis increase in abundance. The trends in relative abundances correspond to increasing salinity and generally cooler

temperatures.

The depth range 95 to 191 meters (-1 to 4°C, 33 to 34.2‰ salinity) contains the association of Adercotryma glomerata-Proteonina atlantica-Spiroplectammina biformis. Arenaceous species are dominant in this association which occurs in sandy substrates. It is replaced laterally in part and vertically by the association of Angulogerina fluens-Islandiella islandica-Buccella inusitata-Elphidium incertum 'group'-Bulimina marginata 'group'. It was observed between 155 and 250 meters (-1 to 4.2°C, 33.5 to 34.5‰ salinity) in sandy pelites.

Buccella inusitata, Bulimina exilis, B. marginata 'group', Elphidium incertum 'group', Islandiella islandica and Nonionellina labradorica characterise water depths between 250 and 398 meters (4.2 to 5.5°C, 34.2 to 34.6‰ salinity) in Hooper's data matrices. In the west off the north shore and Gaspé Peninsula the Angulogerina fluens association is replaced at depths greater than 237 meters by the association of Buccella inusitata-Islandiella islandica-Bulimina exilis-Nonionellina labradorica-Angulogerina fluens. In the east off Anticosti Island and Gaspé Peninsula the Angulogerina fluens association is replaced by the association of Bulimina marginata 'group'-Buccella inusitata-Islandiella islandica-Bulimina exilis at depths greater than 256 meters.

In the Laurentian Trough the Buccella inusitata association which occurs in sandy pelites in the west, passes laterally into the Bulimina marginata 'group' association in the east in sandy pelites, pelites and calcipelites. At depths greater than 365

meters off Anticosti Island the Bulimina marginata 'group' association is replaced by the association of Elphidium incertum 'group'-Bulimina exilis-Nonionellina labradorica-Buccella inusitata-Bulimina marginata 'group'. The latter association is replaced by the association of Pullenia quinqueloba-Elphidium incertum 'group'-Cassidella schreibersiana-Bolivina pseudopunctata at depths greater than 384 meters in a deep basin off the western end of Anticosti Island.

Associations comparable to those of Angulogerina fluens, Bulimina marginata 'group' and Elphidium incertum 'group' were observed by the writer in modern bottom sediment samples from Sackville Cruise 46 between 183 and 365 meters in the lower St. Lawrence Estuary. The abundance of Globobulimina auriculata was much higher and that of Buccella inusitata was lower than indicated in Hooper's data matrices.

A comparison between weighted pair group cluster analysis and factor vector analysis of the dead data matrix reveals that the former technique produces a more subtle classification of the samples thereby permitting the recognition of lateral and depth-related trends in faunal associations.

ACKNOWLEDGEMENTS

Special thanks are extended to Dr. K. Hooper for the opportunity to study his data matrices compiled from bottom sediment samples of the lower St. Lawrence Estuary. Stimulating discussions with Dr. R. Yole, W. Yzerdraat and J. Exton were greatly appreciated. The writer is indebted to Carleton University for the use of computing facilities.

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CHAPTER 1

INTRODUCTION

1.1 General

Micropaleontology is generally accepted and used as a tool for correlating sedimentary strata. Intensive investigations have shown that lateral gradations in microfaunas exist and that completely different microfaunas may be of the same age and may merely reflect different environmental conditions. Therefore it is necessary to determine distributional patterns of modern microfaunas to interpret ancient environments of the same or similar fossil forms.

Models based on the distribution of living foraminifera have been used to interpret paleoenvironments. Live populations reflect their surrounding environmental conditions; however they are not necessarily indicative of the population structure at the time of burial. Hence models based on these populations may not be directly applicable to paleoecologic studies.

There are many environmental parameters affecting the population structure before burial. Dead populations represent the fauna accumulated over many years and as such bear a close resemblance to fossil populations. The total population reflects the maximum faunal homogeneity and reveals the average environmental conditions up to the time of sampling. Compositionally it should be similar to the dead population.

1.2 Purpose of study

The immediate purpose of this study is to derive objective classifications of samples of the live, dead and total benthonic foraminiferal populations obtained from modern sediments in the northwest Gulf of St. Lawrence and to relate the elements of the classifications (i.e. species and their repeated occurrences) to environmental parameters such as depth, salinity, substrate and temperature. A further aim is to compare the associations of the live and dead populations reported upon by Hooper (1969, 1970a, 1975) to those of this study.

The study area lies between English Point and the western end of Anticosti Island in the Gulf of St. Lawrence and is sometimes referred to as the lower St. Lawrence Estuary. It is located between long. $67^{\circ} 10' W.$ to $63^{\circ} 40' W.$, and lat. $50^{\circ} 25' N.$ to $49^{\circ} N.$ and covers approximately 22,000 square kilometers (Text Fig. 1.1).

1.3 Previous investigations

The Gulf of St. Lawrence has received much attention from specialists interested in Foraminifera. Studies wholly or partially restricted to the lower St. Lawrence Estuary may be regarded as either qualitative or quantitative in approach. The earlier studies by G. M. Dawson (1870) and J. W. Dawson (1872) in the St. Lawrence system, Whiteaves (1872) off Gaspé Peninsula and Anticosti Island, and Sproule (1962) in Chaleur Bay, Magdalen Shallows and the Laurentian Channel east of long. $65^{\circ} W.$, were qualitative. Sproule suggested that some zonation is possible for benthonic forms.

Text Figure 1.1. Index map showing the location of the sample area in the Gulf of St. Lawrence.

4

Hooper (1968, 1970b), in regional quantitative studies of the distribution of foraminifera over a wide area of the continental shelf extending from English Point to Flemish Cap, postulated seven major benthonic foraminiferal associations for the region. Five of these associations were reported by Hooper (1969, 1970a, 1975) in a more detailed quantitative study of the lower St. Lawrence Estuary.

CHAPTER 2

SUBMARINE GEOLOGY AND HYDROGRAPHY

2.1 Physiography

The lower St. Lawrence Estuary has an irregular topography consisting of a deep long valley (the Laurentian Trough) bordered by shelves of varying width (Text Fig. 2.1). Water depths are less than 450 meters. Loring and Note (1973) divided the shelves as follows:

- a. Shelves of the St. Lawrence Estuary.
- b. North Shore shelf.
- c. Anticosti shelf.

The shelves of the St. Lawrence Estuary consist of the narrow Les Escoumins and Gaspé shelves. Les Escoumins shelf merges into the broad North Shore shelf east of Sept Iles. The latter has a steeply terminating area at the 100-meter contour followed seaward by a series of deep elongate depressions parallel to the shore with water depths up to 231 meters. Anticosti shelf is less steeply sloping. At the western end of Anticosti Island it tapers seaward into a series of banks separated by short transverse channels along its length.

2.2 Surface sediments

The terminology for surface sediments used herein is shown in Table 2.1. Surficial sediments in the lower St. Lawrence Estuary can be divided into pelites, sands and gravels. Their distribution is controlled by the submarine topography. Finer grained sediments

Text Figure 2.1. Physiographic divisions of the lower St. Lawrence estuary (after Lorne and Jota, 1973).

Table 2.1. Classification of surface sediments of the Gulf of St. Lawrence (after Loring and Nota, 1972).

Sediment Size Grades and Particle Diameters		Nomenclature					
Size Grade	Calcium Carbonate Equiv	Particle Diameter (mm)	Critical Limits of the various components are 5% and 30% by weight				
			<5% by Weight	5-30% by Weight	5-30% CaCO ₃ by Weight	>30% by Weight*	>30% CaCO ₃ by Weight
Pelite	Calcipelite	<0.05	Not Named	Pelite	Calcareous and /or Calcipelite	Pelite	Calcipelite
Clay	-	<0.002	-	-	-	Pelite	-
Silt	Calcipelite	0.002-0.05	-	-	-	-	-
Sand	Calcarenite	0.05-2.0	-	Sandy	Calcareous and /or Calcarenitic	Sand	Calcarenite
Very Fine Sand	-	0.05-0.125	-	-	-	Very Fine Sand	-
Fine Sand	-	0.125-0.25	-	-	-	Fine Sand	-
Medium Sand	-	0.25-0.5	-	-	-	Medium Sand	-
Coarse Sand	-	0.5-2.0	-	-	-	Coarse Sand	-
Gravel	Calcirudite	>2.0	-	Gravelly	Calcareous and /or Calcirudite	Gravel	Calcirudite

*If two components represent more than 30% each the finer grained component is indicated by its noun, the other with an adjective with the adverb "very" e.g. very sandy pelite and not very pelitic sand. The term calcipelite is also extended to include calcipelite pelite.

(pelites) occupy the floor of the trough whereas coarser grained sediments (sands and gravels) form the cover on the slopes and adjacent shelves (Text Fig. 2.2).

In the west, at depths greater than 280 meters, the floor of the Laurentian Trough is covered by pelites. It passes laterally into calcareous pelites in the east. Coarser grained sediments enclose the deep water pelites. Sandy pelites cover the slopes on both shores and most of the floor of the trough in the west. With increasing sand and silt content the sandy pelites merge with very sandy pelites on the upper slope. Very sandy pelites occur between 20 and 220 meters. On Gaspé, Les Escoumins and North Shore shelves it is replaced by pelitic sands, gravelly pelites and gravelly sandy pelites. Calcarenite, calcirudite and gravelly pelitic sand cover Anticosti shelf.

2.3 Hydrography

The oceanography of the Gulf of St. Lawrence was reported upon by Lauzier (1957, 1958) and Trites (1971). During the summer a 'cold layer' extending from about 50 meters down to 135 meters with salinities of 31 to 33‰ and temperatures at or below 0°C separates the warm upper layer from the deep layer below. The two upper layers become one layer thermally during the winter when there is a cold layer extending down to approximately 135 meters with temperatures as low as -1.7°C and salinities between 32 and 33‰. A transitional zone characterised by increasing temperatures and salinities concomitant with increasing depth occurs below the cold layer. In this zone, between approximately 135 and 200 meters,

Text Figure 2.2. Distribution of surface sediments in the lower St. Lawrence estuary (after Loring and Lota, 1972).

temperatures and salinities increase from about 1 to 4°C and 33 to 34.2‰ respectively. This zone is underlain by water with more uniform temperatures (4 to 6°C) and salinities (34.2 to 34.6‰).

The volume of the cold layer decreases considerably in spring and summer as the upper water is heated by the sun and freshened by spring runoff. Hence a third layer appears at the surface extending down to 50 meters with temperatures as high as 16°C and salinities of 29‰ or lower. The deep layer is not affected by seasonal climatic variations.

The watermass in the Gulf of St. Lawrence is herein divided into four main layers (Text Fig. 2.3). The upper layer, extending down to 50 meters with temperatures ranging from -1 to 16°C and salinities less than 33‰, is characterised by considerable thermal and salinity variations. The constantly cold layer, with temperatures less than 1°C and salinities between 32 and 33‰, occurs between 50 and 135 meters. During the winter it merges with the upper layer to form one cold layer. From 135 to 200 meters, with temperatures of 1 to 4°C and salinities of 33 to 34.2‰, is the deep transitional layer. The deep warm layer lies below 200 meters with temperatures and salinities of 4 to 6°C and 34.2 to 34.6‰ respectively.

Comparable temperature and salinity profiles have been reported by Hooper (1969, 1970a, 1975) for the lower St. Lawrence Estuary. The watermass boundaries defined above are arbitrarily chosen by necessity and may be difficult to distinguish in practice.

Text Figure 2.3. Salinity and temperature profiles for summer and winter in the Gulf of St. Lawrence (after Trites, 1971).

CHAPTER 3

PREPARATION OF SAMPLES FOR ANALYSIS

3.1 Method

Sixty-two bottom sediment samples were collected, using a Dietz-Laford grab sampler from the lower St. Lawrence Estuary during the June, 1965, cruise of the longliner Marc St. The position of the samples are shown in Text Figure 3.1.

The samples were prepared for faunal analysis under the supervision of Dr. K. Hooper. On board ship representative portions were taken from each sample by pressing a cylindrical plastic core liner, 8 cm in length and 3 cm in diameter, into the sediment and recovering the top 6 cm of material. The sediment and its overlying sea water were placed immediately into alcohol.

Subsequently the sediment-alcohol mixture was treated with the organic stain rose Bengal. Each sample was divided into six grades by washing through a set of sieves. The sizes of the mesh openings were:

Grade 1		> 1190mu
Grade 2		> 590mu < 1190mu
Grade 3		> 297mu < 590mu
Grade 4		> 149mu < 297mu
Grade 5		> 62mu < 149mu
Grade 6		< 62mu

After grading the material was stored in plastic vials. Any liquid lost during storage was replaced, hence the foraminifers were not

Text Figure 3.1. Sample collecting stations in the lower St. Lawrence estuary. Stations indicated by number (after Mooney, 1975).

allowed to dry out.

For microscope work the rose Bengal-alcohol solution was removed. This was done by filtration and dilution with distilled water. Specimens were judged to be either live (protoplasm stained pink) or dead (not stained). Foraminifera greater than 62 μ were identified by Hooper. Commonly more than 300 specimens were counted. Where the amount of material of a grade size was small, all the contained foraminifers were identified and counted. In cases where a large quantity of material was present the contents of the vial were shaken and allowed to settle. When all the material had settled a capillary tube, .5 mm in diameter, was inserted into the sediment. The contents of the tube were drained into a tray and the foraminifers identified and counted. The procedure was repeated until the count reached three hundred. The material comprising the fraction picked was weighed to obtain the fraction weight. The grade weight was also determined.

3.2 Computation of taxa abundances

Raw data comprising the grade weights, fraction weights and counts of foraminiferal taxa were processed by Control Data G.20 Computer to obtain the live, dead and total data matrices using the Fortran program DATA MATRIX (Hooper, 1967). The data matrices showed frequencies of benthonic taxa as percentages of the total benthonic fauna as calculated for each population.

CHAPTER 4

DESCRIPTIVE TERMINOLOGY

4.1 Taxa

The terminology for describing groups of taxa which are commonly found together in samples of either modern or ancient sediments is rather varied (Pickerill and Brenchley, 1975). Paleontologists have used the term community for such associations. Most modern and fossil associations on which communities are based have come from different bedding planes separated in space and time. Thus community as used by paleontologists is different from that of ecologists.

The starting point for examining the relationships between various taxa is a number of samples. In this study the samples consist of live and dead components which are differentiated by the rose-Bengal staining technique (Text Fig. 4.1). Specimens of the live and dead taxa are identified and counted in each sample. The sum of the number of live and dead specimens of a taxon represents the total number of specimens of that taxon in the sample. The abundance of each taxon is expressed as a percentage of the total number of specimens in each sample of the population under consideration. The basic data (taxa abundance) is arranged in tables in which rows represent samples and columns variables (taxa). Quantitative analysis (e.g. cluster analysis) of the basic data produces a hierarchical classification of the samples. The classification shows samples arranged in clusters based on the

Text Figure 4.1. The relationship between samples and environmental parameters.

repeated occurrences of abundant taxa (i.e. associations) related to specific environmental parameters. Each association is characterised by a reasonably coherent body of taxa which can be recognised by other workers.

4.2 Associations

The associations of benthonic foraminiferal taxa described in this paper are assigned codes consisting of three or four symbols. The first symbol refers to the population - L, D and T for live, dead and total populations respectively. The second symbol indicates the approximate position of the association in the water-mass - S (shallow), mainly in the upper layer, I (intermediate), mainly in the constantly cold layer and D (deep), mainly in the deep layers. The third symbol, A, represents association. The fourth symbol, a number, is assigned if there is more than one association within a designated interval. The number is arbitrarily chosen. Hence the code TDA3, Total Deep Association 3, refers to association number 3 of the total population occurring in the deep layers.

Associations are defined with respect to average abundances of their dominant taxa. Dominant taxa are arbitrarily defined as those having average abundances greater than or equal to 5 percent.

4.3 Discussion

Whereas most species occur in more than one association (assemblage of Hooper), some are restricted. Species restricted to a single association have been described as 'indicator species' by

Hooper (1968). Since the associations described by Hooper are depth- and watermass-related his indicator species may be regarded as being indicative of the environmental conditions to which they are restricted. There are several ecological parameters affecting the distribution of benthonic foraminifera. A species which occurs in low numbers in a sample may be recognised as an indicator species because of its low abundance in the population, low sample density and inadequate picking of the samples. The distribution of benthonic foraminifera is controlled by factors related to depth but it is not as precise as implied by the indicator species concept of Hooper. For example Lagena apiopleura and Patellina corrugata indicator species from the upper watermass layer have been reported by Sen Gupta (1971) at a depth of 656 meters on the Tail of the Grand Banks. Similarly Dentalina beggi and Parafissurina himatiostoma, indicator species from Hooper's deep associations 5 and 1 respectively of the deep layers (depth greater than 155 meters), have been reported by Sen Gupta (op cit.) at depths less than 100 meters. Thus these species can tolerate a wider range of environmental conditions than reported by Hooper.

In order to avoid misinterpretation the term indicator species of Hooper is not used in this paper. Species restricted to a single association can be obtained from the Appendix. Environmental conditions of associations to which these species are apparently restricted should not be inferred from their presence in samples, from any depth, within or outside of the lower St. Lawrence Estuary.

CHAPTER 5

QUANTITATIVE PROCEDURES

5.1 Quantitative method

The complexity of the data was such that detailed interpretations could not have been achieved by qualitative evaluation. Multivariate analytical techniques have been used by paleontologists to determine subtle distribution patterns and relationships inherent in faunal data. One technique commonly used is cluster analysis. It permits the researcher to arrange samples measured on taxa abundance into a hierarchical classification from which ecological relationships can be extracted.

The Fortran program CLUSTER (Davis, 1973) which performs weighted pair group cluster analysis (WPGA) in Q-mode was used to classify the samples of Hooper's live, dead and total data matrices. The essential features of Q-mode WPGA is as follows:

1. A data matrix based on n samples measured on m taxa (variables) is compiled. The data matrix contains frequencies of taxa as percentages of the total fauna in samples of the population.
2. The similarity between each pair of samples is computed. The product moment correlation coefficient was used to determine the similarity between sample pairs.

Let n = the number of variables.

X_{ij} = i^{th} observation of variable X in sample j .

X_{jk} = j^{th} observation of variable X in sample k .

r_{jk} = correlation between samples j and k.

$$\text{Then } r_{jk} = \frac{\sum_{i=1}^n x_{ji} x_{ki} - (\sum_{i=1}^n x_{ji} \sum_{i=1}^n x_{ki}) / n}{\sqrt{[\sum_{i=1}^n x_{ji}^2 - ((\sum_{i=1}^n x_{ji})^2 / n)] [\sum_{i=1}^n x_{ki}^2 - ((\sum_{i=1}^n x_{ki})^2 / n)]}}$$

Maximum similarity is indicated by unity.

3. Each column of the upper half of the similarity matrix is scanned to locate the largest similarity coefficient. The sample pair with the largest similarity is grouped or clustered.
4. After two samples are grouped their similarities with all other samples are averaged. The routine returns to step 3 and thence to step 4 until all samples are clustered.
5. The results of the cluster analysis are displayed by a dendrogram.

5.2 Modification process

A faunal list consisting of 222 benthonic foraminiferal taxa was reported by Hooper (1969, 1975) for the dead data matrix. The total data matrix was based on 233 taxa. Examination of the data matrices revealed that the contributions to the total composition of the samples by some of the taxa were negligible. They were omitted from the data matrices (Table 5.1). The excluded taxa occurred in only one and rarely two samples and were less than two percent of the total composition of the samples (Tables 5.2 and 5.3).

In the process of identifying the taxa Hooper attempted to distinguish potentially useful ecological varieties. Forms with minor morphological variations were distinguished from those that

Table 5.1. Taxa excluded from Hooper's dead and total data matrices.

TAXA NUMBER	TAXA	DATA MATRIX	
		DEAD	TOTAL
15	CIBICIDES SP.	X	X
18	DISCOPHIS SP. CF. D. SQUAMATA	X	X
20	PROTEUPHICUM SP.	X	X
41	GUTTULINA SP.	X	X
43	LARYNGOSIGMA HYALOCIDA	X	X
50	NONION SP. CF. N. GHALEUCPI	X	X
61	QUINGUELOCULINA SP.	X	X
63	QUINGUELOCULINA SP. CF. Q. HINGVANGI	X	X
64	QUINGUELOCULINA SP. ALKERI	X	X
83	SPIRILLINA SP.	X	X
96	CASSIDULINA LAEVIGATA AFF. C. CARINATA	X	X
114	CIBICIDES SP. CF. C. PSEUDOCIBICIANUS	X	X
121	DENTALINA SP.	X	X
122	EPONIDES SP.	X	X
124	NONION SP. CF. N. SCAPHUM	X	X
129	VAGINULINA SPINIGERA	X	X
136	ANCHALINA SP.	X	X
139	LEPTODERMELLA SP.	X	X
147	GUTTULINA LACTEA AFF. G. AUSTRIACEA	X	X
148	PROTEONINA SP.	X	X
156	LENTICULINA SP.	X	X
164	BOLIVINA SP. A	X	X
165	BOLIVINA SP. B	X	X
172	COLINA SP.	X	X
183	TRECHAMMIA SP. CF. T. SQUAMATA	X	X
185	PROTEONINA SP. CF. P. AMPULLACEA	X	X
195	AMMOSCALARIA SP. CF. A. TENJIMARGO	X	X
196	BOLIVINA SP. B. PUNCTATA	X	X
197	LAGENA PA-RI	X	X
202	PSEUDONOTSARIA SP. CF. P. TORHIDA	X	X
204	CASSIDULINA TERETIS AFF. C. LAEVIGATA	X	X
205	TRECHAMMIA SP. CF. T. BULLATA	X	X
211	CIBICIDES SP. A	X	X
212	CIBICIDES SP. B	X	X
215	HYPERAMMIA SP. A	X	X
216	HYPERAMMIA SP. B	X	X
217	DENDROPHYA SP.	X	X
218	RHABDAMMIA SP.	X	X
222	POLYMERHINA SP.	X	X
225	CANCERIS SP.	X	X
226	BOLIVINA FARLANDI	X	X
230	ANCHALINA SP. AFF. A. PUNCTULATA	X	X
231	BOLIVINA SP. CF. B. ALBATROSSI	X	X
241	TRECHAMMIA SP. CF. PATELLINA CORRUGATA	X	X
243	AMMODISCUS SP. CF. A. ANGUILLAE	X	X

TAXA NUMBERS FROM HOOPER, 1969.

Table 5.2. Number of taxa in samples of the dead data matrix.

SAMPLE NO.	UNMODIFIED MATRIX (UM)			MODIFIED MATRIX (MM)	DIFFERENCE (UM-MM)
	NO. OF TAXA	NO. OF SPECIES MERGED	NO. OF SPECIES DELETED	NO. OF TAXA	
1	26	2	-	24	-
2	3	-	-	3	-
3	28	1	-	27	-
4	57	2	2	52	-0.6
5	15	2	-	13	-
6	22	2	-	20	-
7	7	1	-	6	-
8	1	-	-	1	-
9	9	-	-	9	-
10	21	1	-	20	-
11	23	1	1	21	-0.7
12	13	1	-	12	-
13	12	1	-	11	-
14	5	-	-	5	-
15	7	-	-	7	-
16	4	-	-	4	-
17	3	-	-	3	-
18	5	-	-	5	-
19	2	-	-	2	-
20	14	-	1	13	-0.8
21	6	-	-	6	-
22	3	-	-	3	-
23	5	-	-	5	-
24	28	1	3	24	-1.2
25	6	-	-	6	-
26	14	-	-	14	-
27	16	-	1	15	-0.17
28	30	1	1	28	-0.8
29	44	3	5	36	-5.3
30	24	1	1	22	-1.7
31	29	1	3	25	-1.9
32	22	1	3	18	-1.767
33	24	1	-	21	-
34	41	1	3	37	-2.06
35	9	-	-	9	-
36	17	-	2	15	-1.126
37	17	-	3	14	-1.415
38	14	-	-	14	-
39	7	-	-	7	-
40	33	1	1	31	-1.351
41	16	-	-	16	-
42	5	-	-	5	-
44	14	-	1	13	-0.59
45	33	2	2	29	-0.58
46	2	-	-	2	-
47	6	-	-	6	-
48	27	-	1	26	-0.51
49	22	-	1	21	-0.70
50	24	1	-	23	-
51	35	1	2	32	-2.25
52	12	-	-	12	-
53	24	2	1	21	-3.07
54	28	1	1	26	-5.59
55	3	-	-	3	-
56	9	-	-	9	-
57	6	-	-	6	-
58	14	-	-	14	-
59	12	-	-	12	-
60	27	-	-	27	-
61	5	-	-	5	-
62	11	-	-	11	-
63	3	-	-	3	-

LOW COUNT OF POPULATION

Table 5.3. Number of taxa in samples of the total data matrix.

SAMPLE NO.	UNMODIFIED MATRIX (UM)			MODIFIED MATRIX (MM)	DIFFERENCE -% (UM-MM)
	NO. OF TAXA	NO. OF SPECIES MERGED	NO. OF SPECIES DELETED	NO. OF TAXA	
1	30	2	1	27	+0.31
2	3	-	-	3	-
3	29	1	-	28	-
4	61	2	3	56	+0.5
5	15	2	-	13	-
6	24	2	-	22	-
7	9	1	-	8	-
8	2	-	-	2	-
9	10	-	1	9	1.761
10	21	1	-	20	-
11	25	1	1	23	+0.5
12	19	1	-	18	-
13	12	1	-	11	-
14	5	-	-	5	-
15	8	-	-	8	-
16	5	-	-	5	-
17	3	-	-	3	-
18	7	-	-	7	-
19	2	-	-	2	-
20	15	-	2	13	+6.21
21	6	-	-	6	-
22	3	-	-	3	-
23	6	-	-	6	-
24	36	2	4	30	+1.28
25	7	-	-	7	-
26	16	-	1	15	+0.28
27	18	-	2	16	1.762
28	33	1	2	30	+3.27
29	48	3	6	39	+5.19
30	24	1	1	22	+1.37
31	32	1	4	27	+2.4
32	22	1	3	18	1.767
33	26	1	1	24	+6.12
34	41	1	3	37	+20.5
35	13	-	-	13	-
36	18	-	2	16	1.192
37	22	-	4	18	1.657
38	16	-	-	16	-
39	8	-	-	8	-
40	34	1	1	32	1.235
41	16	-	-	16	-
42	6	-	-	6	-
44	15	-	1	14	+0.56
45	38	2	2	34	+3.72
46	2	-	-	2	-
47	8	-	-	8	-
48	28	-	1	27	+0.48
49	30	-	2	28	+4.06
50	24	1	-	23	-
51	36	2	1	33	+1.97
52	12	-	-	12	-
53	25	2	1	22	+3.03
54	28	1	1	26	+5.84
55	4	-	-	4	-
56	9	-	-	9	-
57	7	-	-	7	-
58	16	-	1	15	1.417
59	13	-	-	13	-
60	28	-	-	28	-
61	6	-	-	6	-
62	11	-	-	11	-
63	3	-	-	3	-

! LOW COUNT OF LIVE AND DEAD POPULATIONS

were characteristic of the species as originally described. This approach resulted in the recognition of varieties which were often difficult to re-identify (Hooper, 1970a). Splitting of species is unnecessary if the objective of the study is the recognition of repeated occurrences of taxa. Hence species and their varieties were merged. The generic and/or specific names of some species were also emended. A faunal list based on 152 taxa resulted from the modification process (Appendix I).

The dead and total data matrices were further modified before cluster analysis by changing the format statement of the read routine for the input data matrix in program CLUSTER. Thirteen samples based on low counts were excluded (see Tables 5.2 and 5.3). As pointed out by Hooper (1975, p. 222) samples based on low counts may be of low statistical reliability.

The live data matrix was based on 59 samples and 124 taxa. Live specimens were not observed in samples 32, 62 and 63. Many of the samples were based on low counts (Table 5.4). The live data matrix was modified by merging species and their varieties. A faunal list based on 113 taxa resulted from the modification of the live data matrix (see Appendix I). Each data matrix was divided into four sub-matrices for quantitative analysis (Table 5.5).

Table 5.4. Number of taxa in samples of the live data matrix.

SAMPLE NO.	UNMODIFIED MATRIX		MODIFIED MATRIX	LOW COUNT OF POPULATION
	NO. OF TAXA	NO. OF SPECIES MERGED	NO. OF TAXA	
1	25	2	23	
2	1	-	1	X
3	8	1	7	X
4	27	-	27	
5	3	-	3	X
6	10	-	10	X
7	9	1	8	X
8	1	-	1	X
9	7	-	7	X
10	12	1	11	
11	10	-	10	
12	15	1	14	
13	3	1	2	X
14	3	-	3	X
15	5	-	5	
16	2	-	2	X
17	2	-	2	X
18	4	-	4	X
19	1	-	1	X
20	12	-	12	
21	1	-	1	X
22	3	-	3	X
23	5	-	5	X
24	23	-	23	
25	3	-	3	
26	7	-	7	
27	12	-	12	
28	14	-	14	X
29	19	-	19	X
30	1	-	1	X
31	20	1	19	
32	-	-	-	
33	14	-	13	
34	2	-	2	X
35	8	-	8	
36	9	-	9	X
37	13	-	13	
38	8	-	8	X
39	6	-	6	X
40	5	-	5	X
41	4	-	4	X
42	5	-	5	X
44	5	-	5	X
45	24	1	23	
46	2	-	2	X
47	6	-	6	
48	14	-	14	X
49	24	-	24	
50	1	-	1	X
51	18	-	18	
52	1	-	1	X
53	4	-	4	X
54	6	-	6	X
55	2	-	2	X
56	4	-	4	
57	6	-	6	
58	13	-	13	
59	2	-	2	X
60	11	-	11	X
61	3	-	3	X
162	-	-	-	
163	-	-	-	

162 LIVE SPECIMENS RECORDED

Table 5.5. Sub-matrices analysed in this study.

DATA MATRIX	HOOPER'S DATA MATRICES		TAXA MODIFIED DATA MATRICES	
	NO. OF SAMPLES	NO. OF TAXA	NO. OF SAMPLES	NO. OF TAXA
TOTAL	62	233	62	152
	49	233	49	152
DEAD	62	222	62	152
	49	222	49	152
LIVE	59	126	59	119
	22	126	22	113

SOME SAMPLES IN THE FIRST ROW OF EACH DATA MATRIX ARE BASED ON LOW COUNTS. THOSE IN THE SECOND ROW ARE BASED ON VALID COUNTS ONLY.

CHAPTER 6

CLUSTER ANALYSIS OF THE TOTAL DATA MATRIX

6.1 Total data matrix - 62 samples, 233 taxa

The results of cluster analysis of Hooper's total data matrix is shown in Text Figure 6.1. Thirteen clusters are apparent from the dendrogram. Clusters dominated by samples based on low counts are not considered to be significant. Taxa statistics and depths of samples in each cluster are listed in Table 6.1.

Park (1974, p. 340) in discussing the disadvantages of cluster analysis as a technique for classifying samples states 'Not even the order in which the clusters occur in the dendrogram is significant.' Examination of Table 6.1 reveals that samples characterised by calcareous taxa occur in clusters (A to G) at the top of the dendrogram, whereas samples characterised by arenaceous taxa occur in clusters (H to M) at the bottom of the dendrogram. Furthermore Clusters A through G are linked before being joined to Clusters H through M (see Text Fig. 6.1).

By means of cluster analysis the samples of benthonic foraminiferal populations are arranged into a hierarchical classification. Each cluster consists of a reasonably coherent group of samples and body of taxa. The order in which clusters appear in the dendrogram, in this paper, is determined by the calcareous to arenaceous taxa ratios of the samples in each cluster. The taxa statistics of samples in each cluster listed in tables accompanying the dendrograms presented herein verifies this fact. This clearly

Text Figure 6.1. Dendrogram illustrating Q-mode clusters - Total data matrix (62 samples, 233 taxa).

Table 6.1. Taxa statistics and depths of samples in clusters of total data matrix (62 x 233).

CLUSTER	SAMPLE NO.	DEPTH (F)	NO. OF TAXA	CALCAREOUS/ARENACEOUS RATIO	WATERMASS LAYER OR LAYERS
*A	1	338	30	28/2	DEEP WARM
	41	329	14	13/3	
	51	298	34	30/6	
	30	274	24	21/3	
	28	365	33	29/4	
	53	305	25	22/3	
	54	318	28	24/4	
	8	219	2	1/1	
*B	62	315	11	7/4	DEEP WARM
	7	347	9	8/1	
	32	317	22	19/3	
	52	324	12	12/0	
	34	237	18	15/3	
*C	40	302	28	14/12	DEEP TRANSITIONAL AND WARM
	4	283	61	54/7	
	29	166	48	40/8	
	45	256	38	34/4	
*D	2	183	3	2/1	DEEP TRANSITIONAL TO WARM
	9	155	10	7/3	
	33	250	24	20/6	
	34	222	41	27/14	
	49	205	30	16/14	
	59	219	13	7/6	
*E	48	210	28	19/9	UPPER TO CONSTANTLY COLD
	3	46-91	29	25/4	
	11	55	25	22/3	
	21	56	32	30/2	
	24	37	36	29/7	
*F	10	91	21	16/5	MIXED
	5	390	15	15/0	
	12	18	19	14/5	
	13	18	12	11/1	
*G	6	347	24	22/2	DEEP WARM
	40	398	34	22/12	
*H	50	384	24	21/3	DEEP WARM
	38	275	16	6/10	
I	63	320	3	1/2	CONSTANTLY COLD TO DEEP TRANSITIONAL
	17	48	3	0/3	
	18	40	7	1/6	
*J	61	183	4	0/6	CONSTANTLY COLD TO DEEP TRANSITIONAL
	35	142	13	0/13	
	42	137	6	1/5	
	46	73	2	0/2	
	55	183	4	1/3	
	47	101	8	0/8	
	58	137	16	2/14	
	56	95	9	0/9	
	57	137	7	0/7	
K	39	191	8	0/8	CONSTANTLY COLD TO DEEP TRANSITIONAL
	14	73	5	0/5	
	21	46	4	0/6	
	22	24	3	0/3	
L	23	11	4	0/6	CONSTANTLY COLD TO DEEP TRANSITIONAL
	16	55	5	0/5	
	19	70	2	0/2	
	37	108	22	2/20	
*M	44	165	15	0/15	UPPER
	15	27	8	0/8	
	20	31	15	2/13	
	27	36	18	0/18	
	26	12	16	1/15	
	25	7	7	0/7	

SAMPLE BASED ON LOW COUNTS

SIGNIFICANT CLUSTER

CLUSTER CONTAINS SAMPLES FROM UPPER AND DEEP WARM LAYERS

indicates the significance of the order in which clusters occur in the dendrograms presented herein.

The clusters were evaluated by examining the similarity values of 'inter-cluster' linkages and the abundance of dominant species of the samples in each cluster. The following is a detailed interpretation of the dendrogram. The reader should refer to Text Figure 6.1 for similarities given therein. Dominant species are listed in decreasing order of their average abundances.

CLUSTER A

The cluster consists of a pair grouping of samples 1 and 41 followed by a step-like grouping of samples 51, 30, 28, 53 and 54 linked to a pair grouping of samples 8 and 62 at the .53 similarity level. Sample 8, based on a low count, is compositionally distinct compared to the other samples in the cluster (Table 6.2). All other samples are significant. Dominant species are Bulimina marginata, Buccella inusitata, Cassidulina islandica and Bulimina exilis.

CLUSTER B

A pair grouping of samples 32 and 52 linked to samples 36, 60 and 7 characterise the cluster. Two sub-clusters based on the abundance of dominant species in sample 7 (Table 6.2) and the similarity level (.59) at which it joins the other members of the cluster, are recognised:

Sub-cluster 1

Samples: 32, 52, 36, 60.

Dominant species: Buccella inusitata-Cassidulina islandica-
Bulimina exilis-Nonion labradoricum.

Table 6.2. Frequencies (%) of Significant species of Clusters A and B - Total data matrix (62 x 233).

CLUSTER	A											B				
	1	41	51	30	28	53	54	84	52	7	32	52	36	60		
SAMPLE NO.																
SPECIES																
ANGULOGESINA FLUENS	.000	1.094	.988	3.841	.718	1.790	2.740	.000	10.373	3.268	3.180	.000	12.329	.000		
BUCCELLA INUSITATA	11.329	4.894	13.126	27.572	27.546	8.179	10.137	.000	14.034	19.467	49.117	30.882	26.355	17.614		
BULIMINA ACULEATA	.000	.000	.000	.000	.591	2.721	.000	.000	.000	.000	1.061	.000	.000	.000		
BULIMINA EXILIS	10.334	6.212	2.496	4.938	19.588	7.795	10.685	.000	23.186	18.901	8.481	4.412	1.576	10.795		
BULIMINA MARGINATA	40.960	51.121	32.367	39.918	17.852	17.667	6.027	.000	12.203	.000	.000	8.824	3.109	.000		
CASSIOULINA ISLANDICA	1.909	5.008	13.942	2.195	3.017	14.605	12.329	93.579	34.780	4.902	20.848	23.529	19.462	6.818		
ELPHIDIUM CLAVATUM	1.745	4.153	2.352	.000	10.120	10.058	.000	.000	.000	12.931	.353	10.294	.000	.000		
ELPHIDIUM INCERTUM	5.275	.000	24.883	.274	.000	.203	4.932	.000	.000	26.145	.000	.000	.000	5.682		
GLOROBULIMINA AURICULATA	2.033	6.269	.934	5.350	1.206	.000	.274	.000	.000	.000	1.060	.000	7.111	9.091		
MENTON LAGRADOPICUM	2.618	8.023	.000	24.581	2.260	7.299	.000	.000	1.220	11.237	2.120	5.882	9.029	5.114		
DEPTH (METERS)	338	329	298	274	365	305	318	219	315	347	317	324	237	302		

+ LOW COUNT OF LIVE AND DEAD POPULATIONS.

Sub-cluster 2

Sample: 7.

Dominant species: Elphidium incertum-Buccella inusitata-
Bulimina exilis-Elphidium clavatum-
Nonion labradoricum.

CLUSTER C

A pair grouping of samples 29 and 45 linked to samples 4 and 2 characterise the cluster. Sample 2, based on a low count, is not significant in this cluster (Table 6.3). Dominant species are Bulimina aculeata, Buccella inusitata and Cassidulina islandica.

CLUSTER D

Two pair groupings, samples 33 and 34 - samples 49 and 58, linked to sample 9 at the .65 similarity level and thence to sample 48 at the .59 similarity level characterise the cluster. The dominant species vary considerably in abundance. However they are essentially the same for all members of the cluster (Table 6.3). Dominant species are Angulogerina fluens, Cassidulina islandica and Buccella inusitata.

CLUSTER E

A pair grouping of samples 3 and 11 linked to samples 31, 24 and 10 characterise the cluster. The similarities for the linkages in this cluster are above the .7 level. Dominant species are Cibicides lobatulus, Elphidium clavatum, Cassidulina islandica and Cassidulina teretis (Table 6.4).

CLUSTER F

A pair grouping of samples 12 and 13 linked to sample 5

Table 6.3. Frequencies (%) of significant species of Clusters C and D - total data matrix (62 x 233).

CLUSTER	C				D						
	2+	4	29	45	9	33	34	49	59	48	
SPECIES											
ANCOLOGESINA FLUENS	.000	1.425	5.377	2.168	26.392	13.184	27.347	25.862	52.696	31.262	
BUCCELLA INUSITATA	45.065	17.750	20.351	18.602	1.70	10.408	3.941	13.011	19.304	.241	
BULIMINA ACULEATA	.000	22.295	24.130	40.202	.000	.000	.000	.000	.000	.000	
BULIMINA EXILIS	.000	3.448	2.446	5.843	.000	9.796	.480	.000	.000	1.390	
BULIMINA MARGINATA	.000	.000	4.811	.000	.000	4.694	7.471	.000	.000	2.004	
CASSIDULINA ISLANDICA	.000	10.124	7.751	4.041	23.639	15.918	17.032	11.577	1.838	1.956	
ELPHIDIUM CLAYATUM	.000	3.307	5.528	.186	8.805	.000	3.050	.000	8.273	.000	
ELPHIDIUM INCERTUM	.000	4.193	.000	2.327	.000	.000	.034	.000	.000	13.070	
GLOBOBULIMINA AURICULATA	.000	2.526	1.081	2.459	.000	6.122	10.698	2.937	.000	1.114	
NONION LABRADORICUM	.000	1.170	1.534	2.627	.000	5.306	4.592	.000	8.273	1.667	
DEPTH (METERS)	183	283	166	276	155	250	222	205	219	210	

+ LOW COUNT OF LIVE AND DEAD POPULATION.

Table 6.4. Frequencies (%) of significant species of Clusters E and F - total data matrix (62 x 233).

SPECIES	E										F					
	SAMPLE NO.	3	11	31	24	10	5	6	12	13						
ANGULGERINA FLUENS		.268	.154	.920	.000	1.359	.000	.000	.000	.000						
BUCCELLA INUSITATA		2.502	4.254	7.902	.039	3.303	7.590	2.894	1.134	1.353						
BULIPINA ACULEATA		.000	.000	.000	.000	.000	2.777	.643	.000	.000						
BULIPINA EXILIS		.020	.000	.019	.000	.558	4.985	9.325	.000	.000						
BULIPINA MARGINATA		.000	.000	.000	.000	.000	4.722	18.328	.000	.000						
CASSIDULINA ISLANDICA		10.650	4.566	7.053	.658	31.341	9.348	.322	.008	.000						
CASSIDULINA TERETIS		3.853	2.492	13.397	1.550	5.807	1.389	.643	.116	.535						
CIBICIDES LOBATULUS		67.285	78.089	50.775	60.786	35.417	4.350	.643	34.460	35.947						
ELPHIDIUM CLAVATUM		12.184	6.539	5.695	29.598	13.548	45.540	22.186	49.346	53.175						
ELPHIDIUM INCERTUM		.302	.090	.000	.035	3.089	11.107	4.180	4.161	5.667						
GLCBOBULIMINA AJRICULATA		.000	.059	.000	.000	.000	2.146	.000	.000	.000						
NONION LABRADORICUM		.748	.766	.210	.022	1.403	2.712	16.720	.000	.000						
DEPTH (METERS)		46-91	55	56	37	91	390	347	18	18						

at the .83 similarity level and thence to sample 6 at the .6 similarity level characterise the cluster. Two sub-clusters are recognised based on the average abundances of the dominant species (Table 6.4):

Sub-cluster 1

Samples: 12, 13.

Dominant species: Elphidium clavatum-Cibicides lobatulus.

Sub-cluster 2

Samples: 5, 6.

Dominant species: Elphidium clavatum-Bulimina marginata-
Elphidium incertum-Bulimina exilis.

Samples 12 and 13 were collected from 18 meters, samples 5 and 6 from 390 and 347 meters respectively. Thus the deeper samples may be interpreted as containing displaced species. The overall species composition of samples 5 and 6 is consistent with those of samples from comparable depths. However the abundance of Elphidium clavatum is much higher in the samples of Sub-cluster 2. The anomalous abundance of E. clavatum in samples 5 and 6 is not attributable to down slope displacement of sediment and its contained microfauna from shallower depths. It indicates that E. clavatum (of Hooper) can tolerate a wide range of environmental conditions. The samples of this cluster are grouped together on the abundance of E. clavatum. Cluster F is interpreted as a 'Mixed Cluster' containing samples from the upper and deep warm watermass layers.

CLUSTER G

The cluster consists of a pair grouping of samples 40 and 50 linked at the .45 similarity level. Species common to members of the cluster vary considerably in abundance (Table 6.5). Dominant species are Pullenia quinqueloba, Virgulina complanata and Bolivina pseudopunctata.

CLUSTER H

Two samples linked at the .54 similarity level constitute the cluster. Sample 63 is based on a low count (see Table 6.1). The cluster is not significant.

CLUSTER I

The samples of this cluster are based on low counts. The cluster is not significant.

CLUSTER J

The cluster consists of a pair grouping of samples 42 and 46 linked to sample 55 and thence to the pair grouping of samples 47 and 58. They are joined by samples 56 and 35 above the .7 similarity level and samples 57 and 39 below the .7 similarity level.

Adercotryma glomerata, the significant variable of the cluster, is the only species common to members of the cluster (Table 6.6). The abundances of the species in the samples are rather variable. This possibly reflects non-uniform conditions affecting the live and/or dead populations. The samples, excluding 46 and 55 which are based on low counts, are significant. Dominant species are Adercotryma glomerata and Proteonina atlantica.

Table 6.5. Frequencies (%) of significant species of Cluster G - total data matrix (62 x 233).

SPECIES	CLUSTER G		
	SAMPLE NO.	40	50
BOLIVINA PSEUDOPUNCTATA		3.70*	9.77†
BUCCELLA INUSITATA		2.66*	3.55†
BULIMINA EXILIS		4.93*	2.66†
BULIMINA MARGINATA		1.23*	3.60†
ELPHIDIUM CLAVATUM		2.66*	.00
GLOBOBULIMINA AURICULATA		7.40†	.20†
MONION LABRADORICUM		3.70*	2.38†
PULLENIA QUINQUELOBA		8.66†	19.54†
VIRGULINA COMPLANATA		8.66†	7.99*
DEPTH (METERS)		398	384

Table 6.6. Frequencies (%) of significant species of Cluster J -
total data matrix (62 x 233).

CLUSTER		J										
SPECIES	SAMPLE NO.	35	42	46	55	47	58	56	57	39		
ADERCOTRYNA GLOMERATA		42.393	50.286	62.987	62.540	47.957	35.768	51.621	40.618	16.194		
ALVEOLOPHRAGMIUM CRASSIMARGO		.000	24.720	37.013	.000	2.939	.000	.398	.000	.000		
PROTEONINA ATLANTICA		1.769	.000	.000	.000	5.716	11.191	.000	41.236	20.120		
SPIROPLECTAMINA BIFORMIS		.000	.000	.000	.000	.000	.000	4.404	7.317	.000		
DEPTH (PETERS)		142	137	73	123	101	137	95	137	191		

+ LOW COUNT OF LIVE AND DEAD POPULATIONS.

CLUSTER K

Three of the four samples in the cluster are based on low counts. The cluster is not significant.

CLUSTER L

A pair grouping of samples 37 and 44 at the .82 similarity level followed by a step-like linkage of samples 19 and 16 comprise the cluster. Samples 16 and 19 are based on low counts and are not significant. The relationship between samples 37 and 44 and the other valid samples of the data matrix is not apparent from the dendrogram. The cluster is not regarded as being significant.

Spiroplectammina biformis, Adercotryma glomerata, Proteonina atlantica and Reophax scotti are the dominant species of the valid samples in this cluster (Table 6.7).

CLUSTER M

A pair grouping of samples 15 and 20 followed by a step-like linking of samples 27, 26 and 25 constitute the cluster. The samples are linked above the .7 similarity level except for sample 25 at the .49 similarity level.

Two sub-clusters are recognised based on the abundance of dominant species (Table 6.7) and the similarity level at which sample 25 joins the cluster:

Sub-cluster 1

Samples: 15, 20, 27, 26.

Dominant species: Eggerella advena-Spiroplectammina biformis-Trochammina sp. cf. T. ochracea-Reophax scotti.

Table 6.7. Frequencies (%) of significant species of Clusters L and M - total data matrix (62 x 233).

SPECIES	L											M			
	16+	19+	37	44	15	20	27	26	25						
ADERCOTRYNA GLOMERATA	.000	.000	33.490	23.303	3.491	3.527	4.255	.036	.000						
ALVEOLOPHRAGMIUM CRASSIPARQO	.896	27.534	.052	.000	1.234	2.115	.248	.054	.000						
AMPHOTIUM CASSIS	.000	.000	.000	.700	.000	.000	.029	.000	40.430						
EGGERELLA AOVENA	.000	.000	.000	.000	25.224	22.952	24.039	53.644	39.893						
MILLIAMINA FUSCA	.000	.000	.000	.000	.000	.000	.000	.000	16.018						
PROTONIYA ATLANTICA	.000	.000	13.251	1.982	.000	.000	.247	.000	.000						
PEOPHAX ARCTICA	.000	.000	.000	.000	.000	.000	.000	.000	.000						
PEOPHAX SCOTTI	.000	.000	5.777	4.902	4.995	11.645	13.518	.000	.000						
SPIROPECTAMINA BIFORTIS	42.913	72.466	26.410	49.021	23.355	15.175	25.366	27.944	.000						
TROCHAMINA SP. CF. T. OCHRACEA	.000	.000	.000	.000	37.968	25.666	10.228	.000	3.120						
DEPTH (METERS)	55	70	108	165	27	31	36	12	7						

+ LOW COUNT OF LIVE AND DEAD POPULATIONS.

Sub-cluster 2

Sample: 25.

Dominant species: Ammotium cassis-Eggerella advena-
Miliammina fusca.

6.2 Total data matrix - 49 samples, 233 taxa

Cluster analysis of the total data matrix based on statistically valid samples (49) and 233 taxa yielded 9 clusters. The dendrogram illustrating the clusters is shown in Text Figure 6.2. Taxa statistics and depths of samples in each cluster are listed in Table 6.8. The interpretation of the clusters is presented in the form of a comparison to the clusters of the un-modified total data matrix (62 samples, 233 taxa) in Table 6.9.

6.3 Taxa modified total data matrix - 62 samples, 152 taxa

Fourteen clusters result from cluster analysis of the taxa modified total data matrix based on 62 samples and 152 taxa (Text Figure 6.3). Eight of these clusters are significant. Taxa statistics and depths of samples in each cluster are listed in Table 6.10. A detailed interpretation of the dendrogram is presented below. The reader should refer to Text Figure 6.3 for similarities given therein. Dominant species are listed in decreasing order of their average abundances.

CLUSTER A

A pair grouping of samples 30 and 45 followed by a step-like linking of samples 29, 51 and 4 joined to the pair grouping of samples 53 and 54 characterise the cluster. Six species are common

Text Figure 6.2. Dendrogram illustrating Q-mode clusters - Total data matrix (49 samples, 233 taxa).

Table 6.8. Taxa statistics and depths of samples in clusters of total data matrix (49 x 233).

CLUSTER	SAMPLE NO.	DEPTH (M)	NO. OF TAXA	CALCAREOUS/ ANEYACEOUS RATIO	WATERMASS LAYER OR LAYERS
1	1	338	30	28/2	DEEP WARM
	41	329	16	13/3	
	51	298	36	30/6	
	30	274	24	21/3	
	28	365	33	29/4	
	53	305	25	22/3	
	54	318	28	24/4	
2	62	315	11	7/4	DEEP WARM
	7	347	9	8/1	
	32	317	22	19/3	
	52	324	12	12/0	
	36	237	18	15/3	
3	60	302	28	16/12	DEEP TRANSITIONAL AND WARM
	4	283	61	54/7	
	29	166	48	40/8	
4	45	256	38	34/4	UPPER TO CONSTANTLY COLD
	3	46-91	23	29/4	
	11	55	25	22/3	
	31	56	32	30/2	
	24	37	36	29/7	
5	10	91	21	16/5	MIXED
	6	390	15	15/0	
	12	18	19	14/5	
	13	18	12	11/1	
6	4	347	24	22/2	DEEP WARM
	40	398	34	22/12	
7	50	384	24	21/3	DEEP TRANSITIONAL TO WARM
	9	155	10	7/3	
	33	250	26	20/6	
	34	222	41	27/14	
	49	205	30	16/14	
	59	219	13	7/6	
	48	210	28	19/9	
8	138	275	16	6/10	CONSTANTLY COLD TO DEEP TRANSITIONAL
	35	142	13	0/13	
	42	137	8	1/5	
	47	101	8	0/8	
	58	137	16	2/14	
	56	95	9	0/9	
	57	137	7	0/7	
	37	108	22	2/20	
	44	165	15	0/15	
9	39	191	8	0/8	UPPER
	15	27	8	0/8	
	20	31	15	2/13	
	27	36	18	0/18	
	26	12	16	1/15	
	25	7	7	0/7	
	21	46	6	0/6	

† CLUSTER CONTAINS SAMPLES FROM UPPER AND DEEP WARM LAYERS.

‡ SAMPLE CONTAINS DISPLACED SPECIES.

Table 6.9. Interpretation of dendrogram of total data matrix (49 x 233) with respect to total matrix (62 x 233).

Cluster	Interpretation
1	Identical to interpreted Cluster A.
2	Identical to Cluster B.
3	Identical to interpreted Cluster C.
4	Identical to Cluster E.
5	Identical to Cluster F.
6	Identical to Cluster G.
7	Consists of members of Cluster D and sample 38 of Cluster H which was interpreted as insignificant. Sample 38, linked to the other members of the cluster at the .22 similarity level, is dominated by arenaceous species. Its abundant species are characteristic of the members of Clusters D and J of the deep transitional and constantly cold watermass layers. It is interpreted as containing species displaced from the constantly cold and deep transitional watermass layers.
8	Consists of members of Cluster J and samples 37 and 44 of Cluster L which was interpreted as insignificant.
9	<p>Consists of members of Cluster M and sample 21 of Cluster K which was interpreted as insignificant. Three sub-clusters are recognised as follows:</p> <p><u>Sub-cluster 1</u> Samples: 15, 20, 26, 27. Dominant species: <u>Eggerella advena-Spiroplectammina biformis-Trochammina sp. cf. T. ochracea-Reophax scotti.</u></p> <p><u>Sub-cluster 2</u> Sample: 25. Dominant species: <u>Ammotium cassis-Eggerella advena-Miliammina fusca.</u></p> <p><u>Sub-cluster 3</u> Sample: 21. Dominant species: <u>Reophax scotti-Spiroplectammina biformis.</u></p>

Text Figure 6.3. Dendrogram illustrating Q-mode clusters - Total data matrix (62 samples, 152 taxa).

Table 6.10. Taxa statistics and depths of samples in clusters of total data matrix (62 x 152).

CLUSTER	SAMPLE NO.	DEPTH (M)	NO. OF TAXA	CALCAREOUS/ARENACEOUS RATIO	WATERMASS LAYER OR LAYERS
*A	1	338	27	24/1	DEEP TRANSITIONAL AND WARM
	41	329	16	13/3	
	4	283	56	49/7	
	29	166	39	33/6	
	30	274	22	19/3	
	45	256	34	30/4	
	51	298	33	27/6	
	28	365	30	26/4	
	53	305	22	19/3	
*B	54	318	26	22/4	DEEP WARM
	32	317	18	15/3	
	52	324	12	12/0	
	36	237	16	13/3	
C	60	302	28	16/12	
	8	219	2	1/1	
*D	62	315	11	7/4	DEEP TRANSITIONAL TO WARM
	9	155	9	6/3	
	33	250	24	19/5	
	34	222	37	24/13	
	49	205	28	15/13	
	48	210	27	19/8	
*E	59	219	13	7/6	UPPER TO CONSTANTLY
	3	46-91	28	24/4	
	11	55	9	6/3	
	31	56	27	26/1	
	24	37	30	23/7	
*F	10	91	20	15/5	MIXED
	5	390	13	13/0	
	7	347	8	7/1	
	12	18	18	13/5	
*G	13	18	11	10/1	DEEP WARM
	6	347	22	20/2	
	40	398	32	20/12	
H	50	384	23	20/3	
	2	183	3	2/1	
I	61	183	6	0/6	
	17	48	3	0/3	
J	18	40	5	1/6	
	14	73	5	0/5	
	21	46	6	0/6	
	22	24	3	0/3	
K	23	11	5	0/6	
	16	55	3	0/5	
	19	70	2	0/2	
*L	44	165	14	0/14	UPPER
	15	27	8	0/8	
	20	31	15	2/13	
	26	36	16	1/15	
	27	12	18	0/18	
*M	25	7	7	0/7	CONSTANTLY COLD TO DEEP TRANSITIONAL
	35	142	13	0/13	
	42	137	6	0/6	
	46	73	2	0/2	
	55	183	4	1/3	
	47	101	8	0/8	
	58	137	15	1/14	
	56	95	9	0/9	
	37	108	18	2/16	
	57	137	7	0/7	
N	39	191	8	0/8	
	38	275	16	6/10	
	63	320	3	1/2	

! SAMPLE BASED ON LOW COUNTS.

* SIGNIFICANT CLUSTER.

0 CLUSTER CONTAINS SAMPLES FROM UPPER AND DEEP WARM LAYERS.

to the samples and three species occur in nine of the ten samples in the cluster (Table 6.11). Dominant species are Bulimina marginata 'group', Buccella inusitata, Bulimina exilis, Islandiella islandica, Elphidium incertum 'group' and Nonionellina labradorica.

CLUSTER B

A pair grouping of samples 32 and 52 followed by a step-like linkage of samples 36 and 60 characterise the cluster. Dominant species are Buccella inusitata, Islandiella islandica, Bulimina exilis and Nonionellina labradorica (Table 6.11).

CLUSTER C

One of the two samples in the cluster is based on a low count (Table 6.12). The cluster is not significant.

CLUSTER D

The cluster consists of a pair grouping of samples 39 and 49 linked to sample 33 and the pair grouping of samples 48 and 59 thence to sample 9. The dominant species vary considerably in abundance, however they are essentially the same for all members of the cluster. Dominant species are Angulogerina fluens, Islandiella islandica, Buccella inusitata and Bulimina marginata 'group'.

CLUSTER E

A pair grouping of samples 3 and 11 linked to samples 31, 24 and 10 compose the cluster. Dominant species are Cibicides lobatulus, Elphidium incertum 'group', Islandiella islandica and Islandiella teretis (Table 6.13).

CLUSTER F

A pair grouping of samples 12 and 13 linked to the pair

Table 6.11. Frequencies (%) of significant species of Clusters
A and B - total data matrix (62 x 152).

CLUSTER	A															B				
	SAMPLE NO.																			
SPECIES	1	41	4	29	30	45	51	23	53	54	32	52	36	60						
ARGULOCERINA FLUENS	.000	1.094	1.426	6.410	3.846	2.176	.990	.720	1.795	2.755	3.237	.000	12.478	4.545						
BUCCELLA INUSITATA	11.332	4.834	17.787	20.457	27.610	18.672	13.152	27.636	8.204	10.193	50.001	30.882	27.179	17.614						
BULIMINA EXILIS	10.307	6.212	3.449	2.459	4.945	5.865	2.501	19.632	7.319	10.744	8.634	4.412	1.595	10.795						
BULIMINA MARGINATA 'GROUP'	40.972	51.122	22.303	29.092	39.973	40.354	32.432	18.604	20.451	6.060	4.677	8.824	3.147	.000						
ELPHIDIUM INCERTUM 'GROUP'	7.022	4.153	7.503	5.557	1.236	2.522	5.145	10.555	10.333	10.744	.359	10.294	.000	5.682						
GLOBOBULIMINA AURICULATA	2.034	6.269	2.527	1.087	5.357	2.478	.936	1.210	.000	.276	1.079	.020	7.197	9.091						
ISLANDIELLA ISLANDICA	1.910	5.008	10.128	7.792	2.198	4.056	13.970	3.027	14.650	12.397	21.223	23.529	19.097	6.818						
MONIONELLINA LABRADORICA	7.575	8.028	2.044	1.712	2.885	5.360	3.095	2.267	7.321	5.509	2.158	5.882	9.135	5.114						
PULLENIA QUINGUELOBA	6.046	.000	4.162	2.757	1.374	.619	5.343	.921	2.678	6.611	.720	.000	.000	.000						
DEPTH (METERS)	338	329	223	166	274	256	298	365	305	318	317	324	237	302						

Table 6.12. Frequencies (%) of significant species of Clusters C and D - total data matrix (62 x 152).

SPECIES	CLUSTER										
	C					D					
SAMPLE NO.	8	62	9	23	34	49	48	59			
ANGULOCERATINA FLUENS	.000	10.373	26.866	19.303	27.424	25.967	31.277	52.897			
BUCCELLA INUSITATA	.000	14.024	.478	10.472	3.949	13.064	.241	19.304			
BULIMINA EXILIS	.000	23.186	.000	9.857	.481	.000	1.391	.000			
BULIMINA MARGINATA (GROUP)	.000	12.203	.000	4.723	7.486	17.940	2.035	.000			
ELPMIDIMUM INCERTUM (GROUP)	.000	.000	8.963	8.419	3.090	.000	13.076	8.273			
GLOBOBULIMINA AURICULATA	.000	.000	.000	6.160	10.921	2.045	1.127	.000			
ISLANDIELLA ISLANDICA	93.579	34.780	24.063	16.016	17.067	11.624	1.957	1.838			
MONIONELLINA LABRADORICA	.000	1.220	.000	5.749	4.601	.000	1.668	8.273			
PULLENIA QUINQUELOBA	.000	.000	.000	.205	.000	.000	2.238	.000			
DEPTH (PETERS)	219	315	155	250	222	205	210	219			

+ LOW COUNT OF LIVE AND DEAD POPULATIONS.

grouping of samples 5 and 7 and thence to sample 6 compose the cluster. Two sub-clusters are recognised based on dominant species (Table 6.13):

Sub-cluster 1

Samples: 12, 13.

Dominant species: Elphidium incertum 'group'-Cibicides lobatulus.

Sub-cluster 2

Samples: 5, 6, 7.

Dominant species: Elphidium incertum 'group'-Bulimina exilis-Nonionellina labradorica-Buccella inusitata.

As reasoned for Cluster F of the un-modified total data matrix, this cluster is interpreted as a 'Mixed Cluster' containing samples from the upper and deep warm watermass layers.

CLUSTER G

A pair grouping of samples 40 and 50 constitute the cluster. Dominant species are Pullenia quinqueloba, Elphidium incertum 'group', Cassidella schreibersiana and Bolivina pseudo-punctata (Table 6.13).

CLUSTER H

The samples in this cluster are based on low counts; hence the cluster is not significant.

CLUSTER I

The samples in this cluster are based on low counts; hence the cluster is not significant.

CLUSTER J

Three of the four samples in this cluster are based on low counts; hence the cluster is not significant.

CLUSTER K

Two of the three samples in this cluster are based on low counts; hence the cluster is not significant.

CLUSTER L

A pair grouping of samples 15 and 20 linked to a pair grouping of samples 26 and 27 at the .78 similarity level and thence to sample 25 at the .44 similarity level characterise the cluster. Two sub-clusters based on the abundance of dominant species and the similarity level at which sample 25 joins the cluster are recognised (Table 6.14):

Sub-cluster 1

Samples: 15, 20, 26, 27.

Dominant species: Eggerella advena-Spiroplectammina
biformis-Trochammina ochracea-
Reophax scotti.

Sub-cluster 2

Sample: 25.

Dominant species: Armotium cassis-Eggerella advena-
Miliammina fusca.

CLUSTER M

The cluster consists of a pair grouping of samples 42 and 46 linked to sample 55 and the pair grouping of samples 47 and 58 thence to samples 56 and 35. They are joined by the pair grouping

Table 6.14. Frequencies (%) of significant species of Cluster L - total data matrix (62 x 152).

SPECIES	CLUSTER L						
	SAMPLE NO.	15	20	26	27	25	
ADERCOTRYPA GLOMERATA	3.491	3.549		.036	.329	.000	
APOTIUM CASSIS		.000	.000	.036	.030	.0430	
CRIBROSTOMOIDES CRASSIMARGO	1.234	2.128	.054	.252	.000		
EGGERELLA ADVENA	25.224	23.093	53.697	24.455	39.593		
MILIAMINA FUSCA		.000	.000	.398	.907	16.218	
REGIMAX SCOTTI	4.925	11.717	.000	13.752	.000		
SPIROPECTAMHINA BIFORMIS	23.355	15.268	27.950	25.805	.000		
TROCHAMINA CCHRACEA	37.968	25.824	8.806	10.805	3.120		
DEPTA (PETERS)	27	31	12	36	7		

of samples 37 and 57, and sample 39. As reasoned for Cluster J of the un-modified total data matrix the variable abundances of species in members of this cluster may be due to non-uniform environmental conditions affecting the live and/or dead populations. Samples 46 and 55 which are based on low counts, are not significant in the cluster. Dominant species are Adercotryma glomerata and Proteonina atlantica (Table 6.15).

CLUSTER N

One of the two samples in the cluster is based on a low count; hence the cluster is not significant.

6.4 Taxa modified data matrix - 49 samples, 152 taxa

Cluster analysis of the taxa modified total data matrix based on statistically valid samples (49) and 152 taxa yielded eight clusters. The dendrogram illustrating the clusters is shown in Text Figure 6.4. Taxa statistics and depths of samples in each cluster is listed in Table 6.16. The interpretation of the dendrogram is presented in Table 6.17 in the form of a comparison to the clusters of the taxa modified total data matrix based on 62 samples and 152 taxa.

6.5 Discussion

Q-mode cluster analysis of the total data matrix based on the samples collected, reveals that samples based on low counts produce clusters which are insignificant. The clusters consist wholly of invalid samples or may contain some valid samples. The relationships of the valid samples in these clusters to the members of the

Table 6.15. Frequencies ($\bar{p}$) of significant species of Cluster
M - total data matrix (62 x 152).

CLUSTER	1									
SAMPLE NO.	35	42	46+	55+	47	58	56	37	57	39
ADERCOTRYNA GLOMERATA	42.393	50.282	62.987	62.841	47.956	36.233	51.622	34.055	40.618	16.194
CRIBROSTOMOIDES CRASSIMARCO	.000	24.720	37.013	.000	24.689	.000	.398	.053	.000	.000
PROTECNINA ATLANTICA	1.769	.000	.000	.000	5.716	11.352	.000	18.569	41.286	20.120
SPIROPLECTAMINA BIFORMIS	.000	.000	.000	.000	.000	44.467	7.317	26.856	.000	.000
DEPTH (METERS)	1-2	147	73	143	101	137	95	108	137	191

+ LOW COUNT OF LIVE AND DEAD POPULATIONS.

Text Figure 6.4. Dendrogram illustrating Q-mode clusters - Total data matrix (49 samples, 152 taxa).

Table 6.16. Taxa statistics and depths of samples in clusters of total data matrix (49 x 152).

CLUSTER	SAMPLE NO.	DEPTH (M)	NO. OF TAXA	CALCAREOUS/AMENACEOUS RATIO	WATERMASS LAYER OR LAYERS
1	1	338	27	26/1	DEEP TRANSITIONAL AND WARM
	41	329	14	13/3	
	4	283	56	49/7	
	29	166	39	33/6	
	30	274	22	19/3	
	45	256	34	30/4	
	51	298	33	27/6	
	28	345	30	26/4	
	52	305	22	19/3	
	54	318	24	22/4	
	62	315	11	7/4	
2	32	317	18	15/3	DEEP WARM
	52	324	12	12/0	
	34	237	16	13/3	
	60	302	28	14/12	
3	9	155	9	6/3	DEEP TRANSITIONAL TO WARM
	33	250	24	19/5	
	34	222	37	24/13	
	49	205	28	15/13	
	48	210	27	19/8	
4	59	219	13	7/6	UPPER TO CONSTANTLY COLD
	3	46-51	28	24/4	
	11	55	9	6/3	
	31	56	25	26/1	
	24	37	30	23/7	
5	10	91	20	15/5	MIXED
	6	390	13	13/0	
	7	347	8	7/1	
	12	18	18	13/5	
	13	18	11	10/1	
6	6	347	22	20/2	DEEP WARM
	40	398	32	20/12	
7	50	384	23	20/3	UPPER
	15	27	8	0/8	
	20	31	15	2/13	
	26	36	16	1/15	
	27	12	18	0/18	
	25	7	7	0/7	
8	21	46	6	0/6	CONSTANTLY COLD TO DEEP TRANSITIONAL
	35	142	13	0/13	
	42	137	6	0/6	
	47	101	8	0/8	
	58	137	15	1/14	
	56	95	9	0/9	
	57	137	7	0/7	
	37	108	18	2/16	
	44	165	14	0/14	
	39	191	8	0/8	
	138	275	14	6/10	

§ CLUSTER CONTAINS SAMPLES FROM UPPER AND DEEP WARM LAYERS.
+ SAMPLE CONTAINS DISPLACED SPECIES.

Table 6.17. Interpretation of dendrogram of total data matrix (49 x 152) with respect to total matrix (62 x 152).

Cluster	Interpretation
1	Consists of members of Cluster A and sample 62 of Cluster K which was interpreted as insignificant.
2	Identical to Cluster B.
3	Identical to Cluster D.
4	Identical to Cluster E.
5	Identical to Cluster F.
6	Identical to Cluster G.
7	<p>Consists of members of Cluster L and sample 21 of Cluster J which was interpreted as insignificant. Three sub-clusters are recognised as follows:</p> <p><u>Sub-cluster 1</u> Samples: 15, 20, 26, 27. Dominant species: <u>Eggerella advena-Spiroplectammina biforis-Trochammina ochracea-Reophax scotti.</u></p> <p><u>Sub-cluster 2</u> Sample: 25. Dominant species: <u>Ammotium cassis-Eggerella advena-Miliammina fusca.</u></p> <p><u>Sub-cluster 3</u> Sample: 21. Dominant species: <u>Reophax scotti-Spiroplectammina biforis.</u></p>
8	Consists of members of Cluster M and samples 38 and 44 of insignificant Clusters N and K respectively. Sample 38 joins the cluster at the .14 similarity level. Its abundant species are characteristic of the deep transitional and constantly cold water-mass layers. The sample was collected from the deep warm water-mass layer. It is interpreted as containing species displaced from the constantly cold and deep transitional water-mass layers.

significant clusters are not apparent from the dendrogram. However they are manifested on exclusion of the invalid samples.

A comparison of the dendrograms illustrating Q-mode clusters of the un-modified and taxa modified total data matrices (Text Figs. 6.2 and 6.4) reveals the following:

1. Members of Clusters 1 and 3 of the un-modified matrix form Cluster 1 of the taxa modified matrix.
2. Sample 7, Cluster 2 of the un-modified matrix, joins the members of Cluster 4 of that matrix to form Cluster 5 of the taxa modified matrix.
3. Similarity levels for 'inter-cluster' linkages are lower for Clusters 1, 2, 3 and 6 (deep watermass layers) of the taxa modified matrix compared to Clusters 1, 2, 6 and 7 of the un-modified matrix. These clusters consist of the same members.

The exclusion of taxa which occur in one and rarely two samples and are less than two percent of the total composition of any sample, does not affect the clusters because the members of the clusters are determined by the abundance of their dominant species.

Höglund (1947) discussed the variability of Bulimina marginata. He concluded that the species displays great variation from very spiny specimens to those with only slight crenulations on the undercutting margins. Specimens lacking undercuttings were also observed. Thus B. marginata comprise many forms previously listed as distinct species e.g. B. aculeata, B. elongata, B. gibba.

Feyling-Hanssen (1964) reached a similar conclusion. A similar

range of variation was observed for varieties of B. marginata in samples from the lower St. Lawrence Estuary. Thus they were merged to B. marginata 'group' in this study.

Cushman (1930, pp. 18-19, pl. 7, figs. 8-9) described and figured Elphidium incertum. In the same paper (p. 20, pl. 7, fig. 10) he described a variety Elphidium incertum var. clavatum. Cushman (1944) and other workers found that there is a great amount of variation in these forms. Parker (1952a) wrote that it was impossible, in the area investigated by her, to separate Cushman's E. incertum from the variety clavatum. In 1953 Loeblich and Tappan raised the variety to specific rank. Buzas (1966) showed by statistical analysis and wall structure investigation that E. clavatum and E. incertum of Cushman's concept can not be separated. Gevirtz et al. (1971) in their study of the paraecology of benthonic foraminifera off Long Island, New York, treated the species of Elphidium as a single variable citing Buzas' work as the basis for their decision. Feyling-Hanssen (1974) reported that E. clavatum Cushman and E. incertum Cushman (not Williamson) were synonymous with E. excavatum (Terquem). The writer has examined specimens from the upper and deep watermass layers in the lower St. Lawrence Estuary. Specimens in samples from the upper watermass layer appears to be morphologically distinct compared to those from the deep layers. This is not apparent from Hooper's data matrices. A detailed morphological study of these forms is presently in progress. In this paper E. incertum sensu Cushman and its variety clavatum, as conceived by Hooper, are regarded as a single variable.

The recognition of varieties as distinct variables based on subtle morphological variations is not necessary if the objective of the study is the recognition of repeated occurrences of taxa (i.e. associations) because it tends to split associations into 'sub-units' prior to quantitative analysis. These 'sub-units' may appear as separate clusters upon analysis and are not readily interpreted from the dendrogram. For example, the dominant species and their average abundances of Clusters 1 and 3 of the un-modified total data matrix based on valid samples are:

CLUSTER 1

Samples: 1, 41, 51, 30, 28, 53, 54, 62.

Dominant species: <u>Bulimina marginata</u>	27.3%
<u>Buccella inusitata</u>	14.6%
<u>Cassidulina islandica</u>	10.9%
<u>Bulimina exilis</u>	10.6%

CLUSTER 3

Samples: 4, 29, 45.

Dominant species: <u>Bulimina aculeata</u>	28.9%
<u>Buccella inusitata</u>	18.9%
<u>Cassidulina islandica</u>	7.3%

Clusters 1 and 3 are differentiated primarily on the abundance of B. marginata and B. aculeata. The members of these clusters comprise Cluster 1 of the taxa modified total data matrix.

Dominant species and their average abundances of Cluster 1 are:

<u>Bulimina marginata</u> 'group'	28.5%
<u>Buccella inusitata</u>	15.8%

Islandiella islandica 10.0%

Bulimina exilis 8.8%

Elphidium incertum 'group' 5.9%

A comparison of the dominant species and their average abundances for the clusters listed above indicates that they are essentially similar. Cluster 1 of the taxa modified data matrix represents a coherent body of samples.

Misclassification of samples can also result from the splitting of species. Cluster 2 of the un-modified total data matrix was interpreted as containing two sub-clusters based on the abundance of dominant species and the similarity level (.59) at which sample 7 joins the cluster:

Sub-cluster 1

Samples: 32, 52, 36, 60.

Dominant species: Buccella inusitata-Cassidulina islandica-
Bulimina exilis-Nonion labradoricum.

Sub-cluster 2

Sample: 7.

Dominant species: Elphidium incertum-Buccella inusitata-
Bulimina exilis-Elphidium clavatum-
Nonion labradoricum.

Sample 7 is more similar compositionally to Sub-cluster 2 of Cluster 5 - Samples 5 and 6, Dominant species: Elphidium clavatum-Bulimina marginata-Elphidium incertum-Bulimina exilis. It was placed in the same cluster with samples 5 and 6 in the dendrogram for the taxa modified data matrix (Text Fig. 6.4).

Cluster 5 of the taxa modified total data matrix contains two sub-clusters (see Text Fig. 6.4) as follows:

Sub-cluster 1

Samples: 12, 13.

Sub-cluster 2

Samples: 5, 6, 7.

The members of Sub-cluster 1 have the same overall taxa composition as the members of Cluster 4 of the taxa modified total data matrix. They are not grouped together because the abundance of Elphidium incertum 'group' (the significant variable of Cluster 5) in samples 12 and 13 is more comparable to that in samples 5, 6 and 7 (see Table 6.13). In the description of the associations presented below samples 12 and 13 are included with the members of Cluster 4. Samples 5, 6 and 7 are retained as a distinct group. The apparent misclassification results from the misidentification of species of Elphidium in samples 5, 6 and 7 from the deep warm watermass layer.

The varieties of Bulimina marginata and Elphidium incertum are more abundant than the other varieties of species which were merged. Whereas the varieties of E. incertum are abundant in all of the watermass layers, those of B. marginata are abundant only in the deep watermass layers. The modification of the composition of the clusters and the similarity levels of 'inter-cluster' linkages are attributed to the merging of species and their varieties, in particular the varieties of B. marginata and E. incertum.

The clusters of the un-modified total data matrix based on valid samples requires careful interpretation. Those of the

equivalent taxa modified total data matrix provides a more objective classification of the samples. Hence the classification obtained from the taxa modified matrix based on 49 samples and 152 taxa is used to document the areal distribution of benthonic foraminiferal associations of the total (live plus dead) population.

6.6 Benthonic foraminiferal associations of the total population

Eight benthonic foraminiferal associations (total population) result from Q-mode weighted pair group cluster analysis of 49 samples based on 152 taxa. One sample, number 38, contains displaced species. The areal distribution of the associations is shown in Text Figure 6.5. Taxa present in each association are listed in Appendix II.

TSA1, characteristic of the shallow water of Sept Iles Bay, ranges in depth from 7 to 46 meters. It occurs in coarse to medium grained sands. The calcareous to arenaceous taxa ratio is 1/25. Dominant species and their average abundances are Eggerella advena (28.2%), Reophax scotti (17.2%), Spiroplectammina biformis (16.8%), Trochammina ochracea (14.4%) and Ammotium cassis (7.6%).

A comparable association characterised by E. advena, S. biformis and Reophax spp. was reported by Schafer (1975) in western Chaleur Bay. Vilks (1968) reported a relatively sparse modern foraminiferal population dominated by arenaceous species from Magdalen Shallows. E. advena, S. biformis and Bigenerina arctica are the most abundant species in the area. The foraminiferal population (total) of the Shallows shows the following trends related to depth:

Text Figure 6.5. Areal distribution of total (live plus dead)
benthonic foraminiferal associations.

1. Depths less than 58 meters approximately.

- a. Eggerella advena is the dominant species.
- b. The number of calcareous species is low.
- c. Species diversity (number of species per sample) is low.

2. Depths greater than 58 meters approximately.

- a. Spiroplectammina biformis replaces E. advena in part.
- b. Calcareous species are more abundant.
- c. Species diversity increases.

The fauna at depths less than 58 meters approximately is similar to that of Sept Iles Bay. One striking difference is the absence of Bigennerina arctica in the Bay. The samples examined by Vilks were collected away from surrounding shorelines; hence the foraminifers are not influenced by fresh water discharge. This may account for the absence of B. arctica in Sept Iles Bay. The fauna at depths greater than 58 meters was not observed in the lower St. Lawrence Estuary. Its greater species diversity together with an increase in the number of calcareous species is possibly related to an increase in the amount of clay and silt in the substrate. It may be present off the north shore west of Sept Iles and off the south shore of Anticosti Island where similar substrate and watermass conditions exist.

TSA2 ranges in depth from 18 to 91 meters. The calcareous to arenaceous taxa ratio is 49/16. Dominant species and their average abundances are Cibicides lobatulus (51.9%), Elphidium incertum 'group' (26.2%) and Islandiella islandica (7.6%). The association was

observed off Gaspé Peninsula east of long. $65^{\circ} 30' W$; in gravelly pelitic to pelitic sands. The same association was observed by the writer in a sample of gravelly pelitic sand from 75 meters off the western end of Anticosti Island. The presence of TSA2 off Gaspé Peninsula in the west and off the north shore is inferred in pelitic sands and gravelly pelitic sands within the observed depth range of the association.

TIA occurs in sandy substrates in the constantly cold and deep transitional watermass layers between 95 and 191 meters. The calcareous to arenaceous taxa ratio is 4/38. Dominant species and their average abundances are Adercotryma glomerata (38.1%), Proteonina atlantica (11.4%) and Spiroplectammina biformis (9.7%). The association occurs off both shores but off the south shore it was only observed west of long. $65^{\circ} W$. Its absence in the east may be due to sample density. The abundances of dominant species are very variable. These variations do not appear to be depth-related but may be indicative of subtle changes in the clay and silt content of the substrate. The presence of TIA is inferred off the southern shore of Anticosti Island in very sandy pelites within the observed depth range of the association.

TDA1 ranges in depth from 155 to 250 meters. The calcareous to arenaceous taxa ratio is 38/26. It is associated with sand-rich pelites in the deep transitional and top of the deep warm watermass layers. Dominant species and their average abundances are Angulogerina fluens (30.6%), Islandiella islandica (12.1%), Buccella inusitata (7.9%), Elphidium incertum 'group' (7.0%) and Bulimina

marginata 'group' (5.4%). It occurs off the north shore and east of long. 65° W. off Gaspé Peninsula. Its presence off Gaspé Peninsula in the west and off the south shore of Anticosti Island is inferred in sandy substrates within the observed depth range of the association.

TDA2 occurs in the western sector of the study area and appears to be restricted to sandy pelites in the deep warm water mass layer between 237 and 324 meters. The calcareous to arenaceous taxa ratio is 27/15. Dominant species and their average abundances are Buccella inusitata (31.4%), Islandiella islandica (17.8%), Bulimina exilis (6.4%), Nonionellina labradorica (5.6%) and Angulogerina fluens (5.1%).

TDA3 occupies the area east of long. 66° 40' W. in the Laurentian Trough between 256 and 365 meters. It was also observed at the base of a bank off Anticosti Island at a depth of 166 meters. The calcareous to arenaceous taxa ratio is 78/22. Dominant species and their average abundances are Bulimina marginata 'group' (28.5%), Buccella inusitata (15.8%), Islandiella islandica (10.0%) and Bulimina exilis (8.8%). This association occurs in clay and/or silt rich substrates.

TDA4 is restricted to the Laurentian Trough in the west between 347 and 390 meters in the deep warm water mass layer. The calcareous to arenaceous taxa ratio is 24/2. Dominant species and their average abundances are Elphidium incertum 'group' (40.7%), Bulimina exilis (11.1%), Nonionellina labradorica (10.2%), Buccella inusitata (10.0%) and Bulimina marginata 'group' (8.8%).

TDA5 occurs in a deep basin off Gaspé Peninsula. The calcareous to arenaceous taxa ratio is 29/14. It was found in only two samples from depths of 384 and 398 meters. Dominant species and their average abundances are Pullenia quinqueloba (14.1%), Elphidium incertum 'group' (11.8%), Cassidella schreibersiana (8.4%) and Bolivina pseudopunctata (6.8%).

6.7 Trends in associations of the total population

Detailed interpretation of the dendrogram (Text Fig. 6.4) from which associations in the total population were deduced, based on taxa abundance and the similarity levels of 'inter-cluster' linkages, reveals several depth- and substrate-related trends.

At depths less than 100 meters approximately, in the upper and constantly cold watermass layers, there are two associations related to distinct substrates. TSA1, dominated by arenaceous taxa, occurs in gravelly to medium grained sands and is characteristic of the shallow water of Sept Iles Bay. A change in the abundance of dominant species from Ammotium cassis-Eggerella advena-Miliammina fusca through Eggerella advena-Spiroplectammina biformis-Trochammina ochracea-Reophax scotti to Reophax scotti-Spiroplectammina biformis corresponds to an increase in depth from 7 to 46 meters. The Ammotium cassis fauna, at a depth of 7 meters, reflects the influence of fresh water discharge into the Bay. Bartlett (1966) reported that M. fusca is generally indicative of low salinity and intertidal environments in Miramichi Estuary, New Brunswick. Its presence as a dominant component (16.0%) together with A. cassis supports the interpretation presented above. The deeper Reophax scotti fauna represents the

replacement of E. advena with depth in more saline and cool water. A similar trend, i.e. the replacement of E. advena with depth, was previously described for the Magdalen Shallows. Schafer (1975) reported similar depth-related trends in western Chaleur Bay.

Calcareous species are dominant in TSA2. The association was observed in gravelly pelitic to pelitic sands between 18 and 91 meters. At 18 meters, in the upper (variable) layer, Elphidium incertum 'group' is more abundant than Cibicides lobatulus. In the interval 37 to 91 meters, corresponding to the lower part of the upper layer to the constantly cold layer, C. lobatulus replaces E. incertum 'group' as the dominant component. Concomitantly, Islandiella islandica and I. teretis increase in abundance. The shallow sub-association reflects the influence of a wide range of variations in temperature and salinity. The deeper sub-association is related to generally cooler and more saline water. It is characterised by a greater number of taxa.

A substrate-habitat relationship has been reported for the sessile species Cibicides lobatulus. The species prefers sandy, gravelly or rocky bottoms (Phleger, 1952; Parker, 1952b; Sen Gupta, 1971). Its low abundance in the shallow sub-association may also be related to variations in the amount of coarse to fine particles in the substrate.

The interval between 75 and 200 meters approximately is characterised by sand rich substrates. It is associated with the constantly cold and deep transitional watermass layers with temperatures of -1 to 4°C and salinities of 32 to 34.2‰. TIA,

arenaceous taxa dominant, was observed between 95 and 191 meters.

The Angulogerina fluens association (TDA1), depth range 155 to 250 meters, replaces T1A laterally in part and at depths greater than 191 meters.

Buccella inusitata, Bulimina exilis, Bulimina marginata 'group', Elphidium incertum 'group', Islandiella islandica and Nonionellina labradorica characterise water depths from 250 to 390 meters (temperature 4 to 6°C, salinity 34.2 to 34.6‰) in Hooper's total data matrix. Variations in their relative abundances define four faunal associations.

In the west off both shores TDA1 is replaced by the Buccella inusitata association at depths greater than 237 meters. In the east, TDA1 is replaced by the Bulimina marginata 'group' association at depths greater than 256 meters.

In the Laurentian Trough, TDA2, associated with sandy pelites, passes laterally into TDA3 in pelites, calcipelites and sandy pelites. At approximately 365 meters the Elphidium incertum 'group' association (TDA4) replaces TDA3. Off Gaspé Peninsula the Pullenia quinqueloba association (TDA5) succeeds TDA4 at depths greater than 384 meters approximately.

The changes in associations in the deep watermass layers recognised from Hooper's total data matrix were tested by examination of 20 samples, collected on Sackville Cruise 46, ranging in depth from 183 to 503 meters in the Laurentian Channel between English Point and Cape Ray. The samples were processed and the contained fauna (total population) picked, identified and counted by the writer.

In the Estuary associations comparable to TDA1, TDA2 and TDA4 were observed to exhibit the same depth-related changes described above. However, the abundance of Globobulimina auriculata is greater and that of Buccella inusitata is lower in the writer's samples compared to those of the corresponding species in Hooper's total data matrix. East of long. 61° W. at depths greater than 400 meters, TDA4 is succeeded by the association of Bulimina exilis-Pullenia quinqueloba-Elphidium incertum 'group'-Bolivina subaenariensis-Nonionellina labradorica. Globobulimina auriculata is not as abundant in this association as in the deep associations of the Estuary.

CHAPTER 7

CLUSTER ANALYSIS OF THE DEAD DATA MATRIX

7.1 The rose Bengal staining technique

Walton (1952) demonstrated that rose Bengal solution can be used to distinguish living and non-living foraminifera. The solution stains the protoplasm of living specimens pink; dead specimens are not stained. Foraminiferal ecologists have since relied on this technique in studies of Recent foraminifera.

Several workers have reported that inconsistent results are common using rose Bengal because the stain does not penetrate into the protoplasm of all living foraminifers, and because of the various shades of pink in those specimens that do absorb the stain. Empty foraminiferal tests were also reported to stain as intensely as the protoplasm of living specimens. Green (1960) concluded that Walton's technique was of qualitative value only.

The abundances of taxa in Hooper's dead data matrix are based on the difference between the total number of specimens (live plus dead) and the live specimens expressed as a percentage of the total number of dead specimens in each sample. Hooper used rose Bengal solution to distinguish living and dead specimens. Considering the difficulties encountered by other workers using Walton's technique the abundances of taxa in the dead data matrix may not be representative of the dead population.

Walker et al. (1974) reported that Sudan Black B is more accurate and penetrative than the conventional rose Bengal stain.

in distinguishing living and non-living foraminifera. They state that both acetylated and saturated Sudan Black B are specific to the lipids in the protoplasmic component thereby ensuring that identification of a stained specimen is accurate and reliable. The writer anxiously awaits the comments of other workers on the reliability of Sudan Black B.

7.2 Dead data matrix - 62 samples, 222 taxa

The method of interpreting dendrograms obtained from Q-mode weighted pair group cluster analysis was explained in the previous chapter. It is based on the similarity level of linkages and the abundances of taxa in members of the cluster. The similarity levels of 'inter-cluster' linkages provides a means of recognising sub-associations which may be related to environmental parameters. In this chapter the interpretation is presented in tabular form.

Thirteen clusters are recognised from Q-mode weighted pair group cluster analysis of the un-modified dead data matrix based on 62 samples and 222 taxa (Text Fig. 7.1). Nine of these clusters are significant. Taxa statistics and depths of samples in each cluster are listed in Table 7.1. The interpretation of the dendrogram is presented in Table 7.2.

7.3 Comparison of FVA and WPGA of the dead data matrix

Five depth- and watermass-related benthonic foraminiferal associations were reported by Hooper (1969, 1970a, 1975) for the dead population. The associations were deduced from QQ-mode factor vector analysis (FVA) utilising the Fortran program COVAP, described

Text Figure 7.1. Dendrogram illustrating Q-mode clusters - Dend data matrix (62 samples, 222 taxa).

Table 7.1. Taxa statistics and depths of samples in clusters of dead data matrix (62 x 222).

CLUSTER	SAMPLE NO.	DEPTH (M)	NO. OF TAXA	CALCAREOUS/ARENACEOUS RATIO	WATERMASS LAYER ON LAYERS
*A	1	338	26	26/0	DEEP WARM
	41	329	16	13/2	
	81	298	35	30/5	
	30	274	24	21/3	
	28	365	30	27/3	
	83	305	24	21/3	
*B	32	317	22	19/3	DEEP WARM
	36	237	17	14/3	
	82	324	12	12/0	
	60	302	27	16/11	
	33	250	22	19/3	
	62	315	11	8/3	
*C	5	390	15	15/0	DEEP WARM
	6	347	22	22/1	
	7	347	7	7/0	
*D	2	183	3	2/1	DEEP TRANSITIONAL AND WARM
	4	283	57	51/6	
	29	166	44	38/6	
	45	256	33	30/3	
*E	40	398	33	22/11	DEEP WARM
	80	364	24	21/3	
*F	3	16-91	28	26/2	UPPER TO CONSTANTLY COLD
	11	55	23	22/1	
	31	56	29	27/2	
	10	91	21	16/5	
	12	18	13	9/4	
	13	18	12	11/1	
*G	24	37	28	25/3	DEEP TRANSITIONAL TO WARM
	8	219	1	1/0	
	9	155	9	6/3	
	34	222	41	27/14	
	59	219	12	7/5	
	49	205	22	14/8	
H	14	73	5	0/5	
	21	46	6	0/6	
	22	24	3	0/3	
	23	11	5	0/5	
I	16	55	4	0/4	
	19	70	2	0/2	
	44	165	14	1/13	
	37	108	17	0/17	
*J	15	27	7	0/7	UPPER
	27	36	16	0/16	
	20	31	14	1/13	
	26	12	14	1/13	
	25	7	6	0/6	
*K	35	142	9	0/9	CONSTANTLY COLD TO DEEP TRANSITIONAL
	42	137	5	0/5	
	46	73	2	0/2	
	55	183	3	0/3	
	58	137	14	0/14	
	56	95	9	0/9	
	47	101	6	0/6	
	†38	275	14	6/8	
	63	320	3	1/2	
*L	39	191	7	0/7	DEEP TRANSITIONAL
	57	137	4	0/4	
M	17	48	3	0/3	
	18	40	5	0/5	
	61	183	5	0/5	

† SAMPLE BASED ON LOW COUNT OF POPULATION.

* SIGNIFICANT CLUSTER.

† SAMPLE CONTAINS DISPLACED SPECIES.

Table 7.2. Interpretation of dendrogram of dead data matrix (62 x 222).

Cluster	Interpretation
A [†]	All samples are significant. Dominant species are <u>Bullina marginata</u> , <u>Buccella inusitata</u> , <u>Cassidulina islandica</u> and <u>Bullina exilis</u> .
B [†]	All samples are significant. Dominant species are <u>Buccella inusitata</u> , <u>Cassidulina islandica</u> , <u>Bullina exilis</u> , <u>Angulogerina fluens</u> and <u>Bullina marginata</u> .
C [†]	All samples are significant. Dominant species are <u>Elphidium clavatum</u> , <u>Elphidium incertum</u> , <u>Bullina exilis</u> , <u>Forcellina laevis</u> , <u>Buccella inusitata</u> and <u>Bullina marginata</u> .
D [†]	Sample 2 is based on a low count and is not significant. Significant samples are 4, 21 and 45. Their dominant species are <u>Bullina aculeata</u> , <u>Buccella inusitata</u> and <u>Cassidulina islandica</u> .
E [†]	Cluster consists of two samples linked at the .49 similarity level. Dominant species are <u>Pullenia quinqueloba</u> , <u>Verrucina coplanata</u> and <u>Bolivina pseudopunctata</u> .
F [†]	All samples are significant. Dominant species are <u>Cibicides lobatulus</u> , <u>Elphidium clavatum</u> and <u>Cassidulina islandica</u> .
G [†]	Sample 8 is based on a low count and is not significant. Significant samples are 9, 34, 51, 46 and 48. Their dominant species are <u>Angulogerina fluens</u> , <u>Cassidulina islandica</u> and <u>Buccella inusitata</u> .
H	Three of the four samples in this cluster are based on low counts. The cluster is not significant.
I	Two of the four samples in this cluster are based on low counts. The cluster is not significant.
J [†]	All samples are significant. Dominant species are <u>Corborella advena</u> , <u>Spiroplectammina h. form.</u> , <u>Trochammina</u> sp. cf. <u>I. obovata</u> , <u>Amphax scotti</u> and <u>Ammonia</u> sp.
K [†]	Two sub-clusters are recognised: Sub-cluster 1 - Samples 40 and 55 are based on low counts and are not significant. Significant samples are 35, 42, 58, 56 and 57. Their dominant species are <u>Adarcotrya glomerata</u> and <u>Protonina atlantica</u> . Sub-cluster 2 - Consists of two samples. Sample 63 is based on a low count. Sample 38 is interpreted as containing displaced species.
L [†]	Consists of two samples. Dominant species are <u>Protonina atlantica</u> and <u>Adarcotrya glomerata</u> .
M	The samples in this cluster are based on low counts. The cluster is not significant.

† Significant Cluster

by Manson and Imbrie (1964).

Briefly, QQ-mode FVA permits the researcher to resolve samples into a smaller number of significant factors. The results are given in terms of actual samples judged to be significant end-members in the spectrum of diversity under study. The proportion of each sample attributable to each end-member is given in the re-ordered oblique projection matrix. Maximum similarity is indicated by unity. Hooper (1970b) considered a coefficient of similarity greater than .69 to be significant.

A comparison between the results of FVA and WPGA of the unmodified dead data matrix as interpreted by Hooper and the writer respectively, is shown in Table 7.3. It reveals that WPGA provides a more subtle classification of the samples. This is desirable in ecological studies because it permits the recognition of lateral and depth-related changes in faunal associations.

The status of some samples as interpreted by Hooper differs from that of the writer. Hooper recognised four displaced samples - 5, 37, 38 and 44. The coefficients of similarity of these samples compared to their respective end-members as obtained from FVA, are shown in Table 7.4. Hooper (1970b) reasoned that a sample which has been displaced down slope may have its similarity value lowered, with respect to the end-member of the group from which the sample originated in the first place, due to loss or addition of material. He also stated that the sample's coefficient of similarity will remain unchanged if it retains its original composition after displacement down slope. According to Hooper (op cit.) a very low

Table 7.3. Comparison of the classification of samples of the dead data matrix (62 x 222) from factor vector analysis and weighted pair group cluster analysis.

Group	FVA	Cluster	WPGA
1	1, 6, 7, 28, 30, 40, 41, 50, 51, 53.	A	1, 28, 30, 41, 51, 53.
		C	5, 6, 7.
		E	40, 50.
2	35, 38, 39, 42, <u>46</u> , 47, <u>55</u> , 56, 57, 58, <u>61</u> .	K	35, 38, 42, <u>46</u> , 47, <u>55</u> , 56, 58, <u>61</u> .
		L	39, 57.
3	3, 5, 10, 11, 12, 13, 24, 31.	F	3, 10, 11, 12, 13, 24, 31.
4	<u>14</u> , 15, <u>16</u> , <u>17</u> , <u>18</u> , <u>19</u> , 20, 21, <u>22</u> , <u>23</u> , 25, 26, 27, 37, 44.	H	<u>14</u> , 21, <u>22</u> , <u>23</u> .
		I	<u>16</u> , <u>19</u> , <u>37</u> , <u>44</u> .
		J	15, 20, 26, 27.
		M	<u>17</u> , <u>18</u> , <u>61</u> .
5	2, 4, 8, 9, 29, 32, 33, 34, 36, 45, 48, 49, 52, 54, 59, 60, 62, <u>63</u> .	B	32, 33, 36, 52, 54, 60, 62.
		D	2, 4, 29, 45.
		G	8, 9, 34, 43, 49, 59.

19. Sample based on low count.

Sample displaced - Hooper.

Sample contains displaced species - Rodrigues (this paper).

2 2
OF/DE

Table 7.4. Coefficients of similarity of Hooper's displaced samples.

Sample	38	5	44	37
Depth (meters)	275	390	165	108
Coefficient of similarity	.343	.650	.742	.621
End-member sample	55	24	27	27
† Depth range of group (meters)	73-191	18-91	11-73	11-73

† Depth of 'displaced sample' excluded

coefficient of similarity may indicate that the sample is so unlike the end-member with which it is compared that a great loss or gain of material on displacement may have occurred, or it may represent quite a distinct fauna.

In FVA and WPGA samples are grouped on the abundances of dominant variables (taxa). The mathematical procedures for the two techniques are very different. Sample 5 was placed in the group having sample 24 as the end-member because its dominant species Elphidium clavatum is one of the significant variables of the group. Similarly, samples 37 and 44 are placed in the group having sample 27 as its end-member because their dominant species Spiroplectammina biformis is one of the significant variables of the group. Samples 5, 37 and 44 are rather similar to their respective end-members as indicated by the coefficients of similarity (see Table 7.4). Hence it appears that the depth of a sample compared to the other members of the group in which it is placed in addition to its coefficient of similarity with respect to the end-member of its group governs its status in Hooper's interpretation.

In the dendrogram illustrating Q-mode clusters of the unmodified dead data matrix samples 5, 6 and 7 forms Cluster C (see Text Fig. 7.1). Samples 37 and 44 occur with samples 16 and 19 (both based on low counts) in Cluster I which was interpreted as insignificant. In the previous chapter it was shown that the status of valid samples occurring in clusters dominated by invalid samples, can not be determined from the dendrogram. In the following section it will be seen that samples 37 and 44, upon exclusion of the samples

based on low counts, occur in a cluster with the samples of interpreted Cluster K. Compositionally samples 5, 37 and 44 are very similar to the other samples from comparable depths. Hence they do not contain displaced species. Both Hooper and the writer regard sample 38 as containing displaced species. The status of Hooper's 'displaced samples' is consistent in both the total and dead data matrices on the basis of WPGA results. His method of interpreting the status of anomalous samples in groupings obtained from FVA is not objective. The writer believes that the abundances of taxa in the samples must be considered because they form the basis of the classifications derived by quantitative techniques.

7.4 Dead data matrix - 49 samples, 222 taxa

Q-mode cluster analysis of the dead data matrix based on valid samples (49) and 222 taxa yielded nine clusters. The dendrogram illustrating the clusters is shown in Text Figure 7.2. Taxa statistics and depths of samples in each cluster are listed in Table 7.5. The interpretation of the clusters is presented in Table 7.6 in the form of a comparison to the clusters of the un-modified dead data matrix (62 samples, 222 taxa). The affinities of samples 21, 37 and 44 are clearly manifested on exclusion of the invalid samples. This is consistent with WPGA results for the total data matrix.

7.5 Taxa modified dead data matrix - 62 samples, 152 taxa

Eleven clusters result from Q-mode cluster analysis of the taxa modified dead data matrix based on 62 samples and 152 taxa (Text Fig. 7.3). Eight of these clusters are significant. Taxa statistics

Text Figure 7.2. Dendrogram illustrating Q-mode clusters - Dead data matrix (49 samples, 222 taxa).

Table 7.5. Taxa statistics and depths of samples in clusters of dead data matrix (49 x 222).

CLUSTER	SAMPLE NO.	DEPTH (M)	NO. OF TAXA	CALCAREOUS/ARENACEOUS RATIO	WATERMASS LAYER OR LAYERS
1	1	338	24	28/0	DEEP WARM
	41	329	16	13/2	
	51	298	35	30/5	
	30	274	24	21/3	
	28	365	30	27/3	
	53	305	24	21/3	
2	32	317	22	19/3	DEEP WARM
	34	237	17	14/3	
	52	324	12	12/0	
	40	302	27	16/11	
	23	250	22	19/3	
	62	315	11	8/3	
3	4	283	57	51/6	DEEP TRANSITIONAL AND WARM
	29	166	44	38/6	
	45	256	33	30/3	
4	5	350	15	15/0	DEEP WARM
	6	347	22	22/1	
	7	347	7	7/0	
5	3	46-51	28	26/2	UPPER TO CONSTANTLY COLD
	11	55	23	22/1	
	31	54	29	27/2	
	10	31	21	16/5	
	12	18	13	9/4	
	13	18	12	11/1	
6	24	37	28	25/3	DEEP WARM
	40	398	33	22/11	
7	50	384	24	21/3	DEEP TRANSITIONAL TO WARM
	9	155	9	6/3	
	34	222	41	27/14	
	59	219	12	7/5	
	49	205	22	14/8	
	48	210	27	19/8	
8	21	46	6	0/6	UPPER
	38	275	14	6/8	
	15	27	7	0/7	
	27	34	16	0/16	
	20	31	14	1/13	
9	24	12	14	1/13	CONSTANTLY COLD TO DEEP TRANSITIONAL
	25	7	6	0/6	
	25	142	9	0/9	
	42	137	8	0/8	
	54	95	9	0/9	
	58	137	14	0/14	
	47	101	6	0/6	
	37	108	7	0/7	
	44	165	14	1/13	
	39	191	7	0/7	
	57	137	6	0/6	

†SAMPLE CONTAINS DISPLACED SPECIES.

Table 7.6. Interpretation of dendrogram of dead data matrix (49 x 222) with respect to dead matrix (62 x 222).

Cluster	Interpretation.
1	Identical to Cluster A.
2	Identical to Cluster B.
3	Identical to interpreted Cluster D.
4	Identical to Cluster C.
5	Identical to Cluster F.
6	Identical to Cluster E.
7	<p>Consists of members of interpreted Cluster G and samples 21 and 38. Two sub-clusters are recognised:</p> <p><u>Sub-cluster 1</u> Samples: 9, 34, 59, 49, 48. Dominant species: <u>Angulorierina fluens-Cassidulina islandica-Puccella inusitata.</u></p> <p><u>Sub-cluster 2</u> Samples: 21, 38. Sample 38 contains displaced species. Sample 21 is anomalous in this cluster.</p>
8	Identical to Cluster J.
9	Consists of members of Cluster L and interpreted Cluster K and the valid members (37 and 44) of Cluster I which was interpreted as insignificant.

Text Figure 7.3. Dendrogram illustrating Q-mode clusters - Dead data matrix (62 samples, 152 taxa).

and depths of samples in each cluster are listed in Table 7.7. The interpretation of the clusters is presented in Table 7.8.

A comparison of the dendrograms from WPGA of the taxa modified dead data matrix and its equivalent un-modified dead data matrix (Text Figs. 7.1 and 7.2) reveals the following:

1. Members of Cluster A and interpreted Cluster D of the un-modified matrix forms Cluster A of the taxa modified matrix.
2. Members of Clusters C and E of the un-modified matrix forms Cluster E of the taxa modified matrix.
3. Similarity levels for 'inter-cluster' linkages in clusters of the taxa modified matrix containing samples from the deep watermass layers are lower compared to those of the un-modified matrix.

These differences result from the merging of species and their varieties, in particular, the varieties of Bulimina marginata and Elphidium incertum. Similar observations were described in the previous chapter for the total data matrix.

7.6 Taxa modified data matrix - 49 samples, 152 taxa

Seven clusters result from Q-mode cluster analysis of the taxa modified dead data matrix based on valid samples (49) and 152 taxa. The dendrogram illustrating the clusters is shown in Text Figure 7.4. Taxa statistics and depths of samples in each cluster are listed in Table 7.9. The interpretation of the clusters is presented in the form of a comparison to the clusters of the taxa modified matrix (62 samples, 152 taxa) in Table 7.10.

Table 7.7. Taxa statistics and depths of samples in clusters of dead data matrix (62 x 152).

CLUSTER	SAMPLE NO.	DEPTH (M)	NO. OF TAXA	CALCAREOUS/ARENACEOUS RATIO	WATERMASS LAYER OR LAYERS
*A	1	338	24	24/0	DEEP TRANSITIONAL AND WARM
	41	329	16	13/3	
	29	164	36	30/6	
	30	274	22	19/3	
	45	256	29	26/3	
	51	298	32	27/5	
	4	283	53	47/6	
	53	305	21	18/3	
*B	28	345	28	25/3	DEEP WARM
	32	317	18	15/3	
	52	324	12	12/0	
	36	237	15	12/3	
	60	302	27	16/11	
	33	250	21	18/3	
	62	318	11	7/4	
	54	318	26	22/4	
*C	2	182	3	2/1	DEEP TRANSITIONAL TO WARM
	8	219	1	1/0	
	9	155	9	6/3	
	34	222	37	24/13	
	49	205	21	14/7	
	48	210	26	19/7	
	59	219	12	7/5	
	3	46-91	27	24/3	
*D	11	55	21	20/1	UPPER TO CONSTANTLY COLD
	31	54	25	24/1	
	10	91	20	15/5	
	12	18	12	8/4	
	13	18	11	10/1	
	24	37	24	21/3	
	5	390	13	13/0	
	7	347	6	4/0	
*E	6	347	20	19/1	DEEP WARM
	40	398	31	20/11	
	50	384	23	20/3	
	17	48	3	0/5	
*F	18	40	5	0/5	
	61	183	5	0/5	
	14	73	5	0/5	
*G	21	44	6	0/6	
	22	25	3	0/3	
	23	11	5	0/5	
	15	27	7	0/7	
*H	26	12	14	1/13	UPPER
	20	31	13	0/13	
	27	36	15	0/15	
	25	7	6	0/6	
	16	55	4	0/7	
*I	19	70	2	0/2	
	44	165	13	0/13	
	37	108	14	0/14	
	35	142	9	0/9	
*J	42	137	5	0/5	CONSTANTLY COLD TO DEEP TRANSITIONAL
	46	73	2	0/2	
	55	183	3	0/3	
	58	137	14	0/14	
	54	98	9	0/9	
	47	101	6	0/6	
	38	275	14	4/8	
	63	320	3	1/2	
	39	131	7	0/7	
	57	137	6	0/6	
*K					DEEP TRANSITIONAL

! SAMPLE BASED ON LOW COUNT OF POPULATION.

* SIGNIFICANT CLUSTER.

- SEE TABLE 7-8

† SAMPLE CONTAINS DISPLACED SPECIES.

Table 7.8. Interpretation of dendrogram of dead data matrix (62 x 152).

Cluster	Interpretation
A ⁺	All samples are significant. Dominant species are <u>Bulimina marginata</u> 'group', <u>Buccella inusitata</u> , <u>Islandiella islandica</u> , <u>Bulimina exilis</u> and <u>Elphidium incertum</u> 'group'.
B ⁺	All samples are significant. Dominant species are <u>Buccella inusitata</u> , <u>Islandiella islandica</u> , <u>Bulimina exilis</u> , <u>Angulocerin fluens</u> , <u>Bulimina marginata</u> 'group' and <u>Nonionellina lazarodica</u> .
	Sample 2 is linked to Clusters A and B (combined) at the .41 similarity level. It is based on a low count and is not significant.
C ⁺	Sample 8 is based on a low count and is not significant. Significant samples are 9, 34, 40, 48 and 57. Their dominant species are <u>Angulocerin fluens</u> , <u>Islandiella islandica</u> , <u>Buccella inusitata</u> , <u>Bulimina marginata</u> 'group' and <u>Elphidium incertum</u> 'group'.
D ⁺	All samples are significant. Dominant species are <u>Cibicides lobatulus</u> , <u>Elphidium incertum</u> 'group' and <u>Islandiella islandica</u> .
E ⁺	All samples are significant. Two sub-clusters are recognised: Sub-cluster 1 Samples: 5, 6, 7. Dominant species: <u>Elphidium incertum</u> 'group'- <u>Bulimina exilis</u> - <u>Nonionellina lazarodica</u> - <u>Buccella inusitata</u> - <u>Bulimina marginata</u> 'group'. Sub-cluster 2 Samples: 40, 50. Dominant species: <u>Pullenia quinqueloba</u> - <u>Elphidium incertum</u> 'group'- <u>Cassidella schreibersiana</u> - <u>Polivina pseudopunctata</u> .
F	The members of the cluster are based on low counts. The cluster is not significant.
G	Three of the four samples in the cluster are based on low counts. The cluster is not significant.
H ⁺	All samples are significant. Two sub-clusters are recognised: Sub-cluster 1 Samples: 15, 26, 20, 27. Dominant species: <u>Eggerella advena</u> - <u>Spiroplectammina biformis</u> - <u>Neophax scotti</u> - <u>Trochammina ochracea</u> . Sub-cluster 2 Sample: 25. Dominant species: <u>Eggerella advena</u> - <u>Ammonium cassia</u> - <u>Piliammina fusca</u> .
I	Two of the four samples in this cluster are based on low counts. The cluster is not significant.
J ⁺	Two sub-clusters are recognised: Sub-cluster 1 - Samples 46 and 55 are based on low counts and are not significant. Significant samples are 35, 42, 55, 56 and 57. Their dominant species are <u>Adercotryna glomerata</u> and <u>Proteonina atlantica</u> . Sub-cluster 2 - Consists of two samples. Sample 61 is based on a low count. Sample 38 contains displaced species.
K ⁺	Consists of two samples. Dominant species are <u>Proteonina atlantica</u> and <u>Adercotryna glomerata</u> .

† Significant Clusters

Text Figure 7.4. Dendrogram illustrating Q-mode clusters - Dead data matrix (49 samples, 152 taxa).

Table 7.9. Taxa statistics and depths of samples in clusters of dead data matrix (49 x 152).

CLUSTER	SAMPLE NO.	DEPTH (m)	NO. OF TAXA	CALCAREOUS/ARENACEOUS RATIO	WATERMASS LAYER OR LAYERS
1	1	338	24	24/0	DEEP TRANSITIONAL AND WARM
	41	329	16	13/3	
	29	164	36	30/6	
	30	274	22	19/3	
	45	284	29	26/3	
	81	298	32	27/5	
	4	283	53	47/6	
	83	305	21	18/3	
2	28	345	28	25/3	DEEP WARM
	32	317	18	15/3	
	82	324	12	12/0	
	34	237	15	12/3	
	60	302	27	16/11	
	33	250	21	18/3	
3	62	315	11	7/4	DEEP WARM
	54	318	24	22/2	
	5	350	13	13/0	
	7	347	6	6/0	
4	6	347	20	19/1	UPPER TO CONSTANTLY COLD
	40	398	31	20/11	
	50	384	23	20/3	
	3	46-51	27	24/3	
5	11	55	21	20/1	UPPER TO CONSTANTLY COLD
	31	54	25	24/1	
	10	91	20	18/5	
	12	18	12	8/4	
	13	18	11	10/1	
	24	37	24	21/3	
6	9	156	9	6/3	DEEP TRANSITIONAL TO WARM
	24	222	37	24/13	
	49	205	21	14/7	
	48	210	26	19/7	
7	89	219	12	7/5	UPPER
	15	27	7	0/7	
	26	12	14	1/13	
	20	31	13	0/13	
	27	34	15	0/15	
	25	7	6	0/6	
	21	46	6	0/6	
8	† 38	275	14	6/8	CONSTANTLY COLD TO DEEP TRANSITIONAL
	35	142	9	0/9	
	42	137	8	0/8	
	56	95	9	0/9	
	88	137	14	0/14	
	47	101	6	0/6	
	37	108	14	0/14	
	44	165	13	0/13	
	39	131	7	0/7	
	87	137	6	0/6	

† SAMPLE CONTAINS DISPLACED SPECIES.

Table 7.10. Interpretation of dendrogram of dead data matrix (49 x 152) with respect to dead matrix (62 x 152).

Cluster	Interpretation
1	Identical to Cluster A.
2	Identical to Cluster B.
3	Identical to Cluster E.
4	Identical to Cluster D.
5	Identical to interpreted Cluster C.
6	<p>Consists of members of Cluster M, sample 21 of Cluster G and sample 38 of Cluster J. Sample 38 is interpreted as containing displaced species. Three sub-clusters are recognised:</p> <p><u>Sub-cluster 1</u> Samples: 15, 26, 20, 27. Dominant species: <u>Eggerella advena-Spiroplectammina biformis-Reophax scotti-Trochammina ochracea.</u></p> <p><u>Sub-cluster 2</u> Sample: 25. Dominant species: <u>Eggerella advena-Arnotium cassis-Miliammina fusca.</u></p> <p><u>Sub-cluster 3</u> Sample: 21. Dominant species: <u>Reophax scotti-Spiroplectammina biformis.</u></p>
7	<p>Consists of members of Sub-cluster 1 - Cluster J, members of Cluster K and samples 37 and 44 of Cluster I. Three sub-clusters are recognised:</p> <p><u>Sub-cluster 1</u> Samples: 35, 42, 56, 58, 47. Dominant species: <u>Adercotryma glomerata-Protonina atlantica.</u></p> <p><u>Sub-cluster 2</u> Samples: 37, 44. Dominant species: <u>Spiroplectammina biformis-Adercotryma glomerata-Protonina atlantica.</u></p> <p><u>Sub-cluster 3</u> Samples: 39, 57. Dominant species: <u>Protonina atlantica-Adercotryma glomerata.</u></p>

As reasoned for the total data matrix the classification obtained from cluster analysis of the taxa modified data matrix based on 49 samples and 152 taxa, is used to document the areal distribution of benthonic foraminiferal associations of the dead population.

7.7 Benthonic foraminiferal associations of the dead population

Seven benthonic foraminiferal associations are recognised from Q-mode weighted pair group cluster analysis of the dead data matrix based on 49 samples and 152 taxa. One sample, number 38, contains displaced species. The areal distribution of the associations is shown in Text Figure 7.5. Taxa present in each association are listed in Appendix IIF.

DSA1, characteristic of the shallow water of Sept Iles Bay, ranges in depth from 7 to 46 meters. It occurs in coarse to medium grained sands. The calcareous to arenaceous taxa ratio is 1/25. Dominant species and their average abundances are Eggerella advena (29.9%), Spiroplectammia biformis (18.8%), Reophax scotti (18.4%), Trochammia ochracea (11.0%) and Ammotium cassis (5.7%).

DSA2 ranges in depth from 18 to 91 meters. The calcareous to arenaceous taxa ratio is 46/16. Dominant species and their average abundances are Cibicides lobatulus (49.3%), Elphidium incertum 'group' (28.2%) and Islandiella islandica (8.5%). The association occurs off Gaspé Peninsula east of long. 65° 30' in gravelly pelitic to pelitic sands. The presence of this association off Gaspé Peninsula and off the north shore is inferred in gravelly pelitic and pelitic sands within the observed depth range of the association.

Text Figure 7.5. Areal distribution of dead benthonic
foraminiferal associations.

DIA occurs in sandy substrates in the constantly cold and deep transitional watermass layers between 95 and 191 meters. The calcareous to arenaceous taxa ratio is 0/35. Dominant species and their average abundances are Adercotryma glomerata (26.6%), Proteonina atlantica (13.3%) and Spiroplectammina biforidis (10.9%). The association occurs off both shores but off the south shore it was only observed west of long. 65° W. Its absence to the east may be due to sample density. The abundance of dominant species is very variable. These variations do not appear to be depth-related but may be due to subtle changes in the clay and silt content of the substrate. The presence of DIA is inferred off the south shore of Anticosti Island in very sandy pelites within the observed depth range of the association.

DDA1 ranges in depth from 155 to 222 meters. The calcareous to arenaceous taxa ratio is 35/22. It is associated with sand-rich pelites in the deep transitional and top of the deep warm watermass layers. Dominant species and their average abundances are Angulogerina fluens (32.6%), Islandiella islandica (12.5%), Buccella inusitata (7.9%), Bulimina marginata 'group' (6.9%) and Elphidium incertum 'group' (6.8%). It occurs off the north shore and east of long. 65° W. off Gaspé Peninsula. Its presence off Gaspé Peninsula in the west and off the south shore of Anticosti Island is inferred in sandy pelites within the observed depth range of the association.

DDA2 occurs in the western sector of the study area in pelites and sandy pelites of the deep warm watermass layer between 250 and 324 meters. The calcareous to arenaceous taxa ratio is 38/20.

Dominant species and their average abundances are Buccella inusitata (23.5%), Islandiella islandica (19.7%), Bulimina exilis (10.2%), Angulogerina fluens (6.1%), Bulimina marginata 'group' (5.8%), Elphidium incertum 'group' (5.3%) and Nonionellina labradorica (5.3%).

DDA3 occupies the area east of long. 66° 40' W. in the Laurentian Trough between 256 and 365 meters. It was also observed at the base of a bank off Anticosti Island at a depth of 166 meters. The calcareous to arenaceous taxa ratio is 71/22. Dominant species and their average abundances are Bulimina marginata 'group' (33.3%), Buccella inusitata (16.8%), Bulimina exilis (6.9%), Islandiella islandica (6.9%) and Elphidium incertum 'group' (6.1%). This association occurs in clay and/or silt rich substrates and their calcareous equivalents.

DDA4 occurs in the deepest part of the Laurentian Trough off Gaspé Peninsula at depths greater than 347 meters. The calcareous to arenaceous taxa ratio is 41/14. Dominant species and their average abundances are Elphidium incertum 'group' (33.8%), Nonionellina labradorica (10.3%), Bulimina exilis (9.1%), Bulimina marginata 'group' (6.8%), Buccella inusitata (6.4%) and Pullenia quinqueloba (5.9%). The association occurs in calcipelites.

7.8 Trends in associations of the dead population

Detailed interpretation of the dendrogram (Text Fig. 7.4) from which associations in the dead population were deduced, based on the similarity levels of 'inter-cluster' linkages and the abundance of dominant species, reveals depth- and substrate-related trends similar to those described for the total population.

Two associations occur at depths less than 100 meters in the upper and constantly cold watermass layers. DSA1, dominated by arenaceous species, occur in gravelly to medium grained sands and is characteristic of the shallow water of Sept Iles Bay. A change in the abundance of the dominant species of the association from Eggerella advena-Ammotium cassis-Miliammina fusca through Eggerella advena-Spiroplectammina biformis-Trochammina ochracea-Reophax scotti to Reophax scotti-Spiroplectammina biformis corresponds to an increase in depth from 7 to 46 meters.

DSA2 is characterised by calcareous species. The association was observed in gravelly pelitic to pelitic sands between 18 and 91 meters. With increasing depth Cibicides lobatulus replaces Elphidium incertum 'group' as the dominant component and Islandiella islandica and I. teretis increase in abundance.

DIA, arenaceous species dominant, occurs in the constantly cold and deep transitional watermass layers between 95 and 191 meters. The interval is characterised by temperatures of -1 to 4°C and salinities of 32 to 34.2‰. DIA is replaced laterally in part and at depths greater than 191 meters by the Angulogerina fluens association (DDA1).

In the west off both shores DDA1 is replaced by the Buccella inusitata association (DDA2) at depths greater than 237 meters. In the east it is replaced at depths greater than 256 meters by the Bulimina marginata 'group' association (DDA3). In the Laurentian Trough, east of long. 66° 30' W., DDA2 is replaced by DDA3. At depths greater than 347 meters approximately the Elphidium

incertum 'group' association (DDA4) replaces DDA3.

Two sub-associations are recognised for DDA4. Between 347 and 396 meters approximately the dominant species are Elphidium incertum 'group', Bulimina exilis, Nonionellina labradorica, Buccella inusitata and Bulimina marginata 'group'. At depths greater than 384 meters approximately this fauna is replaced by a Pullenia quinqueloba-Elphidium incertum 'group'-Cassidella schreibersiana-Bolivina pseudopunctata fauna.

7.9 Comparison between associations of the dead and total populations

The depth- and substrate-related trends described above for the dead population is identical to that of the total population except for the shallowest fauna of DSA1, in which Eggerella advena is more abundant than Ammotium cassis.

DSA2 is based on seven samples (see Text Fig. 7.4 - Cluster 4). In the dendrogram illustrating the clusters of samples of the total population, five of the samples of DSA2 (3, 10, 11, 24 and 31) formed a separate cluster (number 4 - see Text Fig. 6.4). The other samples of DSA2 (12 and 13) were grouped with samples 5, 6 and 7 to form Cluster 5. The writer reasoned for the total data matrix that samples 12 and 13 belonged with the members of Cluster 4, based on the taxa and their abundances in the samples. The occurrence of these samples in the same cluster in the dendrogram for the dead data matrix is consistent with the interpretation presented for the total data matrix.

The clusters defining DIA and TIA consist of the same members. The members of DDA1 and TDA1, DDA2 and TDA2, and DDA3 and TDA3 are

not identical. Samples are grouped in WPGA on the abundance of dominant taxa. The abundances of taxa in the dead data matrix is similar but not identical to those in the total data matrix. The differences in the members defining the deep associations are attributed to the change in the abundances of taxa resulting from the exclusion of the live specimens in computing values for the cells of the dead data matrix. The writer has shown that lateral variation in and vertical replacement of associations occur in the the deep watermass layers for the total population. Thus the exchange of samples between clusters defining adjacent associations of the populations should be expected.

The samples defining DDA4 consist of those of TDA4 and TDA5. The sub-associations of DDA4 described in the previous section are equivalent to TDA4 and TDA5.

The differences described above for the members of clusters defining associations of the dead and total populations, are restricted to the deep associations. The shallow and intermediate associations are defined on the same samples. The differences and similarities correspond to the proportions of valid and invalid samples within the appropriate depth interval in the live data matrix. Most of the samples of the live population from the shallow and intermediate depth intervals are based on valid counts. Only six of the twenty-one samples from the deep layers are based on valid counts. This suggests that the abundances of taxa in samples from the deep layers are not representative of the dead population.

CHAPTER 8

CLUSTER ANALYSIS OF THE LIVE DATA MATRIX

8.1 Live data matrix - 59 samples, 124 taxa

The dendrogram illustrating Q-mode clusters of the live data matrix based on 59 samples and 124 taxa is shown in Text Figure 8.1. Most of the samples in the clusters are based on low counts and the similarity level of 'inter-cluster' linkages are generally low. Hence the classification obtained from the dendrogram is not considered to be significant.

Hooper (1969, 1970a) reported that factor vector analysis of the same data matrix suggested five depth- and watermass-related benthonic foraminiferal associations. He pointed out that the re-ordered oblique projection matrices did not give solutions that were immediately interpretable in terms of depth associations. He suggested that the reason may lie in the low level of statistical reliability caused by low counts in some samples. The interpreted benthonic foraminiferal associations reported by Hooper for the live data matrix are not significant.

8.2 Live data matrix - 22 samples, 124 taxa

Seven clusters result from Q-mode cluster analysis of the live data matrix based on valid samples (22) and 124 taxa (Text Fig. 8.2). Taxa statistics and depths of samples in each cluster are listed in Table 8.1. Dominant species for each cluster, listed in decreasing order of average abundances, are shown in Table 8.2.

Text Figure 8.1. Dendrogram illustrating Q-mode clusters - Live date matrix (59 samples, 124 taxa).

Text Figure 8.2. Dendrogram illustrating Q-mode clusters - Live data matrix (22 samples, 124 taxa).

Table 8.1. Taxa statistics and depths of samples in clusters of live matrix (22 x 124).

CLUSTER	SAMPLE NO.	DEPTH (M)	NO. OF TAXA	CALCAREOUS/ARENACEOUS RATIO	WATERMASE LAYER OR LAYERS
1	1	338	25	23/2	DEEP WARM
	51	298	18	15/3	
2	4	283	27	21/6	DEEP WARM
	45	254	24	22/2	
3	33	250	14	10/4	DEEP WARM
	49	205	24	12/12	
4	10	91	12	10/2	UPPER TO CONSTANTLY COLD
	11	55	10	8/2	
	24	37	23	18/5	
	12	18	15	12/3	
	31	54	20	20/0	
5	15	27	5	0/5	UPPER
	20	31	12	1/11	
	26	12	7	0/7	
	27	34	12	0/12	
6	38	142	8	0/8	CONSTANTLY COLD TO DEEP TRANSITIONAL
	37	108	13	2/11	
	57	137	6	0/6	
	56	95	4	0/4	
	47	101	6	0/6	
	58	137	12	2/11	
7	25	7	3	0/3	UPPER

Table 8.2. Dominant species of clusters of live data matrix (22 x 124).

Cluster	Dominant Species
1	<u>Bulimina marginata</u> - <u>Buccella inusitata</u> - <u>Bulimina exilis</u> - <u>Cassidulina islandica</u> .
2	<u>Bulimina aculeata</u> - <u>Buccella inusitata</u> - <u>Cassidulina islandica</u> - <u>Globobulimina auriculata</u> .
3	<u>Angulogerina fluens</u> - <u>Cassidulina islandica</u> - <u>Buccella inusitata</u> .
4	<u>Cibicides lobatulus</u> - <u>Elphidium clavatum</u> - <u>Cassidulina islandica</u> .
5	<u>Eggerella advena</u> - <u>Trochammina</u> sp. cf. <u>T. ochracea</u> - <u>Spiroplectammina biformis</u> .
6	<u>Adercotryma glomerata</u> - <u>Proteonina atlantica</u> .
7	<u>Annotium cassis</u> .

8.3 Taxa modified live data matrix - 59 samples, 113 taxa

The dendrogram illustrating Q-mode clusters of the taxa modified live data matrix based on 59 samples and 113 taxa are shown in Text Figure 8.3. As reasoned for the equivalent unmodified live data matrix the classification obtained from the dendrogram is not significant.

8.4 Taxa modified live data matrix - 22 samples, 113 taxa

Six clusters result from Q-mode cluster analysis of the live data matrix based on valid samples (22) and 113 taxa (Text Fig. 8.4). Taxa statistics and depths of samples in each cluster are listed in Table 8.3. The main difference between the classifications obtained from the un-modified and the taxa modified live data matrices based on valid samples is the grouping of the members of Clusters 1 and 2 of the former matrix to form Cluster 1 of the taxa modified matrix. This results from the merging of the varieties of Bulimina marginata.

8.5 Associations of the live population

It was reasoned in Chapter 6 that the taxa modified data matrix based on valid samples produces a more objective classification of samples compared to the other sub-matrices of the population. Hence associations described below are based on the classification obtained from the taxa modified live data matrix (22 samples, 113 taxa).

LSA1, characteristic of the shallow water of Sept Iles Bay, ranges in depth from 12 to 36 meters. It occurs in gravelly to medium grained sands. The calcareous to arenaceous taxa ratio is

Text Figure 8.3. Dendrogram illustrating Q-mode clusters -- Live data matrix (59 samples, 143 taxa).

Text Figure 8.4. Dendrogram illustrating Q-mode clusters - Live data matrix (22 samples, 113 taxa).

Table 8.3. Taxa statistics and depths of samples in clusters of live matrix (22 x 113).

CLUSTER	SAMPLE NO.	DEPTH (M)	NO. OF TAXA	CALCAREOUS/ARENACEOUS RATIO	WATERMASS LAYER OR LAYERS
1	1	338	23	21/2	DEEP WARM
	4	283	27	21/6	
	45	256	23	21/2	
	51	298	18	15/3	
2	33	250	13	9/4	DEEP WARM
	49	205	24	12/12	
3	10	91	11	9/2	UPPER TO CONSTANTLY COLD
	12	18	14	11/3	
	11-6	55	10	8/2	
	24	37	23	18/5	
	31	54	19	19/0	
4	15	27	5	0/5	UPPER
	20	31	12	1/11	
	24	12	7	0/7	
	27	36	12	0/12	
5	35	142	8	0/8	CONSTANTLY COLD TO DEEP TRANSITIONAL
	37	108	13	2/11	
	57	137	6	0/6	
	56	95	4	0/4	
	47	101	6	0/6	
	58	137	13	1/12	
6	25	7	3	0/3	UPPER

1/19. Dominant species and their average abundances are Eggerella advena (32.9%), Trochammina ochracea (22.3%) and Spiroplectammina biformis (19.7%).

LSA2 is based on one sample, number 25 - depth 7 meters, from Sept Iles Bay. Ammotium cassis represents 98% of the fauna in the sample.

LSA3 ranges in depth from 18 to 91 meters. The calcareous to arenaceous taxa ratio is 29/8. Dominant species and their average abundances are Cibicides lobatulus (55.9%), Elphidium incertum 'group' (19.4%) and Islandiella islandica (5.0%). *The association occurs off Gaspé Peninsula east of long. 65° 30' W. in gravelly pelitic to pelitic sands.

LIA occurs in sandy substrates between 95 and 142 meters. The calcareous to arenaceous taxa ratio is 5/20. Dominant species and their average abundances are Adercotryma glomerata (48.4%) and Proteonina atlantica (10.6%).

LDA1 is based on two samples from depths of 205 and 250 meters. The calcareous to arenaceous taxa ratio is 16/14. Dominant species and their average abundances are Angulogerina fluens (40.3%), Buccella inusitata (8.3%) and Islandiella islandica (7.4%).

LDA2 ranges in depth from 356 to 338 meters. The calcareous to arenaceous taxa ratio is 36/8. Dominant species and their average abundances are Bulimina marginata 'group' (33.8%), Buccella inusitata (13.1%), Bulimina exilis (6.2%) and Islandiella islandica (6.1%). This association was observed in pelites, calcipelites and sandy pelites.

8.6 Comparison of associations - live, dead and total populations

Associations of the dead and total populations are essentially similar. Differences between members of the clusters defining the deep associations of these populations result from changes in the abundances of taxa on exclusion of the number of live specimens in computing values for the cells of the dead data matrix (Table 8.4). The quantitative value of the rose Bengal staining technique has been questioned by several workers. Hence the abundances of taxa in the live and dead data matrices may not be representative of their respective population.

A correlation of associations of the live, dead and total populations based on dominant species and their average abundances is shown in Table 8.5. A plot of the observed depth ranges of the associations is shown in Text Figure 8.5. The associations of the live population are based on fewer samples compared to the other populations however, there is general consistency between the associations of the populations. LSA2 is equivalent to the shallow sub-association of DSA1 and TSA1. TDA4 and TDA5 are equivalent to the sub-associations of DDA4.

8.7 Trends in the distribution of living taxa

The abundances of taxa in most cells of the live data matrix are not representative of the live population. However the relationship between living foraminifera, substrate and watermass conditions can be deduced from the live data matrix. For this purpose the samples are arranged in three groups corresponding to the observed depth ranges of the shallow, intermediate and deep associations.

Table 8.4. Members of clusters defining associations of the
live, dead and total populations.

Association	TSA1	DSA1	LSA1
Number of arenaceous taxa	25	25	19 (2) [†]
Number of calcareous taxa	1	1	1
Number of taxa - Total	26	26	20
Samples	15, 20, 21, 25, 26, 27.	15, 20, 21, 25, 26, 27.	15, 20, 26, 27.
Association	TSA2	DSA2	LSA3
Number of arenaceous taxa	16	16	8
Number of calcareous taxa	49	46	29 (1) [†]
Number of taxa - Total	65	62	37
Samples	3, 10, 11, 12, 13, 24, 31.	3, 10, 11, 12, 13, 24, 31.	10, 11, 12, 24, 31.
Association	TIA	DIA	LIA
Number of arenaceous taxa	38	35	25 (2) [†]
Number of calcareous taxa	4	0	5 (1) [†]
Number of taxa - Total	42	35	30
Samples	35, 37, 39, 42, 44, 47, 56, 57, 58.	35, 37, 39, 42, 44, 47, 56, 57, 58.	35, 37, 47, 56, 57, 58.
Association	TDA1	DDA1	LDA1
Number of arenaceous taxa	26	22	14 (1) [†]
Number of calcareous taxa	38	35	16 (1) [†]
Number of taxa - Total	64	57	30
Samples	9, 33, 34, 48, 49, 59.	9, 34, 48, 49, 59.	33, 49.
Association	TDA2	DDA2	
Number of arenaceous taxa	15	20	
Number of calcareous taxa	27	38	
Number of taxa - Total	42	58	
Samples	32, 36, 52, 60.	32, 33, 36, 52, 54, 60, 62.	
Association	TDA3	DDA3	LDA2
Number of arenaceous taxa	22	22	8 (2) [†]
Number of calcareous taxa	78	71	36
Number of taxa - Total	100	93	44
Samples	1, 4, 28, 29, 30, 41, 45, 51, 53, 54, 62.	1, 4, 28, 29, 30, 41, 45, 51, 53.	1, 4, 45, 51.
Association	TDA4	TDA5	DDA4
Number of arenaceous taxa	2	14	14
Number of calcareous taxa	24	29	41
Number of taxa - Total	26	43	55
Samples	5, 6, 7.	40, 50.	5, 6, 7, 40, 50.

[†] Number of taxa excluded from dead and total data matrices.

Table 8.5. Dominant species of associations of the live,
dead and total populations.

Association	TSA1	DSA1	LSA1
Dominant Species			
<u>Eggerella advena</u>	28.2	29.9	32.9
<u>Reophax scotti</u>	17.2	18.4	
<u>Spiroplectammina biformis</u>	16.8	18.8	19.7
<u>Trochammina ochracea</u>	14.4	11.0	22.3
<u>Ammotium cassis</u>	7.6	5.7	
Association	TSA2	DSA2	LSA3
Dominant Species			
<u>Cibicides lobatulus</u>	51.9	49.3	55.9
<u>Elphidium incertum</u> 'group'	26.2	28.2	19.4
<u>Islandiella islandica</u>	7.6	8.5	5.0
Association	TIA	DIA	LIA
Dominant Species			
<u>Adercotrypa glomerata</u>	38.1	26.6	48.4
<u>Protonina atlantica</u>	11.4	13.3	10.6
<u>Spiroplectammina biformis</u>	9.7	10.9	
Association	TDA1	DDA1	LDA1
Dominant Species			
<u>Angulogerina fluens</u>	30.6	32.6	40.3
<u>Islandiella islandica</u>	12.1	12.5	7.5
<u>Buccella inusitata</u>	7.9	7.9	8.3
<u>Elphidium incertum</u> 'group'	7.0	6.8	
<u>Bulimina marginata</u> 'group'	5.4	6.9	
Association	TDA2	DDA2	
Dominant Species			
<u>Buccella inusitata</u>	31.4	23.5	
<u>Islandiella islandica</u>	17.8	19.7	
<u>Bulimina exilis</u>	6.4	10.2	
<u>Nonionellina labradorica</u>	5.6	5.3	
<u>Angulogerina fluens</u>	5.1	6.1	
<u>Bulimina marginata</u> 'group'		5.3	
<u>Elphidium incertum</u> 'group'		5.3	
Association	TDA3	DDA3	LDA2
Dominant Species			
<u>Bulimina marginata</u> 'group'	28.5	33.3	33.8
<u>Buccella inusitata</u>	15.8	16.8	13.1
<u>Islandiella islandica</u>	10.0	6.9	6.1
<u>Bulimina exilis</u>	8.8	6.9	6.2
<u>Elphidium incertum</u> 'group'	5.9	6.1	
<u>Globobulimina auriculata</u>			5.2
Association	TDA4	TDA5	DDA4
Dominant Species			
<u>Elphidium incertum</u> 'group'	40.7	11.8	33.8
<u>Bulimina exilis</u>	11.1		9.1
<u>Nonionellina labradorica</u>	10.2		10.3
<u>Buccella inusitata</u>	10.0		6.4
<u>Bulimina marginata</u> 'group'	8.8		6.8
<u>Pullenia quinqueloba</u>		14.1	5.9
<u>Cassidella schreibersiana</u>		8.4	
<u>Bolivina pseudopunctata</u>		6.8

Text Figure 8.5. Depth ranges of live, dead and total benthonic foraminiferal assemblages.

All the samples from Sept Iles Bay were grouped with those defining the shallow associations. The values in the cells of the matrix are converted to binary (presence or absence) form with respect to the substrate types in the designated intervals. The table resulting from the conversion process is shown in Appendix IV.

Seventeen species live in the upper watermass layer (0 to 50 meters approximately, -1 to 16°C , salinity less than 32.5%) only.

Those identified specifically by Hooper are:

Annotium cassis

Dentalina ittai

Eggerella advena

Eggerella arctica

Elphidium subarcticum

Miliammina fusca

Patellina corrugata

Protonina ampullacea

Protonina fusiformis

Quinqueloculina stalkerii

Reophax arctica

Reophax scotti

Trochammina ochracea

They should not be regarded as being restricted to the upper watermass layer.

Abundance trends related to the groupings are:

1. Between 7 and 91 meters in the upper to constantly cold watermass layers calcareous species are dominant in very

sandy pelites, gravelly pelitic and pelitic sands. Gravelly to medium grained sands are characterised by a high proportion of arenaceous species.

2. In the constantly cold to deep transitional water-mass layers between 73 and 191 meters (-1 to 4°C , 33 to 34.2‰ salinity) arenaceous species are more abundant than calcareous species. Substrates sampled in this interval are pelitic sands, very sandy and sandy pelites, and gravelly pelitic sands. The Adercotryma glomerata association observed in this interval is related to these sandy substrates. Clay and/or silt rich substrates were not sampled. Such substrates should contain an association dominated by Islandiella islandica, Islandiella teretis, Elphidium incertum 'group' and Angulogerina fluens. Cibicides lobatulus may be a dominant component of this association depending on the amount of sand in the substrate.
3. Substrates in the deep transitional and warm water-mass layers (4 to 6°C , 34 to 34.6‰ salinity) between 155 and 398 meters are characterised by calcareous species. Pelites, calcipelites, very sandy and sandy pelites, and pelitic sands occur in this interval. Pelites and very sandy pelites are characterised by a calcareous to arenaceous species ratio less than two. A calcareous to arenaceous species ratio greater than two characterise calcipelites and sandy pelites. The

highest number of species occur in calcipelites.

Very sandy pelites and pelitic sands contain the lowest number of species.

CHAPTER 9

SUMMARY AND RECOMMENDATIONS

9.1 Summary

Live, dead and total data matrices consisting of abundances of modern foraminiferal taxa from sixty-two bottom sediment samples of the lower St. Lawrence Estuary were analysed quantitatively. The data matrices were compiled by Dr. K. Hooper. Sample depths range from 7 to 398 meters. The data matrices were divided into two sub-matrices. Sub-matrix 1 was based on 62 samples and the number of taxa identified by Hooper. Sub-matrix 2 was based on samples with valid counts. The dead and total data matrices were modified as follows:

1. Species and their varieties were merged.
2. Taxa occurring in only one and rarely two samples and which were less than two percent of the total composition of the samples were excluded from the data matrices.

The writer reasoned that splitting of species based on subtle morphological features produced sub-groupings prior to quantitative analysis. Furthermore Hooper (1970a) stated that such splitting resulted in the recognition of varieties which were often difficult to re-identify. Thirty-nine of the forty-four taxa excluded from the data matrices were not specifically identified. Hence their utility to other workers is questionable. The taxa modified dead and total data matrices were divided into two sub-matrices as follows:

1. Sub-matrix 1 - based on 62 samples and 152 taxa.
2. Sub-matrix 2 - based on valid samples only (49) and 152 taxa.

For the live matrix species and their varieties were merged. Taxa were not excluded. The live data matrix was divided into four sub-matrices as follows:

1. Sub-matrix 1 - based on 59 samples and the number of taxa (124) identified by Hooper.
2. Sub-matrix 2 - based on valid samples only (22) and 124 taxa.
3. Sub-matrix 3 - based on 59 samples and 113 taxa.
4. Sub-matrix 4 - based on valid samples only (22) and 113 taxa.

The Fortran program CLUSTER, described by Davis (1973), was used to perform weighted pair group cluster analysis (WPGA) of the sub-matrices. The technique arranges samples into a hierarchical classification based on the abundance of dominant taxa thereby permitting the recognition of repeated occurrences of abundant taxa (i.e. associations). WPGA of the sub-matrices reveals the following:

1. Samples based on low counts are grouped together or occur in clusters with valid samples. Clusters consisting wholly of samples based on low counts are not significant. Clusters dominated by invalid samples are difficult to interpret because the true relationships of the valid samples in these clusters are not apparent from the dendrogram. They are manifested on exclusion

of the valid samples.

2. Exclusion of taxa which do not contribute significantly to the composition of the samples does not affect the classification of the samples because the members of the clusters are determined by the abundances of their dominant variables (taxa).
3. Splitting of species produces sub-groupings prior to quantitative analysis. The sub-groups appear as separate clusters in the dendrogram. On merging species and their varieties the natural relationships between the samples are displayed more clearly.
4. Dendrograms obtained from data matrices based on valid and invalid samples or valid samples only and with species and their varieties treated as separate variables, are difficult to interpret. The dendrograms obtained from the taxa modified data matrices based on valid samples only provide a more objective classification of the samples and are preferred by the writer.

A comparison of the results of QQ-mode factor vector analysis, as interpreted by Hooper, and Q-mode WPGA of the dead data matrix based on 62 samples and 222 taxa shows that the latter technique produces a more subtle classification of the samples. This is desirable in ecological studies because it enhances the recognition of lateral and depth-related changes in faunal associations. The technique used by Hooper to evaluate the status of anomalous samples i.e. samples having depths outside of the range of the

majority of the samples in the group in which it occurs, is questioned by the writer. His approach is based on the coefficient of similarity and the depth of the anomalous sample. Classifications obtained from quantitative techniques are dependant on several factors such as sample density, the choice of variables and the method of computing their abundances, and foremost the mathematical principles underlying the techniques. Most Q-mode techniques group samples on the abundance of their dominant variables. Hence the status of an anomalous sample is best interpreted by comparing its dominant taxa and its overall taxa composition with those of the other members in the group.

An approach to evaluating Q-mode WPGA classifications was illustrated in Chapter 6. The abundances of taxa common to the samples in the cluster must be examined. The abundance of dominant species and the similarity level of 'inter-cluster' linkages are used to recognise sub-associations which may be related to water-mass conditions and/or substrate.

The results of Q-mode WPGA of the dead and total taxa modified data matrices based on valid samples are essentially similar. Differences between members of the clusters defining the deep associations in these matrices are attributed to the changes in the abundances of taxa resulting from the exclusion of the number of live specimens from the total (live-plus dead) number of specimens in computing values for cells of the dead data matrix. The quantitative value of results obtained from the rose Bengal staining technique has been questioned by several workers. Hence the

abundances of taxa in the live and dead data matrices may not be representative of their respective population. Temporal (seasonal) variations of the standing crop may also be a contributory factor.

Associations comparable to those of the dead and total populations were obtained from Q-mode WPGA of the taxa modified live data matrix based on valid samples. This suggests that the live, dead and total populations are in equilibrium and that the present bottom condition has not been drastically changed by such factors as bottom currents and biological activity. Hence associations deduced from the total data matrix are representative of the modern benthonic foraminiferal population in the lower St. Lawrence Estuary.

Eight modern benthonic foraminiferal associations are recognised in the lower St. Lawrence Estuary. At water depths less than 100 meters (-1 to 16°C , salinity less than 32.5‰) there are two associations related to distinct substrates. An association characterised by Eggerella advena-Reophax scotti-Spiroplectammina biformis-Trochammina ochracea-Ammonium cassis occurs in Sept Iles Bay between 7 and 46 meters. At 7 meters the dominant species are A. cassis, E. advena and Miliammina fusca. This fauna which reflects the influence of fresh water discharge into the Bay, is replaced by the Eggerella advena-Spiroplectammina biformis-Trochammina ochracea-Reophax scotti fauna from 12 to 36 meters. R. scotti and S. biformis accounts for more than 75% of the fauna at 46 meters. The replacement of Eggerella advena with increasing depth occurs in more saline and cool water. This association is characterised by arenaceous species and a low species diversity.

An association of Cibicides lobatulus-Elphidium incertum 'group'-Islandiella islandica was observed between 18 and 91 meters in gravelly pelitic to pelitic sands. Calcareous species characterise the association. At 18 meters E. incertum 'group' is more abundant than C. lobatulus. With increasing depth C. lobatulus replaces E. incertum 'group' as the most abundant species and I. islandica and I. teretis increase in abundance. The trends in relative abundances correspond to increasing salinity and generally cooler temperatures.

The depth range 95 to 191 meters (-1 to 4°C, 33 to 34.2‰ salinity) contains the association of Adercotryma glomerata-Proteonina atlantica-Spiroplectammina biformis. Arenaceous species characterise this association which occurs in sandy substrates. It is replaced laterally in part and at depths greater than 191 meters by the association of Angulogerina fluens-Islandiella islandica-Buccella inusitata-Elphidium incertum 'group'-Bulimina marginata 'group'. It was observed between 155 and 250 meters (-1 to 4.2°C, 33.5 to 34.5‰ salinity) in sandy pelites. This association is characterised by a low calcareous to arenaceous species ratio (less than 2).

Buccella inusitata, Bulimina exilis, B. marginata 'group', Elphidium incertum 'group', Islandiella islandica and Nonionellina labradorica characterise water depths between 250 and 398 meters (4.2 to 5.5°C, 34.2 to 34.6‰ salinity) in Hooper's data matrices. In the west off both shores the Angulogerina fluens association is replaced by the association of Buccella inusitata-Islandiella

islandica-Bulimina exilis-Nonionellina labradorica at depths greater than 237 meters. In the east off Anticosti Island and Gaspé Peninsula the Angulogerina fluens association is replaced by the association of Bulimina marginata 'group'-Buccella inusitata-Islandiella islandica-Bulimina exilis at depths greater than 256 meters.

In the Laurentian Trough the Buccella inusitata association which occurs in sandy pelites in the west, passes laterally into the Bulimina marginata 'group' association in the east in pelites, calcipelites and sandy pelites. At depths greater than 365 meters the Bulimina marginata 'group' association is replaced by the association of Elphidium incertum 'group'-Bulimina exilis-Nonionellina labradorica-Buccella inusitata-Bulimina marginata 'group'. The latter is replaced by the association of Pullenia quinqueloba-Elphidium incertum 'group'-Cassidella schreibersiana-Bolivina pseudopunctata at depths greater than 384 meters in a deep basin off the western end of Anticosti Island.

Associations comparable to those of Angulogerina fluens, Bulimina marginata 'group' and Elphidium incertum 'group' were observed by the writer in modern bottom sediment samples from Sackville Cruise 46 between 183 and 365 meters in the lower St. Lawrence Estuary. The abundance of Globobulimina auriculata was much higher and that of Buccella inusitata was lower in the writer's samples compared to their abundances in Hooper's data matrices.

A lateral and vertical substrate distribution diagram of

benthonic foraminiferal associations in the lower St. Lawrence Estuary as deduced from Hooper's data matrices, is shown in Text Figure 9.1.

9.2 Recommendations

Extension of this study east of long. 64° W. would seem to be the logical next step. Emphasis should be placed on benthonic foraminiferal association-substrate relationships and a detailed study of foraminiferal taxa in the area.

Text Figure Q.1. Lateral and vertical substrate distribution diagram for benthonic foraminiferal associations.

REFERENCES

- Bartlett, G. A., 1966. Distribution and abundance of foraminifera and thecamoebina in Miramichi River and Bay. Rep. Bedford Inst. Oceanogr. 66-2, 107 p.
- Buzas, M. A., 1966. The discrimination of morphological groups of Elphidium (Foraminifera) in Long Island Sound through canonical analysis and invariant characters. J. Paleont. 40, pp. 585-594, pls. 71, 72.
- Cushman, J. A., 1930. The foraminifera of the Atlantic Ocean. Part 7. Nonionidae, Camerinidae, Peneroplidae and Alveolinellidae. U. S. Nat. Mus., Bull. 104, pp. 1-79, pls. 1-18.
- 1944. Foraminifera from the shallow water of New England coast. Cushman Lab. Foram. Res., Spec. Publ. 12, pp. 1-37, pls. 1-4.
- Davis, J. C., 1973. Statistics and data analysis in Geology. John Wiley and Sons, Inc., New York, 550 p.
- Dawson, G. M., 1870. On foraminifera from the Gulf and River St. Lawrence. Canadian Naturalist, n.s. 5, pp. 172-180, 1 pl.
- Dawson, J. W., 1872. Post-Pliocene Geology of Canada. Canadian Naturalist, n.s. 6, pp. 241-260.
- Feyling-Hanssen, R. W., 1964. Foraminifera in Late Quaternary deposits from the Oslo-fjord area. Norges Geol. Unders. 225, 383 p., pls. 1-21.
- 1972. The foraminifer Elphidium excavatum (Terquem) and its variant forms. Micropaleontology 18, pp. 337-354, pls. 1-6.
- Gervitz, J. L., Park, R. A., and Friedman, G. M., 1971. Paraecology of benthonic foraminifera and associated micro-organisms of the continental shelf off Long Island, New York. J. Paleont. 45, pp. 153-177.
- Green, K. E., 1960. Ecology of some Arctic foraminifera. Micropaleontology 6, pp. 57-78.
- Höglund, H., 1947. Foraminifera of the Gullmar Fjord and the Skagerak. Zool. Bidr. från Uppsala 26, 328 p.

- Hooper, K., 1967. Processing foraminiferal data: A computer program. Intern. Conf. Planktonic Microfossils, 1st, Geneva (1967), Proc., pp.291-306, Leiden, Brill, 1969, 745 p.
- 1968. Benthonic foraminiferal depth-assemblages of the continental shelf off eastern Canada. Maritime Sed. 4, pp. 96-99.
- 1969. Studies in some post-Wisconsin foraminiferal faunas and sediments of eastern Canada and Atlantic continental shelf. London Univ., Ph. D. Thesis, 505 p.
- 1970a. The distribution of modern benthonic foraminifera in the north west Gulf of St. Lawrence. Maritime Sed. 6, pp. 74-78.
- 1970b. Recent foraminifera of the continental shelf off eastern Canada. Rep. Bedford Inst. Oceanogr. 70-3, 48 p.
- 1975. Foraminiferal ecology and associated sediments of the lower St. Lawrence Estuary. J. Foram. Res. 5, pp. 218-238.
- Lauzier, L. M., 1957. A preliminary report of the winter oceanographic survey in the Gulf of St. Lawrence, 1956. Fisheries Res. Board Canada Rep., Oceanogr. and Limnol. 10, 22 p.
- 1958. Some aspects of the oceanographic conditions in the Gulf of St. Lawrence from Autumn 1956 to Spring 1957. Fisheries Res. Board Canada Rep., Oceanogr. and Limnol. 10, 21 p.
- Loeblich, A. R., and Tappan, H., 1953. Studies in Arctic foraminifera. Smithsonian Inst. Misc. Coll. 121, pp. 1-150, pls. 1-24.
- Loring, D. H., and Nota, D. J. G., 1972. Distribution of surface sediments - Gulf of St. Lawrence. Can. Hydrographic Service, Marine Science Directorate Dept. Environ., 1 Map.
- 1973. Morphology and sediments of the Gulf of St. Lawrence. Fisheries Res. Board Canada, Bull. 182, 147 p.
- Manson, V., and Imbrie, J., 1964. Fortran program for factor and vector analysis of geological data using an IBM 7090 or 7094/1401 computer system. State Geol. Survey and Kansas Univ., Spec. Distr. Publ. 13, 46 p.

- Park, R. A., 1974. A multivariate analytical strategy for classifying paleoenvironments. *J. Intern. Assoc. Math. Geol.* 6, pp. 333-352.
- Parker, F. L., 1952a. Foraminifera species off Portsmouth, New Hampshire. *Harvard Coll., Mus. Comp. Zool., Bull.* 106, pp. 391-423, pls. 1-6.
- 1952b. Foraminiferal distribution in the Long Island Sound-Buzzards Bay area. *Harvard Coll., Mus. Comp. Zool., Bull.* 106, pp. 427-473, pls. 1-5.
- Phleger, F. B., 1952. Foraminifera ecology off Portsmouth, New Hampshire. *Harvard Coll., Mus. Comp. Zool., Bull.* 106, pp. 315-390.
- Pickerill, R. K., and Brenchley, P. J., 1975. The application of the community concept in paleontology. *Maritime Sed.* 11, pp. 5-8.
- Schafer, C. T., 1975. Distribution of foraminifera in Chaleur Bay. *Geol. Survey Canada, Paper* 75-1C, pp. 1-3.
- Sen Gupta, B. K., 1971. The benthonic foraminifera of the Tail of the Grand Banks. *Micropaleontology* 17, pp. 69-98, pls. 1-2.
- Sproule, H. F., 1962. A regional study of the benthonic foraminifera in the Gulf of St. Lawrence, Canada. Unpubl. B. Sc. Thesis, Carleton University, Ottawa, 32 p.
- Trites, R., 1971. The Gulf as a physical oceanographic system. In: Bedford Inst., Dartmouth, N. S., 2nd Gulf of St. Lawrence Workshop, 1970, pp. 32-63.
- Vilks, G., 1968. Foraminifera study of the Magdalen Shallows, Gulf of St. Lawrence. *Maritime Sed.* 4, pp. 14-21.
- Walker, D. A., Linton, A. E., and Schafer, C. T., 1974. Sudan Black B: a superior stain to rose Bengal for distinguishing living from non-living foraminifera. *J. Foram. Res.* 4, pp. 205-215.
- Walton, W. R., 1952. Techniques for recognition of living foraminifera. *Cushman Found. Foram. Res. Contr.* 3, pp. 56-64.
- Whiteaves, J. F., 1872. Notes on a deep-sea dredging expedition round the Island of Anticosti in the Gulf of St. Lawrence. *Annals and Mag. Nat. History*, ser. 4, 10, pp. 341-354.

APPENDIX I Cont'd

TAXA NO.	TAXA OF MOOPER	LIVE	DEAD	TAXA NO.	MODIFIED TAXA	LIVE	DEAD
131	BULIMINELLA ELIGANTISSIMA	X		28	BULIMINELLA ELIGANTISSIMA		X
103	VERGULINA SP. CF. V. PAUCILOCCULATA	X		29	CASSIDELLA PAUCILOCCULATA		X
113	VERGULINA COMPLANATA	X		30	CASSIDELLA SCHREIBERSIANA		X
228	VERGULINA SP. CF. V. SCHREIBERSIANA	X					
19	CIBICIDES LEBATULUS	X		31	CIBICIDES LEBATULUS		X
80	CIBICIDES SP. CF. C. LEBATULUS	X					
130	CIBICIDES REFUGENS	X		32	CIBICIDES REFUGENS		X
211	CIBICIDES SP. A	X		33	CIBICIDES SP. A		X
78	ALVEOLIPHRAGMIDUM CRASSIMAROD	X		34	CRASSIMAROD		X
2	ALVEOLIPHRAGMIDUM JEFFREYSI	X		35	CRASSIMAROD JEFFREYSI		X
128	ALVEOLIPHRAGMIDUM SUBULCROSUM	X		36	CRASSIMAROD SUBULCROSUM		X
142	CYCLAMMINA CANCELLATA	X		37	CYCLAMMINA CANCELLATA		X
16	DENTALINA FAGGI	X		38	DENTALINA FAGGI		X
101	DENTALINA FRIBISHERENSIS	X		39	DENTALINA FRIBISHERENSIS		X
17	DENTALINA ITTAI	X		40	DENTALINA ITTAI		X
200	DENTALINA PAUPERATA	X		41	DENTALINA PAUPERATA		X
220	DENTALINA SP. CF. TROCHAMMINA IDIPERTA	X		42	DENTALINA SP. CF. TROCHAMMINA IDIPERTA		X
22	DENTALINA SP. CF. TROCHAMMINA OCHRACEA	X		43	DENTALINA SP. CF. TROCHAMMINA OCHRACEA		X
19	DENTALINA SP.	X		44	DENTALINA SP.		X
21	DENTALINA SP.	X		45	DENTALINA SP.		X
82	DENTALINA ADVENA	X		46	DENTALINA ADVENA		X
223	DENTALINA ARCTICA	X		47	DENTALINA ARCTICA		X
85	DENTALINA IMMATURE	X		48	DENTALINA IMMATURE		X
31	ELPHIDIELLA ARCTICA	X		49	ELPHIDIELLA ARCTICA		X
224	ELPHIDIELLA GREENLANDICA	X		50	ELPHIDIELLA GREENLANDICA		X
239	ELPHIDIELLA NITIDA	X		51	ELPHIDIELLA NITIDA		X
22	ELPHIDIUM BARTLETTI	X		52	ELPHIDIUM BARTLETTI		X
24	ELPHIDIUM SP. CF. E. BARTLETTI	X					
27	ELPHIDIUM SP. CF. E. EXCAVATUM	X		53	ELPHIDIUM EXCAVATUM		X
27	ELPHIDIUM FRIGIDUM	X		54	ELPHIDIUM FRIGIDUM		X
26	ELPHIDIUM CLAVATUM	X		55	ELPHIDIUM INCERTUM GROUP		X
29	ELPHIDIUM INCERTUM	X					
81	ELPHIDIUM SP. CF. E. CLAVATUM	X					
115	ELPHIDIUM INCERTUM AFF. E. CLAVATUM	X					
28	ELPHIDIUM SUBARCTICUM	X		56	ELPHIDIUM SUBARCTICUM		X
175	ELPHIDIUM SP. CF. E. SUBARCTICUM	X					

APPENDIX I Cont'd

TAXA NO.	TAXA CP. WOODER	LIVE DEAD	TAXA NO.	MODIFIED TAXA	LIVE DEAD
25	ELPHIDIUM SP.	X	57	ELPHIDIUM SP.	X
213	ELPHIDIUM SP. OR NONION SP.	X	58	ELPHIDIUM SP. OR NONION SP.	X
32	EPISTOMINELLA MARAENSIS	X	59	EPISTOMINELLA TAKAYANAGII	X
146	EPISTOMINELLA SP. CF. E. MARAENSIS	X			
245	EPISTOMINELLA SP. CF. E. TAKAYANAGII	X			
104	EPONIDES PUSILLUS	X	60	EPONIDES PUSILLUS	X
30	ESPYRINX CURTUS	X	61	ESPYRINX CURTUS	X
36	FISSURINA CUCURBITASEMA	X	62	FISSURINA CUCURBITASEMA	X
33	FISSURINA MARGINATA	X	63	FISSURINA MARGINATA	X
316	FISSURINA SP. CF. F. MARGINATA	X	64	FISSURINA SEMIMARGINATA	X
35	FISSURINA SEMIMARGINATA	X			
97	FISSURINA SP. CF. F. SEMIMARGINATA	X	65	FISSURINA SERRATA	X
34	FISSURINA SERRATA	X	66	FISSURINA SP.	X
105	FISSURINA SP.	X	67	GLANDULINA LAEVIGATA	X
37	GLANDULINA LAEVIGATA	X	68	GLANDULINA AURICULATA	X
38	GLANDULINA AURICULATA	X	69	GLANDULINA PACIFICA	X
233	GLANDULINA SP. CF. G. PACIFICA	X	70	GUITULINA LACTEA	X
40	GUITULINA LACTEA	X	71	GUITULINA QUINQUELOBA	X
104	GUITULINA SP. CF. G. QUINQUELOBA	X			
145	GUITULINA SP.	X			
160	GUITULINA QUINQUELOBA	X	72	HEMISPHERAMMINA BRADYI	X
189	HEMISPHERAMMINA BRADYI	X	73	HEMISPHERAMMINA SP.	X
91	HEMISPHERAMMINA SP.	X	74	HYPERAMMINA SUBNOGOSA	X
83	HYPERAMMINA SUBNOGOSA	X			
210	HYPERAMMINA SP. A	X	75	HYPERAMMINA SP. A	X
216	HYPERAMMINA SP. B	X	76	HYPERAMMINA SP. B	X
155	HYPERAMMINA SP.	X	77	HYPERAMMINA SP.	X
192	HYPERAMMINA FRAGMENTIS	X	78	HYPERAMMINA FRAGMENTIS	X
10	CASSIDULINA ISLANDICA	X	79	ISLANDIELLA ISLANDICA	X
12	CASSIDULINA NORCROSSI	X	80	ISLANDIELLA NORCROSSI	X
138	CASSIDULINA SP. CF. C. NORCROSSI	X			
11	CASSIDULINA TERETIS	X	81	ISLANDIELLA TERETIS	X
42	LAEVA APIOPLEURA	X	82	LAEVA APIOPLEURA	X
235	LAEVA CLAVATA	X	83	LAEVA CLAVATA	X
227	LAEVA ELONGATA	X	84	LAEVA ELONGATA	X

APPENDIX I' Cont'd

TAXA NO.	TAXA OF WOOPER	LIVE	DEAD	TAXA NO.	MODIFIED TAXA	LIVE	DEAD
43	LAGENA FLATULENTA	X	X	85	LAGENA FLATULENTA	X	X
107	LAGENA GRACILLIMA	X	X	86	LAGENA GRACILLIMA	X	X
182	LAGENA SP. CF. L. GRACILLIMA						
108	LAGENA GRACILLIS			87	LAGENA GRACILLIS	X	X
67	LAGENA LAEVIS	X	X	88	LAGENA LAEVIS	X	X
69	LAGENA MERIDIONALIS	X	X	89	LAGENA MERIDIONALIS	X	X
46	LAGENA POLLIS	X	X	90	LAGENA POLLIS	X	X
197	LAGENA PAPRI	X	X	91	LAGENA PAPRI	X	X
132	LAGENA SEMILINEATA	X	X	92	LAGENA SEMILINEATA	X	X
133	LAGENA STRIATA	X	X	93	LAGENA STRIATA	X	X
238	LAGENA SUBSTRATA	X	X	94	LAGENA SUBSTRATA	X	X
123	LAGENA SP.	X	X	95	LAGENA SP.	X	X
48	LARYNGOSTOMA MYALSCIDA	X	X	96	LARYNGOSTOMA MYALSCIDA	X	X
102	LENTICULINA GIBBA	X	X	97	LENTICULINA GIBBA	X	X
135	LENTICULINA SP. CF. L. GIBBA	X	X	98	LENTICULINA SP. CF. L. GIBBA	X	X
184	MILLIAMINA FUSCA	X	X	99	MILLIAMINA FUSCA	X	X
193	MILLIAMINA SP. CF. M. FUSCA	X	X				
49	MONIDON SP.	X	X	100	MONIDON SP.	X	X
166	MONIDON SP. OR ELPHIDIUM SP.	X	X	101	MONIDON SP. OR ELPHIDIUM SP.	X	X
53	MONIDONELLA AURICULATA	X	X	102	MONIDONELLA AURICULATA	X	X
84	MONIDONELLA SP. CF. N. AURICULATA	X	X				
173	MONIDONELLA AURICULATA AFF. MONIDON ORATELOUPI	X	X	103	MONIDONELLA AURICULATA AFF. MONIDON ORATELOUPI	X	X
109	MONIDONELLA TURGIDA	X	X	104	MONIDONELLA TURGIDA	X	X
51	MONIDONELLA LABRADORICA	X	X	105	MONIDONELLA LABRADORICA	X	X
52	MONIDONELLA LABRADORICUM	X	X				
157	MONIDONELLA IMMATURE	X	X	106	MONIDONELLA IMMATURE	X	X
54	COLINA CAUDIGERA	X	X	107	COLINA CAUDIGERA	X	X
55	COLINA COSTATA	X	X	108	COLINA COSTATA	X	X
175	COLINA LINEATA	X	X	109	COLINA LINEATA	X	X
169	COLINA SP. CF. S. LINEATA	X	X	110	COLINA LINEATA-PUNCTATA	X	X
198	COLINA LINEATA-PUNCTATA	X	X	111	COLINA LINEATA-PUNCTATA	X	X
56	COLINA MELC	X	X	112	COLINA MELC	X	X
208	COLINA SCUMOSA	X	X	113	COLINA SCUMOSA	X	X
57	PARAFISSURINA FUSILIFORMIS	X	X	114	PARAFISSURINA FUSILIFORMIS	X	X
151	PARAFISSURINA HIMATOSTOMA	X	X	115	PARAFISSURINA HIMATOSTOMA	X	X
110	PARAFISSURINA TECTULOSTOMA	X	X	116	PARAFISSURINA TECTULOSTOMA	X	X

APPENDIX I Cont'd

TAXA OF WOOPER		TAXA		MODIFIED TAXA		LIVE DEAD	
TAXA NO.		TAXA NO.					
58	PATELLINA CORRUGATA						
222	POLYMERPHINA SP.					X	X
176	PROTEPHIDIUM CRICULARE					X	X
177	PROTEPHIDIUM SP. CF. P. CRICULARE					X	X
188	PROTEPHINA SP. CF. P. AMPULLACEA					X	X
76	PROTEPHINA ATLANTICA					X	X
185	PROTEPHINA SP. CF. P. ATLANTICA					X	X
203	PROTEPHINA DIFFLUGIFORMIS					X	X
187	PROTEPHINA SP. CF. P. DIFFLUGIFORMIS					X	X
194	PROTEPHINA FUSIFORMIS					X	X
148	PROTEPHINA SP.					X	X
86	PSAMMOSPHAERA SP.					X	X
203	PSUDONOCESARIA ROTUNDATA					X	X
100	PULLENIA BULLICIDES					X	X
112	PULLENIA QUINQUELOBA					X	X
117	PULLENIA SP. CF. P. QUINQUELOBA					X	X
60	QUINQUELOBA SP. CF. QUINQUELOBA					X	X
61	QUINQUELOBA STALKERI					X	X
65	RECURVITES TURBINATUS					X	X
199	RECPHAX AMPULLACEA					X	X
171	RECPHAX ARCTICA					X	X
170	RECPHAX ATLANTICA					X	X
66	RECPHAX CURTUS					X	X
158	RECPHAX FUSIFORMIS					X	X
134	RECPHAX GRACILLIS					X	X
167	RECPHAX PILULIFERA					X	X
67	RECPHAX SCORPIURUS					X	X
48	RECPHAX SCOTTI					X	X
221	RECPHAX SP. CF. R. SCOTTI					X	X
57	RECPHAX SUBFUSIFORMIS					X	X
61	RECPHAX SP. AFF. R. ROSTRATA					X	X
193	RECPHAX SP.					X	X
240	RECHETIA TASMANICA					X	X
191	RETALIDS					X	X
69	SACCANTHAX SP.					X	X
177	SILICOSPHELLINA GREENLANDICA					X	X
116	PATELLINA CORRUGATA					X	X
117	POLYMERPHINA SP.					X	X
118	PROTEPHIDIUM CRICULARE					X	X
119	PROTEPHINA AMPULLACEA					X	X
120	PROTEPHINA ATLANTICA					X	X
121	PROTEPHINA DIFFLUGIFORMIS					X	X
122	PROTEPHINA FUSIFORMIS					X	X
123	PROTEPHINA SP.					X	X
124	PSAMMOSPHAERA SP.					X	X
125	PSUDONOCESARIA ROTUNDATA					X	X
126	PULLENIA BULLICIDES					X	X
127	PULLENIA QUINQUELOBA					X	X
128	QUINQUELOBA ARCTICA					X	X
129	QUINQUELOBA STALKERI					X	X
130	RECURVITES TURBINATUS					X	X
131	RECPHAX AMPULLACEA					X	X
132	RECPHAX ARCTICA					X	X
133	RECPHAX ATLANTICA					X	X
134	RECPHAX CURTUS					X	X
135	RECPHAX FUSIFORMIS					X	X
136	RECPHAX GRACILLIS					X	X
137	RECPHAX PILULIFERA					X	X
138	RECPHAX SCORPIURUS					X	X
139	RECPHAX SCOTTI					X	X
140	RECPHAX SUBFUSIFORMIS					X	X
141	RECPHAX SP. AFF. R. ROSTRATA					X	X
142	RECPHAX SP.					X	X
143	RECHETIA TASMANICA					X	X
144	RETALIDS					X	X
145	SACCANTHAX SP.					X	X
146	SILICOSPHELLINA GREENLANDICA					X	X

APPENDIX I Cont'd

TAXA NO.	TAXA OF WOOPER	LIVE DEAD	TAXA NO.	MODIFIED TAXA	LIVE DEAD
70	SPIROPECTAMMINA BIFORMIS	X	147	SPIROPECTAMMINA BIFORMIS	X
214	TEXTULARIA SP. CF. T. EARLANDI	X	148	TEXTULARIA EARLANDI	X
236	TEXTULARIA PERFECTA	X	149	TEXTULARIA PERFECTA	X
73	TEXTULARIA TORQUATA	X	150	TEXTULARIA TORQUATA	X
125	TEXTULARIA SP. CF. T. TORQUATA	X			
72	TRILSCULINA TRIMEDRA	X	151	TRILSCULINA TRIMEDRA	X
98	TRITAXIS CONICA	X	152	TRITAXIS CONICA	X
159	TRICHAMMINA SP. CF. T. ADAPERTA	X	153	TRICHAMMINA ADAPERTA	X
162	TRICHAMMINA SP. CF. T. ATLANTICA	X	154	TRICHAMMINA ATLANTICA	X
143	TRICHAMMINA GLOBIGERINIFORMIS	X	155	TRICHAMMINA GLOBIGERINIFORMIS	X
126	TRICHAMMINA LONATA	X	156	TRICHAMMINA LONATA	X
75	TRICHAMMINA NANA	X	157	TRICHAMMINA NANA	X
127	TRICHAMMINA SP. CF. T. NANA	X	158	TRICHAMMINA ECHIRACEA	X
74	TRICHAMMINA ECHIRACEA	X			
89	TRICHAMMINA SP. CF. T. ECHIRACEA	X	159	TRICHAMMINA QUADRILoba	X
180	TRICHAMMINA QUADRILoba	X			
181	TRICHAMMINA SP. CF. T. QUADRILoba	X	160	TRICHAMMINA ROTALIFORMIS	X
219	TRICHAMMINA ROTALIFORMIS	X	161	TRICHAMMINA ROTALIFORMIS	X
238	TRICHAMMINA IMMATURE	X	162	TRICHAMMINA IMMATURE	X
90	TRICHAMMINA SP.	X	163	TRICHAMMINA SP. CF. PATELLINA CORRUGATA	X
241	TRICHAMMINA SP. CF. PATELLINA CORRUGATA	X	164	TRICHAMMINELLA ATLANTICA	X
176	TRICHAMMINELLA ATLANTICA	X	165	VAGINULINA SPINIGERA	X
129	VAGINULINA SPINIGERA	X	166	VALVULINA FUSCA	X
201	VALVULINA FUSCA	X			

APPENDIX II

Distribution of taxa in associations of the total population

TAXA NO.	TAXA	ASSOCIATIONS									
		TS41	TS42	T1A	TD41	TD42	TD43	TD44	TD45	TD46	TD47
1	ADENOCOTYLA GLOMERATA	X	X	X	X	X	X	X	X	X	X
2	ALVEOLOPHRAGMIUM SP.			X	X	X	X	X	X	X	X
3	AMMODISCUS CATINUS			X	X	X	X	X	X	X	X
4	AMMODISCUS MINIMUS			X	X	X	X	X	X	X	X
5	AMMODISCUS PLANUS			X	X	X	X	X	X	X	X
6	AMMODISCUS SP.			X	X	X	X	X	X	X	X
7	AMMODISCUS CASSIS			X	X	X	X	X	X	X	X
8	ANGULOGERINA ANGULOSEA			X	X	X	X	X	X	X	X
9	ANGULOGERINA FLUENS			X	X	X	X	X	X	X	X
10	ANGULOGERINA INDETERMINATE			X	X	X	X	X	X	X	X
11	ASTROCYCLION STELLATUM			X	X	X	X	X	X	X	X
12	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
13	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
14	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
15	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
16	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
17	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
18	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
19	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
20	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
21	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
22	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
23	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
24	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
25	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
26	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
27	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
28	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
29	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
30	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
31	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
32	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
33	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
34	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
35	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
36	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
37	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
38	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
39	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
40	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
41	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
42	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
43	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
44	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
45	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
46	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
47	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
48	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
49	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
50	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
51	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
52	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
53	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
54	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
55	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
56	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
57	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
58	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
59	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
60	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
61	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
62	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
63	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
64	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
65	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
66	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
67	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
68	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
69	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
70	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
71	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
72	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
73	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
74	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
75	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
76	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
77	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
78	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
79	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
80	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
81	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
82	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
83	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
84	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
85	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
86	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
87	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
88	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
89	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
90	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
91	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
92	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
93	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
94	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
95	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
96	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
97	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
98	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
99	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X
100	ASTROCYCLION ANGULOSEA			X	X	X	X	X	X	X	X

APPENDIX II Cont'd

TAXA	NO.	TAXA	ASSOCIATIONS									
			TS41	TS42	VIA	TD41	TD42	TD43	TD44	TD45		
133	RECOPHAX ATLANTICA											
134	RECOPHAX CURTUS		X	X	X	X	X	X	X	X		
135	RECOPHAX FUSIFORMIS											
136	RECOPHAX URACILIS											
137	RECOPHAX PILULIFERA											
138	RECOPHAX SCOMPIUS											
139	RECOPHAX SCOTTI											
140	RECOPHAX SUBFUSIFORMIS											
141	RECOPHAX SP. AFF. M. ROSTRATA											
142	RECOPHAX SP.											
143	ROBERTINA TASMANICA											
144	ROTALIS											
145	SACCATINA SP.											
146	SILICISIGILINA GROENLANDICA											
147	SPIROPLECTAMINA BIFORMIS											
148	TEXTULARIA EARLANDI											
149	TEXTULARIA PERFECTA											
150	TEXTULARIA TORQUATA											
151	TRILICULINA TRIMEDUSA											
152	TRITAXIS CONICA											
153	TROCHAMPINA ACAPERTA											
154	TROCHAMPINA ATLANTICA											
155	TROCHAMPINA GLONIGERINIFORMIS											
156	TROCHAMPINA LEBATA											
157	TROCHAMPINA NANA											
158	TROCHAMPINA OCHRAEA											
159	TROCHAMPINA QUADRILORA											
160	TROCHAMPINA ROTALIFORMIS											
161	TROCHAMPINA SP.											
162	TROCHAMPINA SP.											
163	TROCHAMPINELLA ATLANTICA											
164	VALVULINA FUSCA											
165	NUMBER OF CALCAREOUS TAXA		1	49	4	38	27	78	24	29		
166	NUMBER OF AENEACEOUS TAXA		25	16	38	26	15	22	2	14		
167	NUMBER OF TAXA - TOTAL		26	65	42	64	42	100	26	43		
168	NUMBER OF SAMPLES		6	7	9	6	4	11	3	2		

SPECIES OCCURS IN SAMPLE BASED ON LOW COUNT

APPENDIX III

Distribution of taxa in associations of the dead population

TAXA	ASSOCIATIONS									
	OS41	OS42	OS1A	OS41	OS42	OS43	OS44	OS45	OS46	OS47
TAXA	TAXA									
NO.	TAXA									
1	ADERCOETHYA	OLMERATA								
2	ALVEOLOPACHYDUM	SP1								
3	AMMODISCUS	CATINUS								
4	AMMODISCUS	MINIPUS								
5	AMMODISCUS	PLANUS								
6	AMMODISCUS	SP.								
7	APROTION	CASSIS								
8	ANGULOGERINA	ANGULOSA								
9	ANGULOGERINA	FLUENS								
10	AREVACECUS	INDETERMINATE								
11	ASTROCHONIA	STELLATUM								
12	ASTROCHONIA	ANGULOSA								
13	ACOLIVINA	PSEUDOPOLICATA								
14	ACOLIVINA	PSEUDOPOLICATA								
15	ACOLIVINA	OPATHOLATA								
16	ACOLIVINA	SPINIFRONS								
17	ACOLIVINA	SUBAEVARIENSIS								
18	ACOLIVINA	SUBAEVARIENSIS								
19	ACOLIVINA	SUBAEVARIENSIS								
20	ACOLIVINA	SUBAEVARIENSIS								
21	ACOLIVINA	SUBAEVARIENSIS								
22	ACOLIVINA	SUBAEVARIENSIS								
23	ACOLIVINA	SP.								
24	ACOLIVINA	SP.								
25	ACOLIVINA	SP.								
26	ACOLIVINA	SP.								
27	ACOLIVINA	SP.								
28	ACOLIVINA	SP.								
29	ACOLIVINA	SP.								
30	ACOLIVINA	SP.								
31	ACOLIVINA	SP.								
32	ACOLIVINA	SP.								
33	ACOLIVINA	SP.								
34	ACOLIVINA	SP.								
35	ACOLIVINA	SP.								
36	ACOLIVINA	SP.								
37	ACOLIVINA	SP.								
38	ACOLIVINA	SP.								
39	ACOLIVINA	SP.								
40	ACOLIVINA	SP.								
41	ACOLIVINA	SP.								
42	ACOLIVINA	SP.								
43	ACOLIVINA	SP.								
44	ACOLIVINA	SP.								

APPENDIX III Cont'd

TAXA	NO.	TAXA	ASSOCIATIONS			
			DS1	DS2	DIA	DD1 DD2 DD3 DD4
45 DISCORIDAE IMMATURE						
46 EGGERELLA ADVENA			X			X
47 EGGERELLA ARCTICA						
48 ELMIDIIDAE IMMATURE						
49 ELMIDIELLA ARCTICA						
50 ELMIDIELLA GROENLANDICA						
51 ELMIDIELLA NITIDA						
52 ELMIDIUM BARTLETTI						
53 ELMIDIUM EXCAVATUM						
54 ELMIDIUM FRIGIDUM						
55 ELMIDIUM INCERTUM GROUP						
56 ELMIDIUM SUBANTICTICUM						
57 ELMIDIUM SP.						
58 ELMIDIUM SP. CR. MONION SP.						
59 EPIDEMIELLA TAKAYANAGII						
60 EPIDIDES PUSILLUS						
61 ESSVIRINA CURTUS						
62 FISSURINA CUCURBITASEMA						
63 FISSURINA MARGINATA						
64 FISSURINA SEMI-MARGINATA						
65 FISSURINA SERRATA						
66 FISSURINA SP.						
67 GLAUCULINA LAEVIGATA						
68 GLAUCULININA AUMICULATA						
69 GLAUCULININA PACIFICA						
70 GUTTULINA LACTEA						
71 GYRULININA OUTQUELOBA						
72 METISPHAGARININA BRADYI						
73 METISPHAGARININA SP.						
74 HYPERARININA SUBNOBOSA						
75 HYPERARININA SP.						
76 HYPERARININA FRAGMENTA						
77 ISLANDIELLA ISLANDICA						
78 ISLANDIELLA NAGROSSI						
79 ISLANDIELLA TERPITIS						
80 LAGENA APTOPLEURA						
81 LAGENA CLAVATA						
82 LAGENA ELONGATA						
83 LAGENA FLATULENTA						
84 LAGENA GRACILLIMA						

APPENDIX III Cont'd

TAXA	TAXA	ASSOCIATIONS			
		DS11	DS12	DS13	DS14
NO.					
87	LAGENA GRACILIS				
88	LAGENA LAFVIS				
89	LAGENA MENIDIONALIS				
90	LAGENA MOLLIS				
91	LAGENA SEPIOLINEATA				
92	LAGENA STRIATA				
93	LAGENA SUBSTRATA				
94	LAGENA SP.				
95	LENTICULINA GIBBA				
96	LENTICULINA ZAANDAMAE				
97	LENTICULINA FUSCA				
98	LENTICULINA SP.				
99	LENTICULINA SP.				
100	LENTICULINA SP.				
101	LENTICULINA SP.				
102	LENTICULINA SP.				
103	LENTICULINA SP.				
104	LENTICULINA SP.				
105	LENTICULINA SP.				
106	LENTICULINA SP.				
107	LENTICULINA SP.				
108	LENTICULINA SP.				
109	LENTICULINA SP.				
110	LENTICULINA SP.				
111	LENTICULINA SP.				
112	LENTICULINA SP.				
113	LENTICULINA SP.				
114	LENTICULINA SP.				
115	LENTICULINA SP.				
116	LENTICULINA SP.				
117	LENTICULINA SP.				
118	LENTICULINA SP.				
119	LENTICULINA SP.				
120	LENTICULINA SP.				
121	LENTICULINA SP.				
122	LENTICULINA SP.				
123	LENTICULINA SP.				
124	LENTICULINA SP.				
125	LENTICULINA SP.				
126	LENTICULINA SP.				
127	LENTICULINA SP.				
128	LENTICULINA SP.				
129	LENTICULINA SP.				
130	LENTICULINA SP.				
131	LENTICULINA SP.				
132	LENTICULINA SP.				
133	LENTICULINA SP.				

APPENDIX III Cont'd

TAXA	NO.	TAXA	ASSOCIATIONS									
			DS1	DS2	DA	DD1	DD2	DD3	DD4	DD5	DD6	DD7
133	RECIPAX ATLANTICA											
134	RECIPAX CURTUS		X			X	X	X	X	X		
135	RECIPAX FUSIFORMIS		X	X		X	X	X	X	X		
136	RECIPAX GRACILIS											
137	RECIPAX PILULIFERA					X	X	X	X	X		
138	RECIPAX SCORPIURUS					X	X	X	X	X		
139	RECIPAX SCOTTI		X	X		X	X	X	X	X		
140	RECIPAX SUBFUSIFORMIS					X	X	X	X	X		
141	RECIPAX SP. AFF. R. ROSTRATA											
142	RECIPAX SP.											
143	ROSENTINA TASHANICA		X									
144	ROSENTINA TASHANICA											
145	SACCARINA SP.											
146	SILICIS-OILINA GROENLANDICA		X	X		X	X	X	X	X		
147	SPIROPECTAMINA BIFORMIS		X	X		X	X	X	X	X		
148	TEXTULARIA EMBLANDI											
149	TEXTULARIA PERFECTA											
150	TEXTULARIA TONGUATA		X	X		X	X	X	X	X		
151	TRILOCLINA TRIECORA											
152	TRITAXIS CONICA											
153	TROCHAMMINA ADAPERTA											
154	TROCHAMMINA ATLANTICA											
155	TROCHAMMINA GLONIGERIFORMIS		X			X	X	X	X	X		
156	TROCHAMMINA LGATA											
157	TROCHAMMINA NANA											
158	TROCHAMMINA OCHRACEA		X			X	X	X	X	X		
159	TROCHAMMINA QUADRILORA		X			X	X	X	X	X		
160	TROCHAMMINA ROTALIFORMIS											
161	TROCHAMMINA IMPATRE											
162	TROCHAMMINA SP.											
163	TROCHAMMINELLA ATLANTICA		X	X		X	X	X	X	X		
164	VALVULINA FUSCA											
165	NUMBER OF CALCAREOUS TAXA		1	46	0	35	28	71	41			
166	NUMBER OF ARCAECUS TAXA		25	16	35	22	20	22	14			
167	NUMBER OF TAXA - TOTAL		24	62	35	57	58	93	56			
168	NUMBER OF SAMPLES		4	7	9	8	7	9	5			

†SPECIES OCCURS IN SAMPLE BASED ON LOW COUNT

APPENDIX IV

Distribution of living taxa

TAXA	WATERMASH LAYERS DEPTH RANGE (M) SEDIMENT TYPE	UPPER TO CONSTANTLY COLD (0-31)		CONSTANTLY COLD TO DEEP TRANSITIONAL (73-191)		DEEP TRANSITIONAL TO DEEP CONSTANT (155-398)	
		VSP GP-PS GRS OMHS	SP VSP PS GP-PS APS	SP VSP PS GP-PS APS	P CP SP VSP PS		
1 ADEROTRYPA GLOMERATA							
2 ALVEOLOPHRAGMUM SP.							
3 AMPHISCUS MINIMUS							
4 AMPHISCUS SP.							
5 AMPHISCUS SP.							
6 AMPHISCUS SP.							
7 AMPHISCUS SP.							
8 AMPHISCUS SP.							
9 AMPHISCUS SP.							
10 AMPHISCUS SP.							
11 AMPHISCUS SP.							
12 AMPHISCUS SP.							
13 AMPHISCUS SP.							
14 AMPHISCUS SP.							
15 AMPHISCUS SP.							
16 AMPHISCUS SP.							
17 AMPHISCUS SP.							
18 AMPHISCUS SP.							
19 AMPHISCUS SP.							
20 AMPHISCUS SP.							
21 AMPHISCUS SP.							
22 AMPHISCUS SP.							
23 AMPHISCUS SP.							
24 AMPHISCUS SP.							
25 AMPHISCUS SP.							
26 AMPHISCUS SP.							
27 AMPHISCUS SP.							
28 AMPHISCUS SP.							
29 AMPHISCUS SP.							
30 AMPHISCUS SP.							
31 AMPHISCUS SP.							
32 AMPHISCUS SP.							
33 AMPHISCUS SP.							
34 AMPHISCUS SP.							
35 AMPHISCUS SP.							
36 AMPHISCUS SP.							
37 AMPHISCUS SP.							
38 AMPHISCUS SP.							
39 AMPHISCUS SP.							
40 AMPHISCUS SP.							
41 AMPHISCUS SP.							
42 AMPHISCUS SP.							
43 AMPHISCUS SP.							
44 AMPHISCUS SP.							
45 AMPHISCUS SP.							

TAXA	WATERMASS LAYERS DEPTH RANGE (M)	UPPER		CONSTANTLY COLD		TO DEEP TRANSITIONAL	
		TO (0-91)	CONSTANTLY COLD (73-191)	TO (0-91)	CONSTANTLY COLD (73-191)	TO (155-398)	DEEP TRANSITIONAL (155-398)
EGGSELLA ARCTICA							
ELPMIDIDAE IMMATURE							
ELPMIDIDAE ARCTICA							
ELPMIDIDAE BARTLETTI							
ELPMIDIDAE FRIGIDUM							
ELPMIDIDAE INCERTUM GROUP							
ELPMIDIDAE SUBARCTICUM							
ELPMIDIDAE SP.							
ELPMIDIDAE SP. OR NONION SP.							
EPISTOMIDELLA TAKAYANAGII							
EPIDICES PUSILLUS							
FISSURINA PAPUINATA							
FISSURINA SEMIPARVIGATA							
GLAUCOLINIA LAEVIGATA							
GLAUCOLINIA AURICULATA							
GYRGICINA GUINQUELOSA							
HEMISPHERAPHINA BRADYI							
HEMISPHERAPHINA SP.							
HYPERAMPHINA SUBNOBOSA							
HYPERAMPHINA SP. A							
HYPERAMPHINA SP. B							
HYPERAMPHINA SP.							
HYPERAMPHINA FRAGMENTIS							
ISLANDIELLA ISLANDICA							
ISLANDIELLA NORKROSSI							
ISLANDIELLA TEREYIS							
LAGENA AVIOLEUMA							
LAGENA ELONGATA							
LAGENA FLATULENTA							
LAGENA GRACILLIMA							
LAGENA LAEVIS							
LAGENA MERIDIONALIS							

APPENDIX IV Cont'd

WATERMASS LAYERS DEPTH RANGE (M)	SEDIMENT TYPE	UPPER		CONSTANTLY COLD		TO DEEP TRANSITIONAL		DEEP TRANSITIONAL	
		TO CONSTANTLY COLD (0-91)	VSP OP-PS GPS DMRS	TO CONSTANTLY COLD (73-191)	SP VSP PS GP-PS GPS	TO DEEP CONSTANT (155-398)	P CP SP VSP PS		
TAXA									
90 LAGENA MOLLIS								X	X
91 LAGENA PANRI								X	X
92 LAGENA SEMILINEATA									
95 LAGENA SP.		X							
96 LARYNGOSICMA MYALSCIDA									
97 LENTICULINA GIBBA									
99 MELITTAMPINA FUSCA									
100 NOVIUM SP.									
102 MONIONELLA AURICULATA				X					
104 MONIONELLA TUNGIDA									
105 MONIONELLINA LABRADORICA		X		X	X			X	X
106 MONIONIDAE IMMATURE		X		X				X	X
108 DOLINA COSTATA		X		X				X	X
109 DOLINA LINEATA									
111 DOLINA TULO									
116 PATELLINA CORRUGATA				X	X				
117 POLYOMPHINA SP.									
119 PROTEONINA APOLLACEA									
120 PROTEONINA ATLANTICA									
121 PROTEONINA CIFFLUGIFORMIS									
122 PROTEONINA FUSIFORMIS									
123 PROTEONINA SP.									
124 PSAMPICOMMA SP.									
126 PULLENIA BULLOIDES									
127 PULLENIA GUINJOLEOSA									
129 GUINJOLELLINA STALKERI									
130 MECURIOIDES TURBINATUS									
132 MECURIOIDES ARCTICA									
134 MECURIOIDES CURTUS									
135 MECURIOIDES FUSIFORMIS									
137 MECURIOIDES PILULIFERA									
138 MECURIOIDES SCORPIURUS									

APPENDIX IV. Cont'd

TAXA	WATERMASH LAYERS DEPTH RANGE (m) SEDIMENT TYPE	UPPER CONSTANTLY COLD (0-31)		CONSTANTLY COLD TO DEEP TRANSITIONAL (73-191)		DEEP TRANSITIONAL TO DEEP CONSTANT (195-398)	
		VSP	CP+PS	GPS	GMS	SP	VSP+PS
139	RECIPAX SCOTTI		X	X			
140	RECIPAX SUBFUSIFORMIS						
141	RECIPAX SP.						
142	RECIPAX SP.						
143	POTALIDS						
144	POTALIDS						
145	SACCAMPINA SP.						
146	SILICOSPONGILINA GROENLANDICA						
147	SPIROLECTAMMINA BIFORNIS						
148	TEXTULARIA TROJATA						
149	TEXTULARIA CONICA						
150	TRICHAMMINA LORATA						
151	TRICHAMMINA NANA						
152	TRICHAMMINA CONNEXA						
153	TRICHAMMINA SP.						
154	TRICHAMMINA SP. CP. PATELLINE CORRUGATA						
155	TRICHAMMINELLA ATUANTICA						
156	VAGINULINA SPINIGERA						
157	VALVULINA FUSCA						
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CP CALCIPELITE
SP SANDY PELITE
VSP VERY SANDY PELITE
PS PELITIC SAND
GP+PS GRAVELLY PELITIC - PELITIC SAND
GPS GRAVELLY PELITIC SAND
GMS GRAVELLY - MEDIUM GRAINED SAND

† SPECIES OBSERVED LIVING IN UPPER WATERMASH LAYER ONLY

END

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FIN