Reports

Benthonic Foraminiferal Ecology in Covehead Bay, Prince Edward Island - A Preliminary Study*

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Introduction

The purpose of this study is to analyse the benthonic foraminiferal fauna of Covehead Bay, Prince Edward Island, and relate its lateral and temporal distribution to the various physical and chemical parameters within the bay. A comparison is made between the occurrence of the dominant species present in Covehead Bay and their occurrence as noted by other authors in various marine environments from the Arctic to the Gulf of Mexico. The samples were collected during the summer of 1964, with the use of SCUBA, by Dr. G.A. Bartlett. Preliminary laboratory work was performed on the samples at the Bedford Institute, Dartmouth, Nova Scotia, and completed by the writer at Queen's University, Kingston, Ontario.

Previous Work

No previous reports have been written on Covehead Bay; however, Bartlett (1965a) conducted a preliminary investigation of the benthonic foraminiferal ecology in Tracadie Bay, just east of Covehead Bay. Bartlett (personal communication, 1970) is presently preparing a report on the foraminiferal ecology of New London Bay, Prince Edward Island, to the west of Covehead Bay. Foraminiferal studies have been conducted in the Miramichi estuary, New Brunswick, by Bartlett (1966) and Tapley (1968). Vilks (1968) completed a foraminiferal study of the Magdalen Shallows, north of Prince Edward Island, and Schafer (1968) has discussed lateral and temporal variations of the foraminiferal population in and around New London Bay.

Methods of Study

Field Methods:

The samples were collected by SCUBA divers working from the *Elphidium*, a small 18-foot launch. On the bottom, the diver inserted a 1 1/2 inch diameter plastic coring tube into the substrate, capped the top of it, pulled it out, and then capped the bottom. The sample was returned to the launch, the oxidized layer extruded, and the sediment described. The sample was then placed in a bottle and stained with a solution of Rose Bengal and alcohol. Living protoplasm assumes a deep rose colour with this organic stain (Walton, 1952). The reducing layer was distinguished by its darker colour, acidic nature, and reducing potential.

At each station the depth was determined with a Kelvin-Hughes nearshore sounder and checked with a metre line. Salinity, conductivity and temperature of the bottom waters were determined with a portable Beckman R.S.S. salinometer, checked with a sample from a nansen bottle and the average of the two readings recorded. Temperature was checked with a reversing thermometer attached to the nansen bottle, and the value recorded was also an average of the two readings. The pH of the bottom water and substrate was also determined with a Beckman pH metre. Silica, oxygen, sulphate, orthophosphate and nitrate content of the bottom waters were determined with a Hach Engineering Field Kit.

Laboratory Methods:

Fifty ml of sediment was wet sieved through Tyler 0.250 and 0.063 mm sieves. The 50 ml of sediment represents a quantity of material that can be spread out one layer thick over an area 10 cm by 10 cm. The number of foraminifera in each sample can then be converted to foraminifera per square metre. The material retained on both sieves was dried and floated in carbon tetrachloride (S.G. = 2.65). The float was poured off, dried and set aside for faunal analysis. If the foraminiferal number was too large and required splitting, an Otto microsplitter was used. Each sample was completely picked and both the total population and living population at each station were determined. The living foraminifera were determined by the presence of a deep rose stain imparted on the living protoplasm by Rose Bengal.

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Physical Environment

General:

Covehead Bay is located on the northern shore of Prince Edward Island (inset, Figure 1). It is generally S-shaped, being 3 miles in overall length and between one-half and three-quarters of a mile wide. A baymouth bar restricts circulation with the Gulf of St. Lawrence waters, leaving the mouth of the bay less than 100 yards wide.

A ten-foot high bank surrounds the bay. A sharp cliff-break to the shore is present except along the northwest side adjoining a swamp and the baymouth bar. Two small creeks drain into the south end of the bay, but are generally dry during the summer months. Brackley Bay drains into the northwest side of the bay, and a reasonable exchange of water takes place between the bays during tidal changes.

Station Locations:

Samples were analysed from 14 stations within Covehead Bay and 3 offshore (Fig. 1). Stations ranged from 0.2 m to 4.0 m in depth within the bay, and to a depth of 15 m offshore. Samples represent both the intertidal and subtidal zones.

Bathymetry:

The north end of the bay, behind the baymouth bar, is very shallow except for a narrow tidal channel which is 1 m to 3 m deep. Bottom sediments in this area shift irregularly with ebb and flow of the tide and during storms. The topography of the rest of the bay is generally U-shaped and depths range up to 4 m (Fig. 2). The areas less than one metre deep are intertidal and sometimes marshy. Offshore the bottom drops off gradually at about 12 metres per mile.

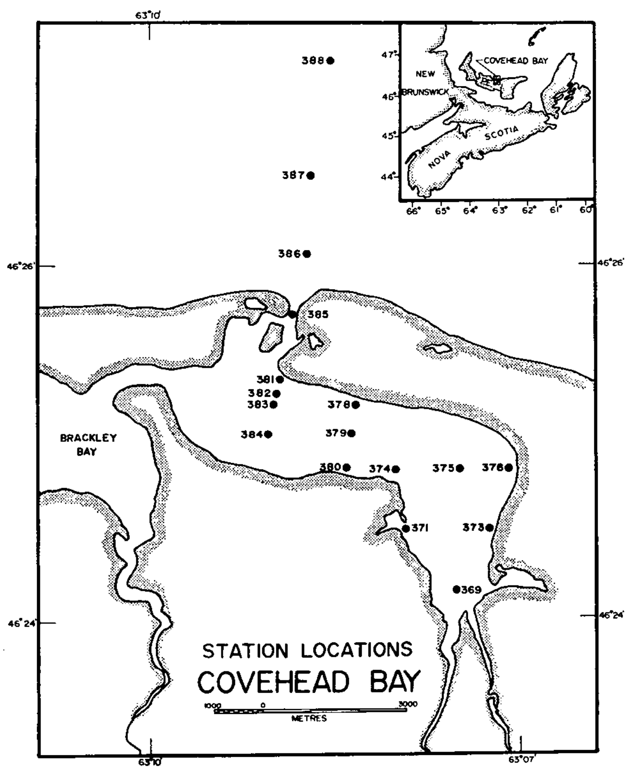


Figure 1 - Station Locations in Covehead Bay.

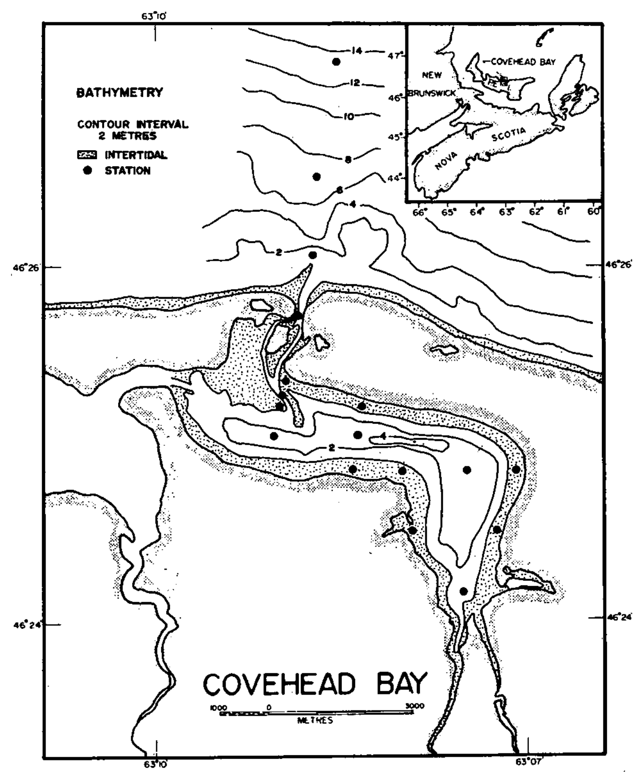


Figure 2 - Bathymetry

Table 1 - Oceanography

Station	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (°/∘∘)	Bottom pH	Sediment pH	Substrate
369	1.0	17.12	26.80	8.0	7.7	Fine sand to silty clay
371	0.5	21.76	28.86	8.25	7.4	Medium sand
373	0.2	24.30	26.08	8.1	7.2	Silty sand to clay
374	0.5	24.85	27.25	8.25	7.4	Medium sand
375	4.0	18.63	27.30	7.90	7.5	Fine sand
376	0.3	26.32	23.42	8.20	7.2	Fine sand
378	0.5	24.03	25.53	8.40	7.7	Fine to medium sand
379	4.0	16.27	26.72	8.0	7.2	Silty clay
380	0.5	21.37	26.04	8.1	7.4	Medium sand
381	0.5	21.87	26.10	8.1	7.2	Fine sand
382	3.0	18.73	24.80	8.1	7.35	Coarse sand
383	1.0	19.54	27.30	8.0	7.02	Medium sand
384	3.8	18.40	26.75	7.85	6.7	Silty clay
385	4.2	19.01	27.08	8.0	7.7	Medium sand
386	5.5	17.03	25.90	7.9	7.6	Medium sand
387	4.5	20.08	26.92	7.8	7.2	Gravel to fine sand
388	15	17.18	27.30	7.6	7.4	Gravel to medium sand

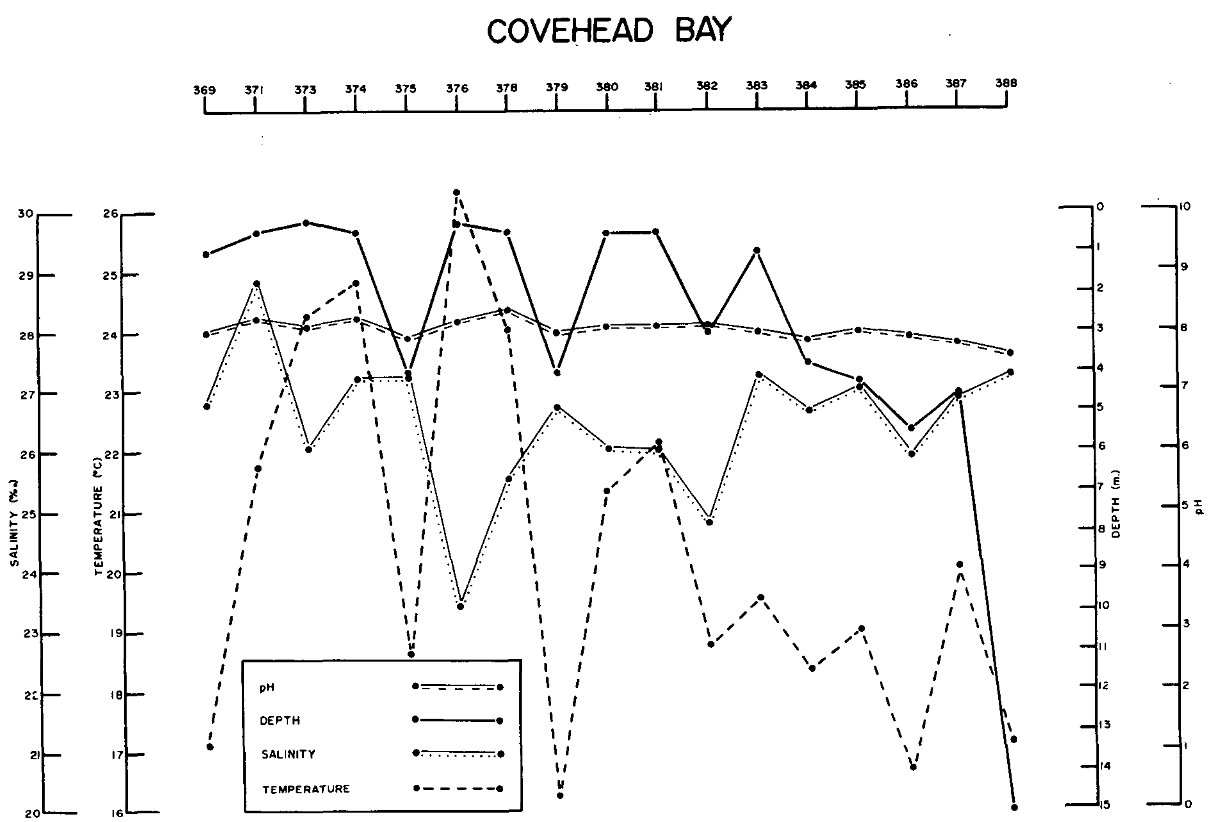


Figure 3 - Relationships Among Depth, Temperature, Salinity and pH.

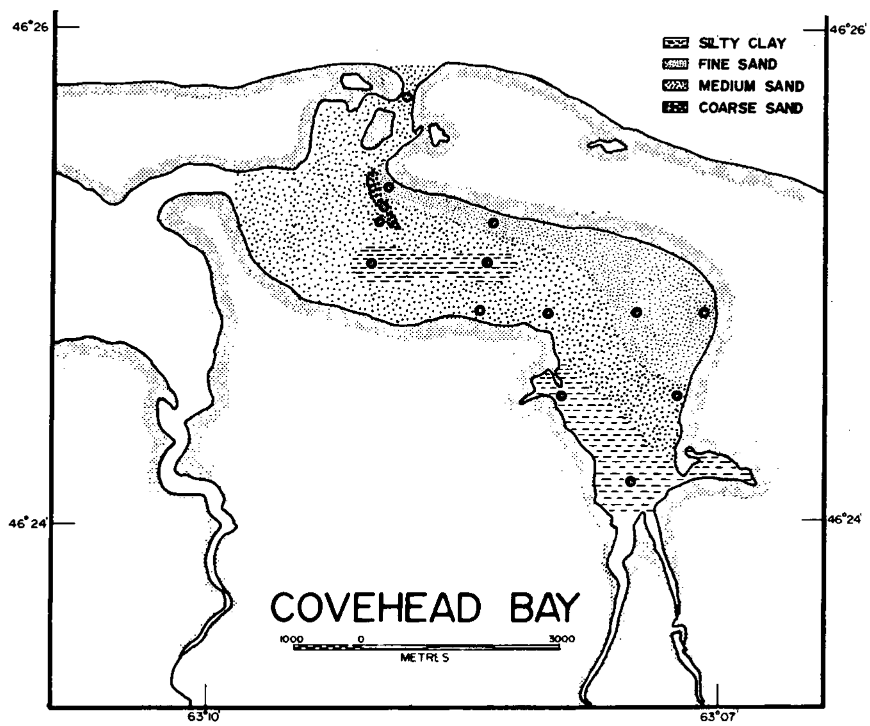
Oceanography:

The longshore currents at the mouth of the bay flow from west to east at approximately 2 knots. Tides, averaging about one metre, are responsible for most of the currents within the bay, although winds create some currents, especially during storms. Decreases in temperature, increases in salinity, and increases in sediment transport result during tidal influx.

Bottom temperatures within the study area are variable, but generally tend to decrease with increasing depth (Fig. 3). Seasonal variations in temperature range from as low as -1.2°C in winter to as high as 27.5°C in summer. Diurnal variations are high, especially during July to October. The main reason for this is the influence of the Gulf of St. Lawrence waters.

Water within the bay is brackish with salinities ranging from 23.42°/oo to 28.86°/oo (Fig. 3). Generally the salinities are fairly constant with all but two stations falling between 24.80°/oo and 27.30°/oo. During spring breakup, salinities in the bay may drop as low as 18°/oo and in summer, surface salinities may be 4°/oo to 5°/oo higher during high tide.

The hydrogen ion concentration (pH) of the bottom water within this environment is relatively constant with values ranging from 7.6 to 8.4 (Fig. 3). The pH of the surface oxidized layer of the sediment is lower and, in one instance, acidic (Table 1). A reduced layer with acidic pH and commonly emitting a hydrogen sulphide odour exists below the surface sediments at a depth of 1 to 3 cm.



gure 4 - Bottom Sediment Distribution.

Sediments:

Laboratory analyses of the sediment samples are not available; consequently sediment distribution shown in Figure 4 is based on the field descriptions. The bay is characterized by medium-grained sand. Coarse sand dominates in portions of the tidal channel. Fine-grained sand is present along most of the northeast side of the bay while silty clay occurs on the southwest side. A small area of silty clay exists in the deeper central part of the bay. Immediately outside the bay the substrate consists of medium grained sand. Offshore the sediments grade from coarse pebbles to fine sand.

The oxidized sediment is generally reddish-brown to brown, and varies from 0.5 cm to 2.0 cm in thickness. The reduced layer below is darker, and in some cases (Stations 379, 380, 384 and 387) emits a hydrogen sulphide odour. The pH of the oxidized layer (Table 1) ranges from 6.7 to 7.7 with only one station (384) having an acidic (6.7) pH.

Table 2 - Chemical Parameters (P.P.M.)

Station	Silica	Oxygen	Sulphate	Phosphate	Nitrate
369	0.25	7	190	0.03	2.0
371					
373					
374	0.25	9	200	0.02	2.0
375					
376					
378	0.21	9	300	0.03	4.0
379	0.27	8	250	0.03	2.0
380	0.25	8	250	0.02	1.5
381					
382	0.21	8.5	270	0.02	3.5
383	0.23	7	250	0.03	4.0
384	0.22	8	200	0.01	4.5
385	0.17	7	175	0.04	3.5
386					
387	0.17	7	160	0.03	1.5
388	0.16	7	190	0.02	6.5

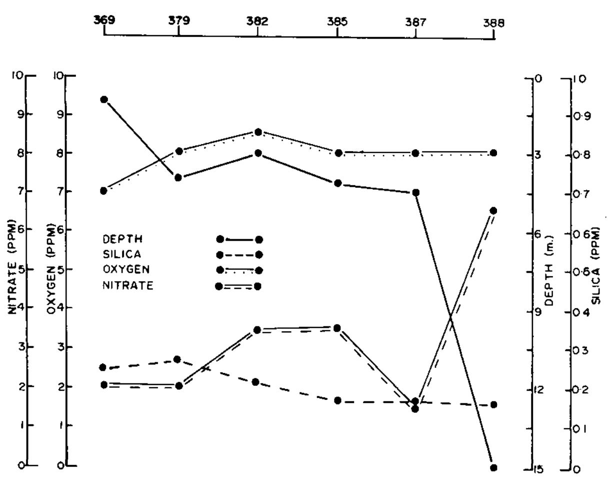


Figure 5 - Depth, Silica, Oxygen and Nitrate along a Longitudinal Traverse of the Bay.

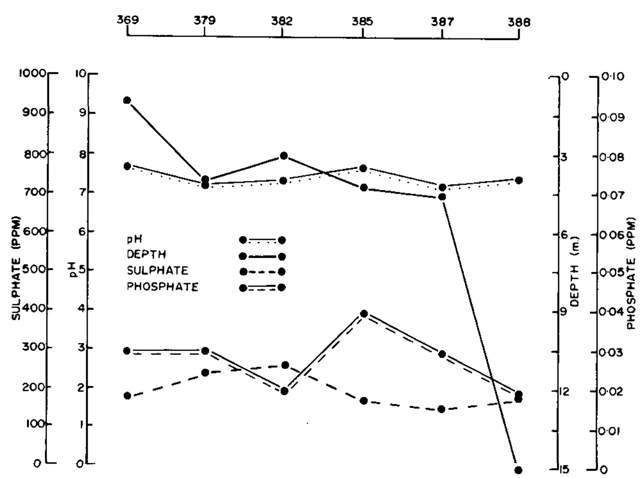


Figure 6 - Sediment pH, Depth, Sulphate and Phosphate along a Longitudinal Traverse of the Bay.

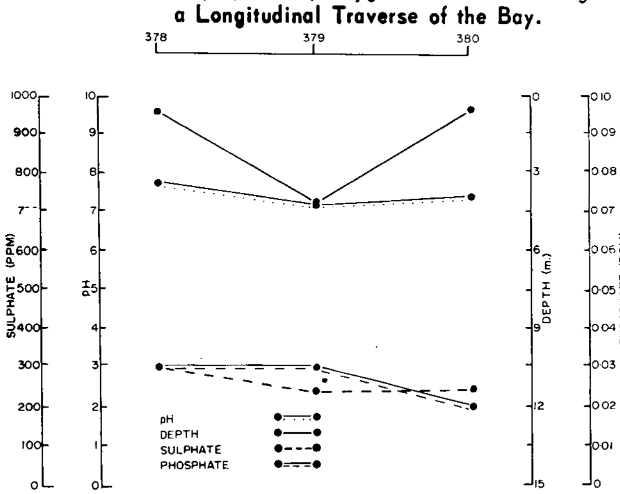


Figure 7 - Depth, Silica, Oxygen and Nitrate along a Cross-Sectional Traverse of the Bay.

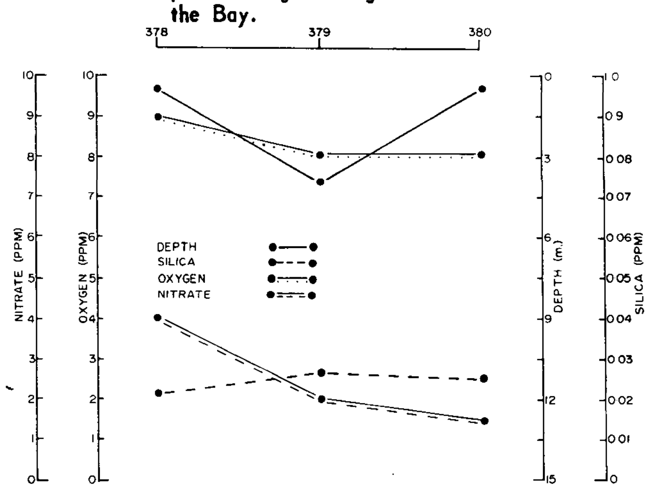


Figure 8 - Sediment pH, Depth, Sulphate and Phosphate along a Cross-Sectional Traverse of the Bay.

Chemical Analysis of Bottom Waters:

Chemical analyses of the bottom water were conducted at several stations. Nitrate, oxygen, phosphate, silica and sulphate concentrations were determined (Table 2). Although information was not complete, values obtained were plotted along two traverses, one along the length of the bay and then offshore (Stations 369, 379, 382, 385, 387 and 388), and the other across the central part of the bay (Stations 378, 379 and 380). These analyses (Figs. 5, 6, 7 and 8) suggest that no distinctive correlation can be made between the various chemical parameters and the foraminiferal distribution in Covehead Bay. There may be several reasons for this lack of correlation: (1) the fauna is eurybathic and can tolerate wide variations in chemical conditions; (2) other factors such as temperature, salinity, composition of the substrate or currents may have a greater effect on the distribution of the fauna and thus mask the effects of the chemical parameters; (3) not enough detail of the variations in the various chemical parameters has been obtained (this could be solved by a more detailed study); (4) no correlation exists at all.

The writer feels that the eurybathic nature of the fauna is mainly responsible for the lack of correlation, but a combination of other factors and lack of detailed information may also be responsible. If any correlation is to be found, a more detailed study of the various physical and chemical parameters and their interrelationships is needed.

Faunal Assemblage

The faunal assemblage in Covehead Bay consists of 18 genera and 26 species (Table 3). Total populations (Table 4) vary from 100 per square metre at Station 385 to 87,000 per square metre at Station 376. The distribution of the living population (Fig. 9) is also irregular. The standing crop varies from zero per square metre at Station 385 to 20,800 per square metre at Station 376. The relationship between the number of living foraminifera and the dead population (Table 5) (Fig. 9) is irregular from one station to another. The largest living and dead population occurs at Station 376, whereas Station 384 has a low living population but the second largest dead population.

Table 3 - Faunal Distribution Chart

STATION NUMBER	369	371	373	374	375	376	378	379	380	381	382	383	384	385	386	387	388
TOTAL POPULATION	98	227	250	328	143	870	443	205	221	293	197	126	682	1	137	159	107
NUMBER LIVING	16	49	143	53	43	208	137	82	37	63	8	13	22	0	2	4	7
AMMOBACULITES DILATATUS		3(0)	X(0)	X(0)					1(0)				X(0)		8(0)		2(0)
AMMODISCUS MINUTISSIMUS			X(0)														
AMMONIA BECCARII		7(35)	2(50)	6(5)			5(70)	8(50)	1(33)	6(58)	6(9)				X(100)	1(0)	42(9)
AMMOTIUM CASSIS						X(0)							5(0)		20(0)	8(0)	
BUCELLA FRIGIDA	24(17)	4(90)	19(94)	2(33)	X(100)	1(20)	1(100)	X(0)	4(11)	X(100)	2(0)		7(0)		3(0)	3(20)	1(0)
CIBICIDES LOBATULUS						X(0)											
EGGERELLA ADVENA	1(0)	7(0)	24(64)		48(32)	78(21)	71(28)	24(28)	56(20)	47(9)	1(0)	4(20)	X(0)		7(0)	6(10)	7(29)
ELPHIDIUM BARTLETTI	2(50)	11(88)	11(61)	2(83)	12(59)	1(0)	5(65)		4(38)	3(67)	2(0)	2(50)	X(0)	1(100)	1(50)		3(0)
ELPHIDIUM INCERTUM "COMPLEX"	49(7)	5(25)	11(33)	45(25)	22(0)	6(46)	X(0)	X(0)	10(13)	10(27)	88(3)	90(7)	87(4)		45(0)	64(2)	7(0)
ELPHIDIUM MARGARITACEUM			11(50)	24(0)	5(14)	2(0)	9(38)	60(48)	6(0)	15(21)							15(0)
ELPHIDIUM ORBICULARE	2(100)		4(11)	2(100)					1(100)		X(100)	5(50)					
ELPHIDIUM SUBARCTICUM			2(50)	8(0)		2(30)	X(0)		3(28)								
HEMISPHAERAMMINA BRADYI	3(0)					1(0)	3(0)		X(0)		X(0)					4(0)	
MILIAMMINA FUSCA	14(0)	1(0)	2(0)	X(0)	1(0)	X(0)	5(0)	5(0)	9(0)	9(0)					4(0)	10(0)	23(0)
PATEORIS HAUERINOIDES						X(100)											
PSEUDOPOLYMORPHINA NOVANGLIAE						X(100)											
QUINQUELOCULINA ARCTICA						1(100)											
QUINQUELOCULINA SEMINULUM					3(100)	X(100)		X(100)	X(100)	5(93)							
REOPHAX ARCTICA		1(0)								X(0)					X(0)	X(0)	
REOPHAX SCOTTII			X(0)														
SACCAMMINA ATLANTICA					2(100)	3(58)											
SCUTULORIS TEGMINIS	1(100)					1(50)				X(100)							
TEXTULARIA TORQUATA		2(0)								2(0)							
TROCHAMMINA LOBATA	4(0)	27(6)	2(20)	10(9)	2(0)	2(0)	1(20)	1(0)	4(0)	2(0)					5(0)	X(0)	
TROCHAMMINA ROTALIFORMIS		2(0)	X(0)		2(67)												1(0)
TROCHAMMINA SQUAMATA		19(0)		2(0)	2(0)						X(0)				4(0)	3(0)	

Table 4 - Faunal Characteristics

Station	Total Pop. per m^2	Living Pop. per m^2	No. of Genera	No. of Species	Percent Arenaceous	Percent Cal. Hyaline	Percent Porcelaneous
369	9,800	1,600	7	9	22	78	0
371	22,700	4,900	9	12	72	28	0
373	25,000	14,300	9	14	30	70	0
374	32.800	5,300	6	11	12	88	0
375	14,300	4,300	7	11	58	39	3
376	87,000	20,800	12	17	85	14	1
378	44,300	13,700	7	10	80	20	0
379	20,500	8,200	7	8	30	69	1
380	22,100	3,700	9	13	70	29	1
381	29,300	6,300	10	12	60	35	5
382	19,700	800	6	8	2	78	0
383	12,600	1,300	2	4	4	96	0
384	68,200	2,200	5	6	6	94	0
385	100	0	1	1	0	100	0
386	13,700	200	9	11	50	40	0
387	15,900	400	9	10	31	69	0
388	10,700	700	7	9	33	67	0

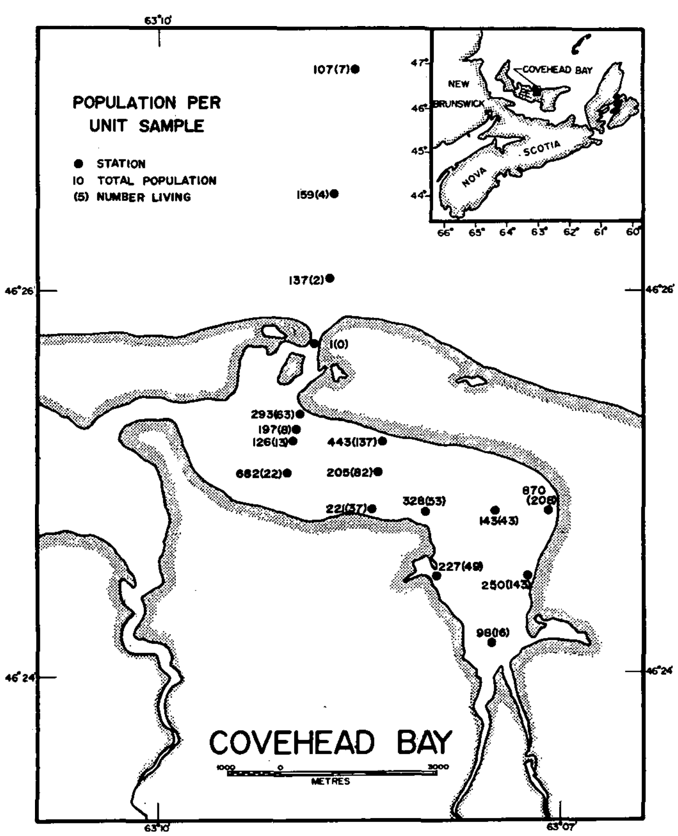


Figure 9 - Population per Unit Sample.

Table 5 - Total Population --

Number and Percent Living

Station	Total Population	Living Population	Percent Living
369	98	16	16
371	227	49	22
373	250	143	57
374	328	53	16
375	143	43	30
376	870	208	24
378	443	137	31
379	205	82	40
380	221	37	17
381	293	63	22
382	197	8	4
383	126	13	10
384	682	22	3
385	1	0	0
386	137	2	1
387	159	4	3
388	107	7	7

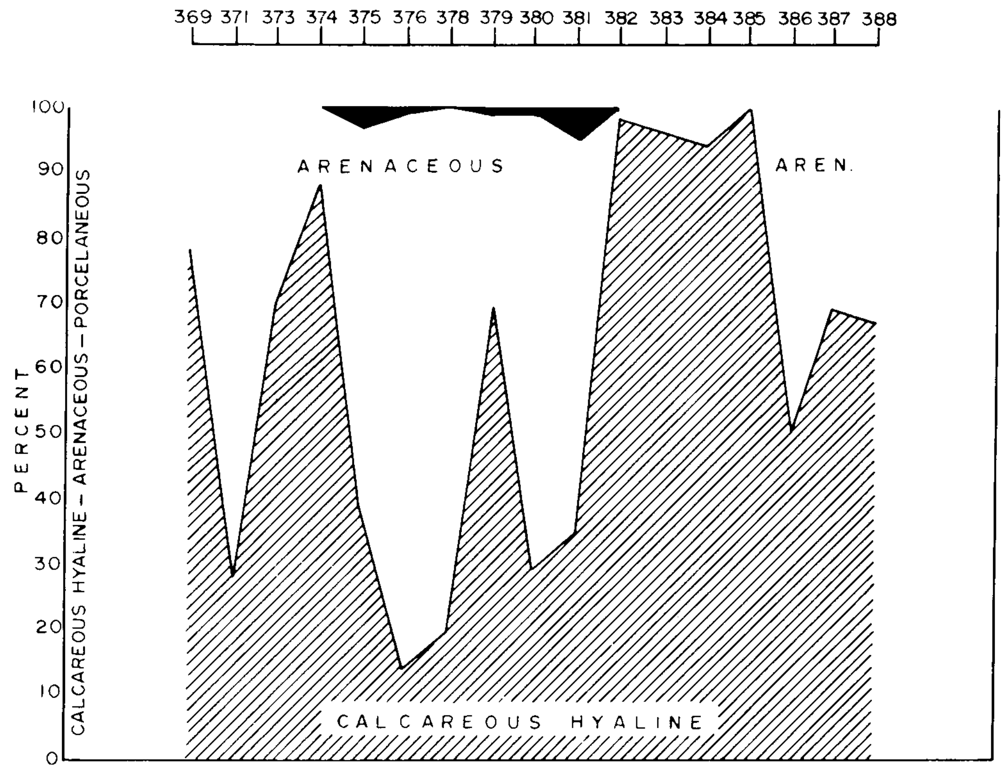


Figure 10 - Percent Calcareous Hyaline, Arenaceous and Porcelaneous Tests.

The total population is fairly equally distributed between calcareous forms and arenaceous forms although differences exist from station to station (Fig. 10). The calcareous forms are slightly more abundant, representing 54% of the total population. *Elphidium incertum* "complex", *Elphidium margaritaceum*, *Bucella frigida* and *Ammonia becarii* dominate the calcareous hyaline fauna. These four species represent 89% of the calcareous hyaline population and 47% of the total population. The arenaceous fauna is dominated by *Eggerella advena*, *Miliammina fusca* and *Trochammina lobata*. These three species represent 88% of the arenaceous population and 41% of the total population. Both the living and dead populations of *Eggerella advena* are slightly higher than those of *Elphidium incertum* "complex". The number of porcelaneous tests in the study area is extremely low (less than 1%). *Quinqueloculina seminulum* and *Quinqueloculina arctica* are the only porcelaneous species represented. However, only one of the porcelaneous specimens found in the bay is not living.

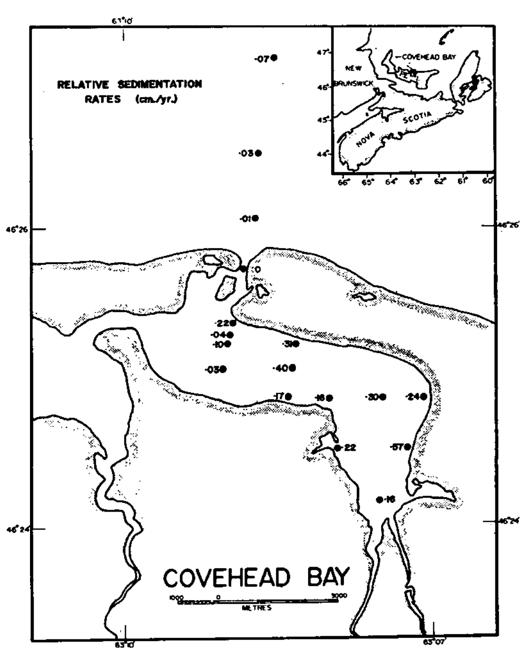


Figure 11 - Relative Sedimentation Rates.

Eighty percent of the total population within the study is comprised of dead tests. This may be a result of the reducing nature of the sediment at some stations (379, 380, 384 and 387), the harsher environment outside the bay at Stations 386, 387 and 388, the relatively low sedimentation rates (Fig. 11) throughout most of the bay, or the inadequacy of the staining technique to determine living specimens. It is difficult to distinguish living and dead arenaceous species. As a result, many living forms may be overlooked and the percentage of living arenaceous forms will seem lower than it actually is. Furthermore, the living to total ratios at stations dominated by arenaceous species will seem lower than they actually are. Bartlett (1964) reported comparable information about the arenaceous fauna in St. Margaret's Bay and Mahone Bay. Counts of living populations should be made while the sample is wet. This does not, however, completely solve the problem of accurately determining the living and dead foraminiferal ratio.

Not all species are represented by both living and dead specimens. Those that have not been found living are: *Ammobaculites dilatus*, *Ammodiscus minutissimus*, *Ammotium cassis*, *Cibicides lobatulus*, *Hemisphaeramina bradyi*, *Miliammina fusca*, *Reophax arctica*, *Reophax scotti*, *Textularina torquata*, *Trochammina rotaliformis* and *Trochammina squamata*. It is interesting to note that only two of these species are calcareous hyaline; the remainder are arenaceous. The two calcareous species that have not been found living in the bay are represented by only one or two specimens and are probably not indigenous to the bay. Most of the arenaceous species, however, are abundant enough to be considered as part of the bay fauna.

Many specimens within the study area are large, indicating slow growth in a somewhat unfavourable environment. Some specimens of *Elphidium orbiculare* and *Elphidium bartletti* have arenaceous "jackets" similar to those described by Bartlett (1965b). These jackets are used for protection against harsh environmental conditions. Many specimens of *Ammonia beccarii* and a few *Elphidium incertum* "complex" show solution of calcium carbonate, revealing a pseudochitinous lining beneath. This development is a result of a lack of calcium carbonate in the environment. Because of the great annual variations in environmental conditions such as temperature, salinity and pH, a hardy eurybathic fauna has developed.

Living to Total Foraminiferal Ratios

The living and dead populations were counted at each station and the ratio of living to total specimens was calculated. This value was used to approximate the relative sedimentation rates at each station (Figure 11) as indicated by the formula proposed by Uchio (1960):

$$1 \div R = T \div \frac{L}{P}$$

where R = sedimentation rate (cm/year), T = total population, L = living population and P = average reproductive period. The living to total ratio is only a valid approximation of the sedimentation rate if the average reproductive period of the specimens is once a year. Bartlett (1965) feels this may be true for the foraminifera in Tracadie Bay, just east of Covehead Bay, but much more information relating to the life cycles of foraminifera is needed before Uchio's formula can be applied directly.

The highest sedimentation rates are found on silty or sandy substrates, except for Station 379 which has a silty clay substrate. The lowest rates are in the tidal channel and off-shore at Stations 382, 383, 385, 386, 387 and 388. The low rates in the tidal channel are due to winnowing by tides and mechanical dredging of the channel. Station 384 has a low sedimentation rate also, but this may only be a result of the large dead population caused by the black, hydrogen sulphide emitting, silty clay substrate. It must be realized that certain factors, completely independent of sedimentation, may make interpretations of sedimentation rates based on living to total ratios invalid. Ideally, a population should be completely indigenous to the area being sampled, and the complete life cycles of each species present should be known. This is seldom, if ever, the case and must be realized when dealing with sedimentation rates based on Uchio's formula. The abundance of dead tests within the study area would seem to make any conclusions based on living to total ratios very questionable.

Distinctive Species and Their Distribution Patterns

General:

Seven species are considered distinct enough to be discussed in detail. They are *Ammonia beccarii*, *Bucella frigida*, *Eggerella advena*, *Elphidium incertum* "complex", *Elphidium margaritaceum*, *Miliammina fusca* and *Trochammina lobata*. These species comprise 88% of the total population. Their distribution within Covehead Bay is discussed and a comparison is made between their occurrence there and in comparable environments from the Arctic to the Gulf of Mexico.

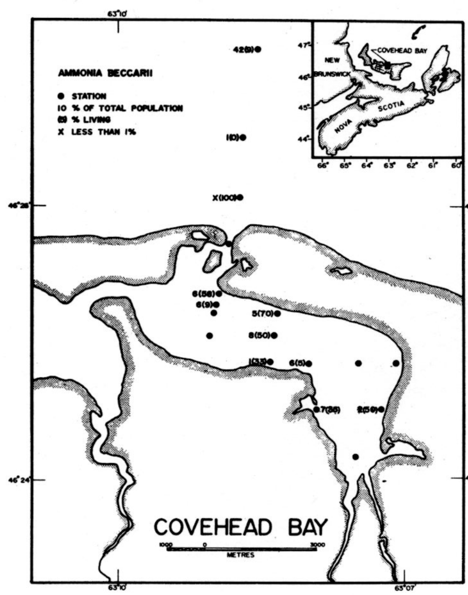


Figure 12 - Distribution of Ammonia beccarii.

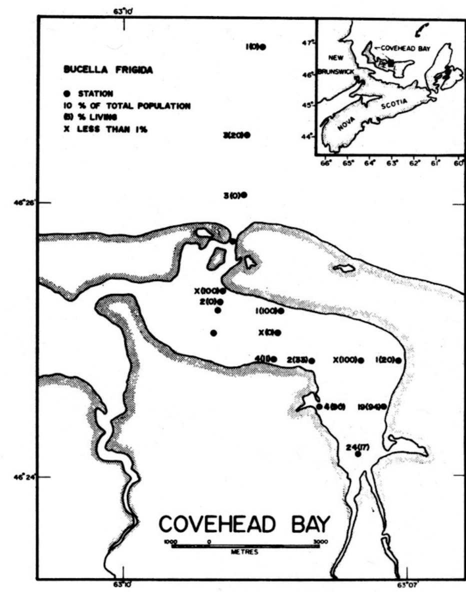


Figure 13 - Distribution of Bucella frigida.

Ammonia beccarii (Fig. 12) is found at eleven stations. Living representatives occur at all but one of these stations. *Ammonia beccarii* is found on a variety of substrates from silty clay to coarse sand but is most prolific on medium sand substrates. Specimens are found both within the bay and offshore. It is most abundant at Station 388 but the percentage of living specimens is higher within the bay where temperatures are higher.

Ammonia beccarii is not a common species on the Atlantic coast of Canada and was only first recorded there by Bartlett (1965a) in Tracadie Bay, Prince Edward Island. Since then it has been found in Miramichi Bay (Bartlett, 1966), Bras d'Or Lakes (Vilks, 1967), St. John River (Schafer, 1969), Bay of Fundy (Bartlett, personal communication, 1970), Sheet Harbour (Bartlett, personal communication, 1970), and New London Bay (Bartlett, personal communication, 1970). It has not been found on the Scotian Shelf (Bartlett, 1963), in St. Margaret's Bay or Mahone Bay (Bartlett, 1964), or on the Magdalen Shallows (Vilks, 1968).

Specimens of *Ammonia beccarii* have been recorded as part of the fauna along the New England Coast by various authors such as Cushman (1944), Phleger and Walton (1950), Parker and Athearn (1959), Todd and Low (1961) and Buzas (1965), and along the northern coast of the Gulf of Mexico by Parker et al. (1953), Phleger (1954, 1955) and Phleger and Lankford (1957).

The specimens of *Ammonia beccarii* are all generally quite large, possibly indicating that they are living under adverse conditions. Bradshaw (1961) found that the optimum reproduction temperature for *Ammonia beccarii tepida* ranges from 20°C to 32°C. He also found that low temperatures give rise to larger sized specimens. The temperatures in Covehead Bay are above 20°C for a short time during the summer only. Winter temperatures can be as low as -1.2°C. To tolerate these extremes of temperature, *Ammonia beccarii* may become dormant or encyst during the winter.

Many specimens of *Ammonia beccarii* have a pseudochitinous lining. In some, the calcareous covering is seen, but many exist with just the pseudochitinous test. This appears to be a result of adverse environmental conditions such as a lack of calcium carbonate or acidic pH of the sediment. Bradshaw (1961) found that under sublethal conditions of pH, *Ammonia beccarii tepida* had some of the calcium carbonate dissolved from its test and formed a tectinaceous test in its place. He also found that later under normal conditions the calcium carbonate reformed on the test walls.

Ammonia beccarii may be a relict fauna to the Atlantic Provinces (Bartlett, 1965a). It has been found in abundance in cores from the Gulf of St. Lawrence and from the Scotian Shelf (Bartlett, personal communication, 1970). Its survival in the Atlantic Provinces is probably due to the warm, brackish waters of the Gulf of St. Lawrence system and to a certain amount of warm water influx northward along the New England coast. The writer is in agreement with Bartlett that *Ammonia beccarii* may be a relict to this area. If it were indigenous to the area, one would expect it to be more widespread, to have a variety of forms from juvenile to adult, and to have more living representatives.

Bucella frigida (Fig. 13) occurs at all but two stations. It is most prolific at Stations 369, 373 and 384, all of which have silty clay substrates. The living population is very low outside the bay but many are living within the bay.

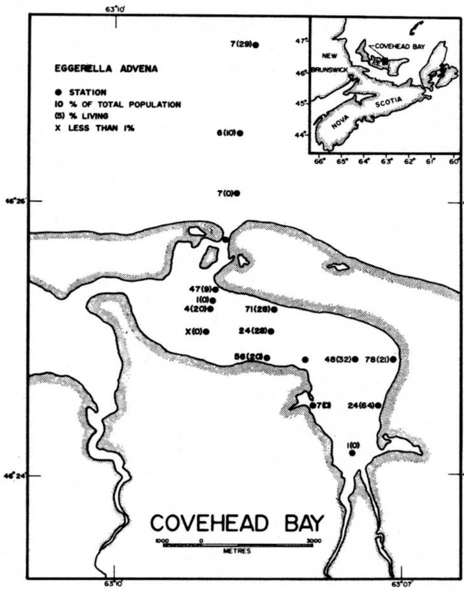


Figure 14 - Distribution of Eggerella advena.

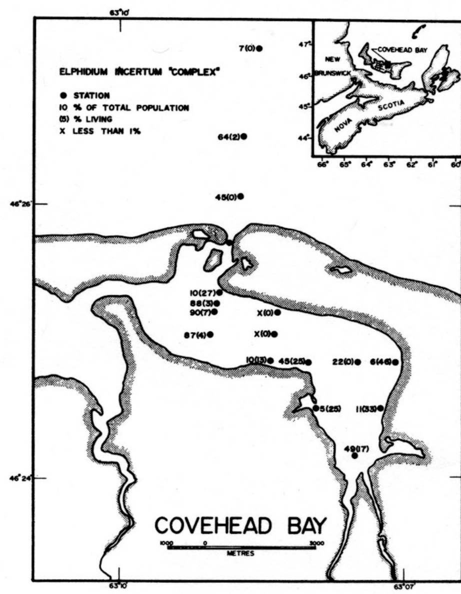


Figure 15 - Distribution of Elphidium incertum "complex".

Bartlett (1964) reported *Bucella frigida* to be a major constituent of the calcareous fauna in Mahone Bay. However, he reported it to be less prolific in Tracadie Bay (Bartlett, 1965a) and Miramichi Bay (Bartlett, 1966). The species is not very prolific in Covehead Bay, representing only 4% of the total population.

Bucella frigida has been reported from the Arctic by Cushman (1948), Phleger (1952), Loeblich and Tappan (1953) and Vilks (1964, 1969), from Hudson Bay by Leslie (1965), from the Chuckchi Sea by Cooper (1964) from the New England coast by Cushman (1944), Phleger and Walton (1950), Todd and Low (1961), and Buzas (1965), but has not been reported along the northern coast of the Gulf of Mexico by Parker et al. (1953), Phleger (1954, 1955), or Phleger and Lankford (1957).

Eggerella advena (Fig. 14) is the most abundant species in Covehead Bay, representing 33% of the total population and 72% of the arenaceous population. It is found at all but two stations and is most prolific on fine to medium sand substrates. Specimens are found both within the bay and offshore, but almost all the living specimens are within the bay. It is the most abundant arenaceous species on the Scotian Shelf (Bartlett, 1963). It has been found in St. Margaret's Bay and Mahone Bay (Bartlett, 1964), in Tracadie Bay (Bartlett, 1965), and in Miramichi Bay (Bartlett, 1966). It has also been found in the Arctic by Cushman (1948), Phleger (1952), Loeblich and Tappan (1953), and Vilks (1964, 1969), in Hudson Bay by Leslie (1965), in the Chuckchi Sea by Cooper (1944), along the New England coast by Cushman (1944), Phleger and Walton (1950), Todd and Low (1961) and Buzas (1965); it has not been found, however, along the northern coast of the Gulf of Mexico by Parker et al. (1953), Phleger (1954, 1955), or Phleger and Lankford (1957).

Elphieium incertum "complex" (Fig. 15) is used here in the sense proposed by Bartlett (1965b). Several varieties are found in the study area, from *Elphidium incertum* (Williamson) to *Elphidium clavatum* Cushman. It is the most prolific calcareous hyaline species group, occurring at all but one station (385). It represents 32% of the total population and 60% of the calcareous hyaline population. Specimens are found on all substrates, with the largest populations associated with silty clay. However, living populations are sparse at all stations. Many specimens are large, indicating slow growth. Although *Elphidium incertum* "complex" is widespread within the environment, it is living under adverse conditions.

There seems to be an inverse relationship between *Elphidium incertum* "complex" and *Eggerella advena*. Station 374, which has the largest living population of *Elphidium incertum* "complex", has no specimens of *Eggerella advena*. This relationship may generally be due to substrate composition but other factors such as temperature, depth, salinity and pH, or any combination of these, must certainly be considered since the substrate at Station 374 is a medium sand.

Elphidium incertum "complex" is the most widely occurring species in the study area. It has been found in the Arctic by Cushman (1948), Phleger (1952), Loeblich and Tappan (1953) and Vilks (1964, 1969), in Hudson Bay by Leslie (1965), in the Chuckchi Sea by Cooper (1964), in the Atlantic Provinces by Bartlett (1963, 1964, 1965a, 1965b, 1966) along the New England Coast by Cushman (1944), Phleger and Walton (1950), Todd and Low (1961) and Buzas (1965), and along the northern coast of the Gulf of Mexico by Parker et al. (1953), Phleger (1954, 1955) and Phleger and Lankford (1957).

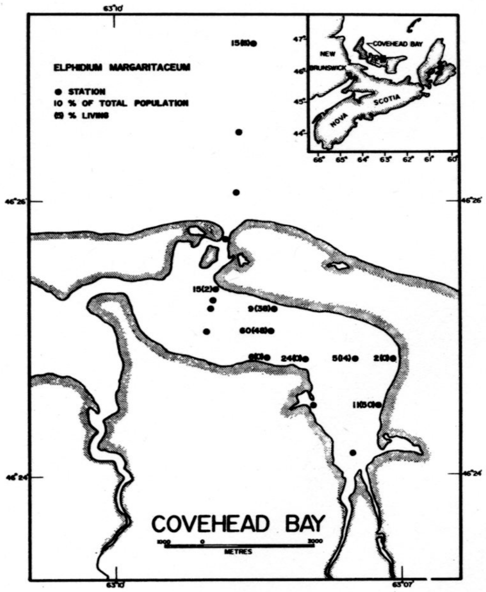


Figure 16 - Distribution of Elphidium margaritaceum.

Elphidium margaritaceum (Fig. 16) is found at nine stations and is most prolific at Station 379. It is the second most abundant calcareous hyaline species, representing 15% of the calcareous hyaline fauna. Bartlett (1964, 1965a) found this species to be mainly confined to intertidal flats in association with *Miliammina fusca*. In the present study, however *Elphidium margaritaceum* is not confined to the intertidal zone although it is generally in association with *Miliammina fusca*. This fact may indicate that both species were transported from the intertidal zone in certain instances. The largest living and total population of *Elphidium margaritaceum* is found at Station 379, which is not intertidal. *Elphidium margaritaceum* seems to be restricted to temperate and cool temperate areas. It has not been reported from the Arctic or the northern coast of the Gulf of Mexico, but has been found in the Atlantic Provinces area by Bartlett (1965a, 1965b, 1966) and Vilks (1967) and along the New England coast by Cushman (1944) and Todd and Low (1961).

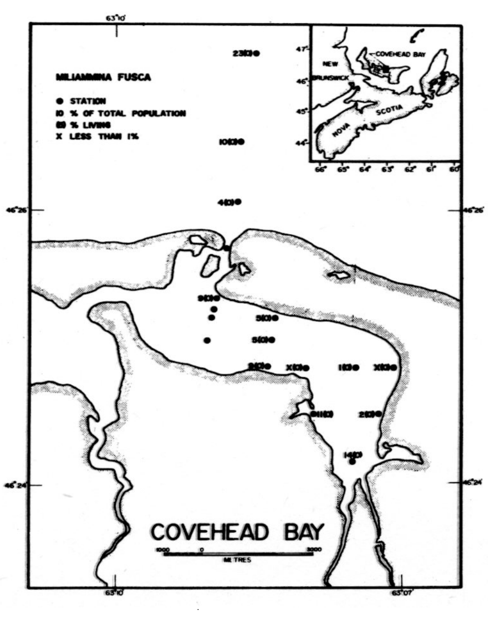


Figure 17 - Distribution of Miliammina fusca.

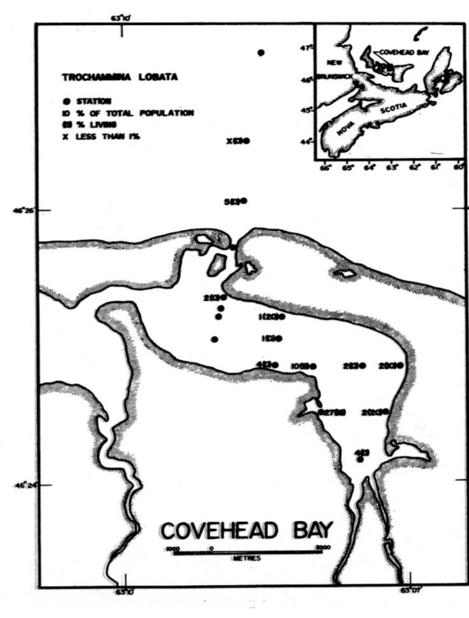


Figure 18 - Distribution of Trochammina lobata.

Miliammina fusca (Fig. 17) is the second most abundant arenaceous species representing 9% of the arenaceous fauna, but it has not been found living anywhere within the study area. This may possibly be due to the inadequacy of the staining technique on certain arenaceous forms. *Miliammina fusca* is found at thirteen stations and is just as abundant offshore as within the bay. It generally occurs as a marsh or intertidal species as noted by Phleger and Walton (1950), Parker et al. (1953), Phleger (1954, 1955), Todd and Low (1961) and Bartlett (1964, 1965a), but has also been found in areas such as the Northumberland Strait (Schafer, 1967), the Bras d'Or Lakes (Vilks, 1967), the Magdalen Shallows (Vilks, 1968), and along the New England coast (Cushman, 1944). It has not been recorded in the Arctic by Cushman (1948), Phleger (1952), Loeblich and Tappan (1953) or Vilks (1964, 1969), or in the Chuckchi Sea by Cooper (1964).

Trochammina lobata (Fig. 18) occurs at twelve stations in the study area and is almost always associated with *Miliammina fusca*. It has living representatives at five stations which are all intertidal. Sand or silty sand substrates dominate. It occurs outside the bay but no living specimens are found there.

Trochammina lobata has not been recorded from the Arctic by Cushman (1948), Phleger (1952), Loeblich and Tappan (1953) or Vilks (1964, 1969), but has been reported in the Chuckçhi Sea by Cooper (1964). It occurs throughout the Atlantic Provinces area as reported by Bartlett (1963, 1964, 1965a, 1966), Vilks (1967, 1968) and Schafer (1967), and is found to some degree along the New England coast as noted by Cushman (1944), Phleger and Walton (1950) and Buzas (1965). It seems to be associated with *Trochammina inflata* along the New England coast and is apparently replaced by *Trochammina inflata* along the northern coast of the Gulf of Mexico.

Faunal Analysis

The microfauna of Covehead Bay is comparable to faunas described for other shallow marine environments from the Arctic to the Gulf of Mexico. The bay typifies a cool, temperate lagoon with a fauna almost identical to that described by Bartlett (1965a) for Tracadie Bay, Prince Edward Island. However, the predominance of calcareous tests reported by Bartlett is not repeated in the present study. It is possible that the larger arenaceous population is a result of greater arctic or subarctic influence. This is unlikely, however, because the two bays are very close together.

The presence of certain species such as *Miliammina fusca*, *Trochammina lobata* and *Elphidium margaritaceum* indicates a shallow water, near-shore intertidal or lagoonal environment. The abundance of arenaceous specimens and the presence of many arctic and subarctic species place this environment in a cool-temperate to subarctic region. The lack of abundant miliolids distinguishes it from the more southerly lagoons and bays like those along parts of the New England coast and the northern coast of the Gulf of Mexico.

The faunal assemblage is very similar to that described by Phleger and Walton (1950) for Barnstable Harbour and Cape Cod Bay. However, there are more representatives of the *Elphidium* fauna in Covehead Bay. Similarities also exist between the Covehead Bay fauna and a combination of the open gulf or sound and marsh faunas described by Phleger (1954, 1955) for the Mississippi delta area.

Most of the species found in the study area have also been found by Cooper (1964) in the Chuckchi Sea. She described the Chuckchi Sea fauna as a meagre Arctic one that is predominantly arenaceous. The Covehead Bay fauna differs mainly in having a higher percentage of calcareous forms.

Biofacies Relationships

Within an area as small as Covehead Bay, it is difficult to distinguish separate biofacies without a very extensive faunal and sedimentological study. No distinct biofacies were established during the present investigation. The bay represents a single biofacies. It typifies a cool-temperate to subarctic lagoon. The offshore fauna can be distinguished from the fauna within the bay by its lower number of tests and smaller living population.

The fauna is very similar to those found in Tracadie Bay by Bartlett (1965a) and in New London Bay by Bartlett (personal communication, 1970). Both these bays are located on the north shore of Prince Edward Island and represent cool-temperate lagoons.

Summary and Conclusions

General:

The results of this and other ecological studies are semi-quantitative or qualitative because of inherent errors in the sampling methods. Interpretations are based on the assumption that the small area sampled at each station is representative of the surrounding area. This may or may not be the case. Bartlett (1964) suggests that the foraminiferal distribution in St. Margaret's Bay and Mahone Bay may be patchy, and Vilks (1967) has shown that this is the case in the Bras d'Or Lakes. Nevertheless, it is possible to correlate to some degree from one study to the next since the same types of errors are generally involved in each study. The author feels that the use of SCUBA in sampling gives a better understanding of a sample area. The diver can visually observe a large lateral area and obtain a sample from a location that appears to be typical. The sample obtained is also an undisturbed one. According to Bartlett (personal communication, 1970) various types of grab samplers generally produce pressure waves in the water below them which disturb the surface layer of the sediment to some degree. As a result, the population sampled may not be as great as it should be. Other factors, such as water turbulence and bottom feeding animals, will certainly disturb the sediment. These are natural factors that cannot be controlled but must be considered in any detailed analysis. The sampling method can be controlled, at least in shallow water areas.

Conclusions:

(1) The fauna of Covehead Bay is a cool-temperate to subarctic lagoonal fauna. It is similar to faunas described by Phleger and Walton (1950), Phleger (1954, 1955), Cooper (1964) and Bartlett (1965a, 1966). (2) There is no distinctive correlation between the various chemical parameters and the foraminiferal distribution in Covehead Bay. The main reason for this is the eurybathic nature of the fauna enabling it to tolerate wide variations in physical and chemical conditions. (3) The distribution of the living population is irregular and bears little relationship to the distribution of the dead population. Eighty percent of the total population is composed of dead tests. (4) The fauna is equally distributed between calcareous forms and arenaceous forms, with two species -- *Elphidium incertum* "complex" and *Eggerella advena* -- dominating the fauna. There is a notable lack of porcelaneous specimens. (5) The environment within the bay is marginal for many species as indicated by the number of large tests, the arenaceous "jackets" on some *Elphidium orbiculare* and *Elphidium bartletti*, and the pseudochitinous linings of some *Ammonia beccarii* and *Elphidium incertum* "complex". (6) Living to total ratios indicate that sedimentation rates are highest on silty or sandy substrates which are generally found in the intertidal zone. Lowest sedimentation rates are found in the tidal channel and offshore. Because of the abundance of dead tests and the irregular relationship between living and dead populations, sedimentation rates based on living to total ratios are very questionable. (7) No distinct biofacies were established within the bay. The offshore area can only be distinguished from the bay by its lower number of tests and smaller living population.

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DESIGNATION OF ILLUSTRATIONS FOR FIGURE 19

1. *Elphidium bartletti* Cushman, a - side view X 90
b - aperture view X100

2. *Elphidium clavatum* Cushman, a - side view X100
b - aperture view X 80

3. *Elphidium orbiculare* (Brady) X 95

4. *Elphidium subarcticum* Cushman, a - side view X 95
b - aperture view X110

5. *Elphidium incertum* (Williamson) a - side view X 90
b - aperture view X110

6. *Elphidium margaritaceum* Cushman, a - side view X 95
b - aperture view X100

7. *Quinqueloculina seminulum* (Linne), X 95

8. *Ammonia beccarii* (Linne), X 90

9. *Pateoris hauerinoides* (Rhumbler), X110

10. *Ammobaculites dilatatus* Cushman and Bronnimann, X 45

11. *Pseudopolymorphina novangliae* (Cushman), X 45

12. *Textularia torquata* Parker, X260

13. *Buccella frigida* (Cushman), a - dorsal view X100
b - ventral view X 90

14. *Ammodiscus minutissimus* Cushman and McCulloch, X100

15. *Eggerella advena* (Cushman), aperture view X110

16. *Reophax arctica* Brady, X100

17. *Ammotium cassis* (Parker), X 25

18. *Miliammina fusca* (Brady), aperture view X110

19. *Reophax scottii* Chaster, X225

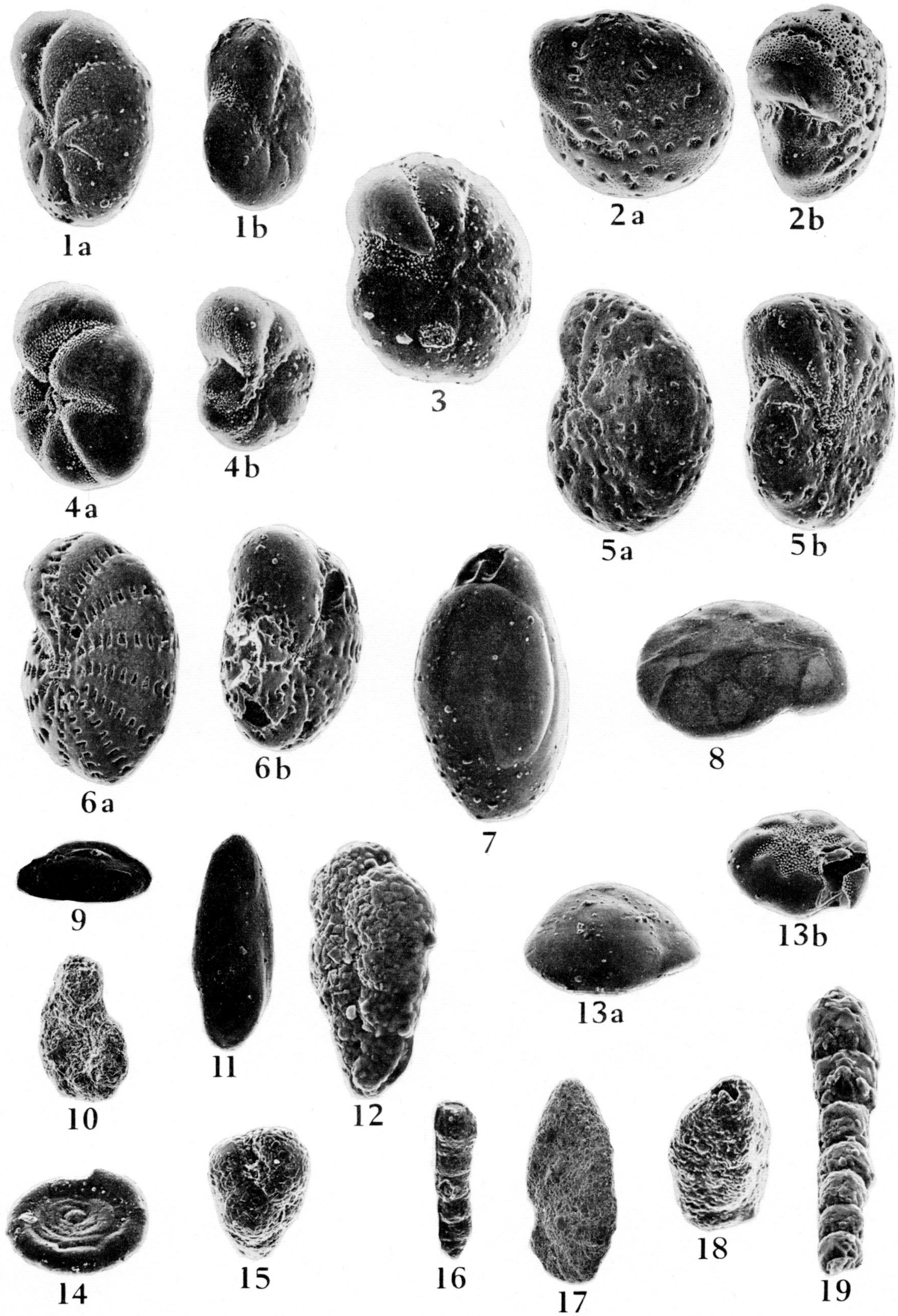

Figure 19 - Scanning electron micrographs of foraminifera from Covehead Bay.