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Résumé de l'article

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Foraminiferal distribution in the study area appears to be determined by sediment patterns ao water temperatures and salinity show little variation.

BENTHONIC FORAMINIFERA FROM LAHAVE ESTUARY

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ABSTRACT

The five most numerous species of benthonic foraminifera sampled from the LaHave River estuary in Nova Scotia were used to define two major faunal assemblage zones. These are the upper estuarine and transitional zones of a "transitional" type of estuary as defined by Scott et al *(1977). The transitional zone is subdivided into upper and lower subzones.*

Foraminiferal distribution in the study area appears to be determined by sediment patterns as water temperatures and salinity show little variation.

INTRODUCTION

The La Have River is one of the largest in Nova Scotia (approximately 100 km long, see Fig. 1), and its estuary has not been previously studied with respect to benthonic foraminifera. Similar studies on the Atlantic coast have been carried out by Bartlett (1964) for St. Margaret's Bay and for Mahone Bay, Gregory (1970) in Halifax Harbour, and Scott (1977) for Chezzetcook Inlet.

METHODS

Samples were collected by D. Scott in late August of 1976 using an Ekman box corer. Replicate 10-cm^3 samples of surficial benthic material were obtained at each location (Fig. 1) except: (1) stations 1 and 2 where the current was too fast and the bottom hard; (2) station 10 where only about 5 cm^3 was collected due to a rocky bottom covered with a mussel bed; and (3) station 13 which was sampled in 50 feet of water with a Dietz-Lafond grab.

Salinity-temperature profies were obtained at all stations (except 13) using an RS-5 recorder.

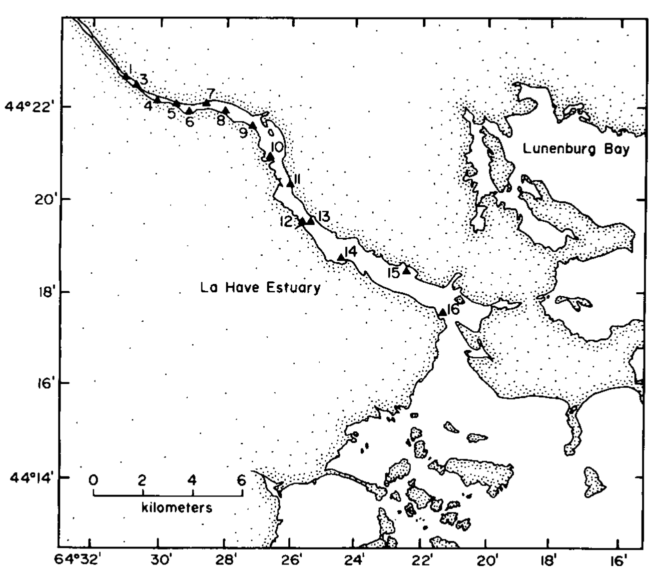

FIG. 1 Sampling locations in LaHave estuary, Nova Scotia.

Samples were prepared the following day by using a 0.841-mm sieve to remove the wood and shell fragments and a $63\text{-}\mu$ sieve to retain the foraminifera and sand. The $63\text{-}\mu$ fraction was treated with buffered formalin and Rose Bengal to stain any living protoplasm pink. Sand was removed from the organic material by heavy liquid separation using pure CCl_4. All samples were immersed in alcohol for storage and examination.

HYDROGRAPHIC DATA

There was little variation in bottom water salinities in LaHave estuary (Fig. 2). Surface water salinities are more variable (5 to 30o/oo), which is a result of the lower density fresh water flowing over the heavier salt water and gradually combining with it due to mixing by currents and diffusion.

Bottom water temperatures varied from $14.8^{\circ}C$ to $16.6^{\circ}C$, with generally higher temperatures at down-river localities. Surface temperatures were more variable and somewhat higher (15.5 to $18.2^{\circ}C$) than those for deeper water (Fig. 2).

RESULTS

The species of foraminifera and their observed live and total populations at each station are presented in Table 1. The sediment type and the living/total percentage of each species per 10 cm^3 sample is given, as is the living/total percentage of all individuals for the same volume.

The five most numerous species were used to delineate the faunal assemblage zones (Fig. 3). Each of these species comprised at least 10 percent of the total population found in all samples. The percentage of each species was plotted against the longitudinal distance down the estuary.

Assemblage zone 1 has a high percentage of *Miliammina fusca* (Brady) and corresponds to the upper estuarine area.

Assemblage zone 2 contains relatively large percentages of *Protelphidium orbiculare* (Brady), *Eggerella advena* (Cushman), *Cribroelphidium excavatum* (Terquem) and *Ammotium cassis* (Parker). This area of mixed fauna is designated the upper transitional zone.

STATION NUMBER	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16A	16B
WATER DEPTH (meters)	2	2	2	2	3	3	2	2	2	2	3	3	3	3	3	3	3	3	3	3	15	15	3	3	2	2	3	3
SEDIMENT TYPE (M=Mud,S=Sand)	S	S	S	S	S	S	M	M	S	S	M	M	S	S	M?	M?	M	M	M	M	M	M	S	S	S	S	S	S
No. of species:Living/total/10cc	1/7	0/4	0/4	0/4	1/7	3/9	3/11	5/13	2/7	1/6	5/12	3/10	6/17	3/13	3/7	6/13	6/12	6/14	6/15	6/15	3/15	3/17	4/14	5/13	3/8	5/13	7/17	3/9
Individuals: Living/total/10cc	1/138	0/37	0/35	0/41	2/107	12/281	221/481	273/454	15/52	3/48	73/220	38/145	32/808	54/924	12/32	82/154	504/710	227/706	598/1100	269/390	7/849	6/2312	40/276	41/403	82/267	12/173	231/418	386/518
Ammotium cassis L/T			/3	/2	/5	/11	/2	X/X		/6	2/15	5/21	X/19	X/24	/9	1/2	6/11	8/19	11/19	7/15	X/1	X/7	12/68	5/67	14/81	15/74	28/59	10/18
Astrammina rara L/T																							/1	/X				
Buccella frigida L/T							X/X	X/X			X/1																	
Cribroelphidium excavatum L/T	X/X						11/28	16/32			12/42	/2	1/1	/3	9/31	5/26	35/46	3/21	6/24	47/51	/14	/8	/X		X/X		2/3	17/26
Cribrostomoides crassimargo L/T																					/X	/X						
Cyclogyra involvens L/T														/X					/X		X/X	/X						
Difflugia capreolata L/T	/16	/27											/X													/2		
Difflugia sp. L/T	/3																											
Eggerella advena L/T			/11		/18	2/16	/X	X/X	/2		/X	/7	/65	/56			X/X	1/3	5/14	2/12	/6	/33	1/10	2/12	/2	3/9	X/5	/X
Hemisphaerammina bradyi L/T		/3	/3	/2	2/2	X/3			/8	/2		5/11	X/1	/X		5/9				/X		/X	X/5	1/6		/6	2/4	
Miliammina fusca L/T	/12	/16	/83	/86	/69	5/54	/3	/1	17/69	/69	X/5	/7	/4	/1		/4		1/3		/X		/X	/11	X/12		X/2	/X	
Pateoris hauerinoides L/T																			X/X									
Pontigulasia compressa L/T	/67	/54		/10	/3		/1	/1																		/X		
Protelphidium orbiculare L/T							35/66	44/65	11/15	6/6	18/34	17/35	2/2	5/7	22/53	37/54	29/38	19/54	31/41	11/15	X/76	X/41	/X		16/16	6/6	27/28	47/53
Quinqueloculina seminulum L/T													X/X		6/6	4/4	X/X	X/X		1/1	/X	X/1						
Reophax arctica L/T																			/X								/X	
Reophax dentaliformis L/T														/2							/X	/X	X/2	X/1	/X		X/X	
Reophax scorpiurus L/T																											X/X	/X
Reophax scottii L/T																			/X									
Saccammina atlantica L/T						/11																/X						
Spiroplectamina biformis L/T													/X					/X	X/X	/1	/X	/6						
Trochammina inflata macrescens L/T	/X				/4		/X	/X	/6	/17	/X	/18	X/2	/4		/1	/4	/X		X/3		/1	/X	/X		X/1	/X	/X
Trochammina lobata L/T						/5							/2	X/2							/X	/1	/X	/X				
Trochammina squamata L/T																					/X							

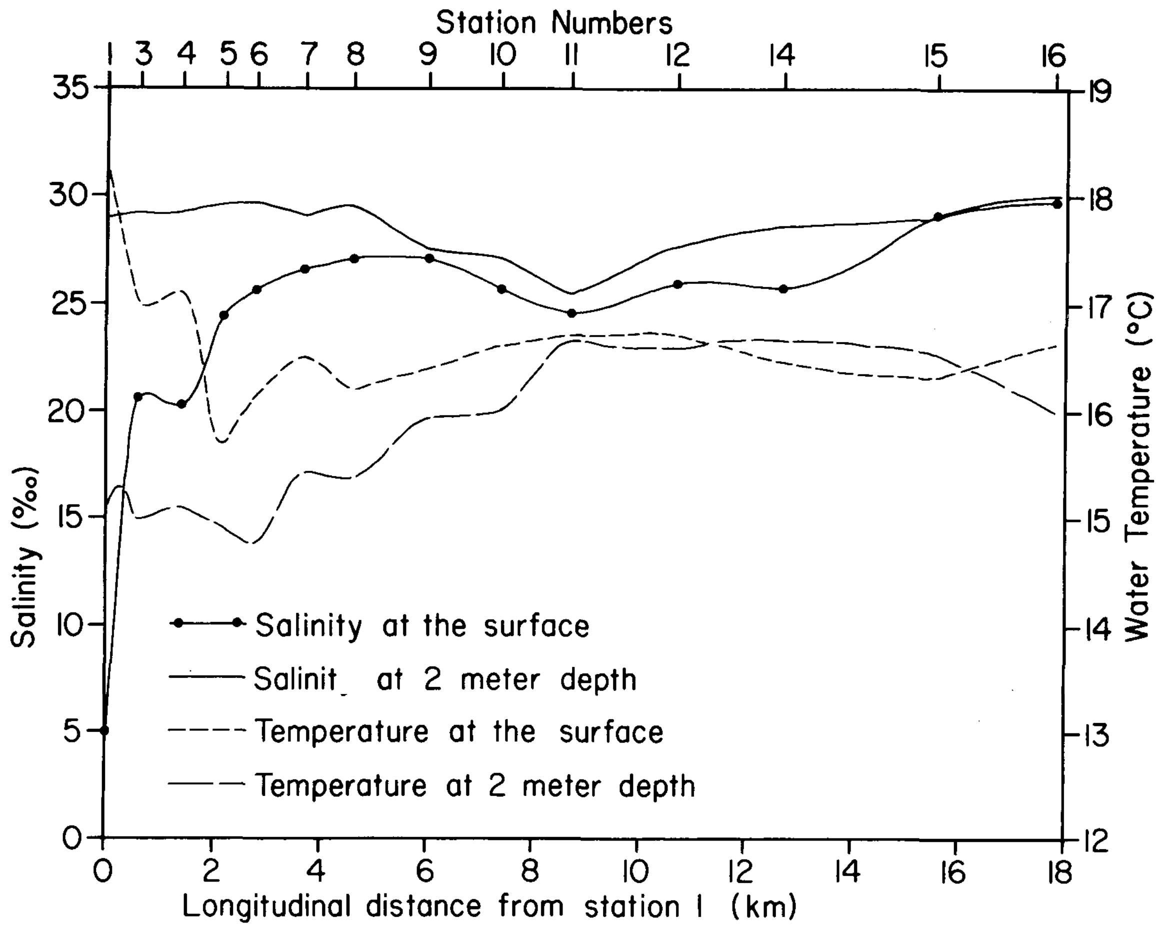

FIG. 2 Temperature-salinity profiles determined at the time of sampling.

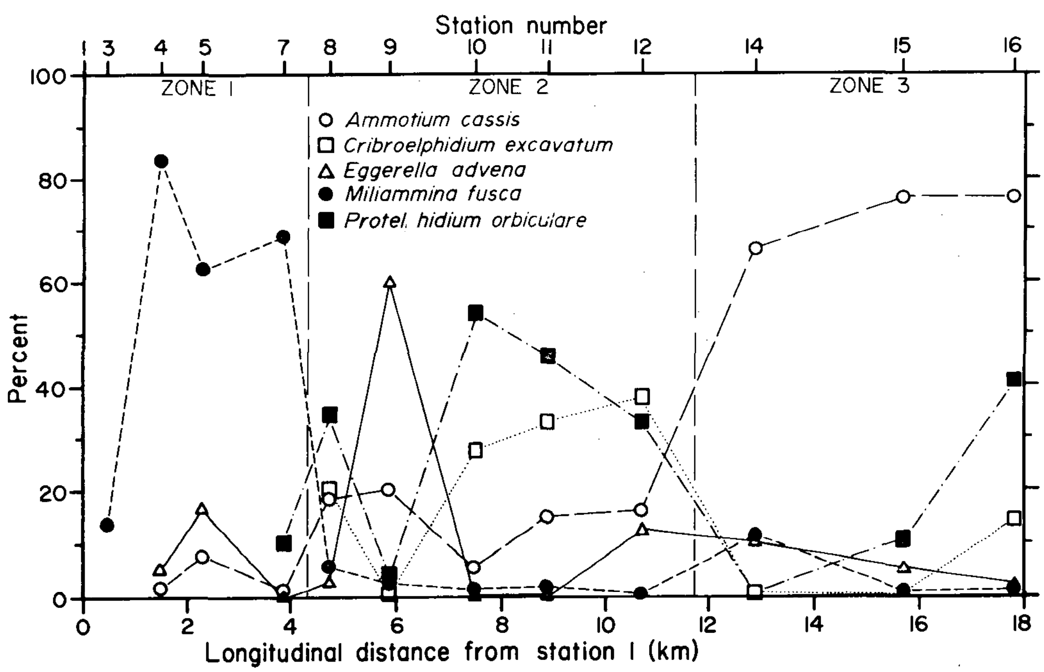

FIG. 3 Abundance curves for the five most common species.
Zone 1 - upper estuarine, zone 2 - upper transitional,
zone 3 - lower transitional.

Assemblage zone 3 delineates the lower transitional zone and is dominated by *A. cassis*.

DISCUSSION

No conclusive evidence of a marginal marine or open bay type of foraminiferal assemblage was found but the presence of a transitional zone establishes the estuary as being of the "transitional" type (Scott *et al* 1977). Continuation of sampling further down-river would almost certainly have encountered the marginal marine assemblage zone. The same type of "transitional" assemblages were noted by Bartlett (1964) at river mouths in Mahone Bay.

Most of the samples were taken in shallow water (1 to 3 m) close to the river banks. Thus the results are slightly biased in favour of shallow water forms. Unfortunately no differentiation was made between *Cribroelphidium excavatum* (an intertidal form) and *C. excavatum clavatum* (a deeper water form, Scott *et al* 1977) which would have further defined the assemblage areas and any biases in sampling locations.

Foraminiferal distributions in this estuary appear to be in part dependent on sediment patterns since bottom water temperature and salinity indicated little variation through the length of the estuary. Other ecologic parameters such as pH and organic content of the sediments, which were not measured in this study, may have an effect on benthic foraminiferal distributions as suggested by Scott *et al* (1977). Muddy bottoms were found to have greater absolute numbers of foraminifera and higher living/total ratios than sandy substrates.

CONCLUSIONS

The two major faunal groups in the area sampled are the estuarine and transitional assemblages. The latter is subdivided into two subzones; the upper with a mixed faunal distribution, and the lower which is dominated by *Ammotium cassis*. If the sampling had been carried further down-river a third faunal group, a marginal marine (open bay) assemblage, would probably have been found. This estuary is classified as "transitional" as defined by Scott *et al* (1977).

Benthic foraminiferal distribution in LaHave Estuary appears to be controlled by a series of factors such as sediment type and sediment pH.

ACKNOWLEDGEMENTS

The authors are indebted to Dr. David B. Scott who collected the samples and helped identify the foraminifera.

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BARTLETT, G.A. 1964. Benthonic foraminiferal ecology in St. Margaret's Bay and Mahone Bay southeast Nova Scotia: Bedford Inst. of Oceanography, Report 64-8, 157 pp.

GREGORY, M.R. 1970. Distribution of Benthonic Foraminifera in Halifax Harbour, Nova Scotia: Ph.D. thesis, Dalhousie University, Halifax.

LOEBLICH, A.R. Jr., and TAPPAN, H. 1964. Sarcodian, chiefly "Thecamoebians" and Foraminiferida *in* Moore, R.C., ed., Treatise on Invertebrate Paleontology, Protista 2, pt. c, Kansas Univ. Press, v. 1, 2, 899 pp.

SCOTT, D.B., MEDIOLI, F.S. and SCHAFER, C.T. 1977. Temporal changes in foraminifera distributions in Miramichi River estuary New Brunswick: Can. Jour. Earth Sci., v. 14, no. 7, pp. 1566-1587.

SCOTT, D.B. 1977. Distribution and population dynamics of marsh-estuarine foraminifera with applications to relocating Holocene sea-levels: Ph.D. dissertation, Dalhousie University, Halifax, 252 pp.

APPENDIX 1

SYSTEMATIC PALEONTOLOGY

All of the generic names are as given in Loeblich and Tappan (1964).

THECAMOEBINA

Only the references used to identify the species are given below.

Difflugia capreolata Penard, Todd and Bronniman, 1957, Cush. Found. Foram. Res., Spec. Publ. 13, p. 21, pl. 1, figs. 3 and 4.

Pontigulasia compressa (Carter), Todd and Bronnimann, 1957, Cush. Found. Foram. Res., Spec. Publ. 13, p. 21, pl. 1, fig. 5.

FORAMINIFERA

Ammotium cassis (Parker)

Lituola cassis Parker in Dawson, 1870, Can. Natural and Quaternary Jour. of Sci. *5*, new series, p. 177, 180, fig. 3.

Haplophragmium cassis (Parker) Brady, 1884, Rept. Scientific Results Explor. Voyage H.M.S. Challenger, Zoology, *9*, p. 304, pl. 33.

Ammobaculites cassis (Parker) Cushman, 1920, U.S. Nat. Hist. Mus. Bull. 104, pt. 2, p. 63, pl. 12, fig. 5.

Ammotium cassis (Parker), Loeblich and Tappan, 1953, Smithsonian Misc. Coll. 121, *7*, p. 33, pl. 2, figs. 12 to 16.

Astrammina rara Rhumbler

Armorella sphaerica Heron-Allen, and Earland, 1932, Jour. of the Roy. Micr. Soc. of London, *52*, Series 3, p. 257, pl. 2, figs. 4 to 11.

Astrammina rara Rhumbler, in Wiesener, 1931, Deutsche Sudpolar Exped. 1901 to 1903, herausgegeban von Erich von Drygaski, *20*, Zool. *12*, pg. 77.

Buccella frigida (Cushman)

Pulvinulina frigida Cushman, 1922, Carnegie Inst. Wash., Publ. *311*, Dept. of Biol. Papers, 17, p. 12.

Eponides frigida (Cushman), Cushman 1931, U.S. Nat. Hist. Mus. Bull., *104*, pt. 8, p. 45.

Buccella frigida (Cushman) Anderson, 1952, Jour. Washington Acad. Sci., *42*, p. 144, figs. 4a to 4c, 5, 6a to 6c.

Cribroelphidium excavatum (Terquem)

Polystomella excavata (Terquem, 1976. Societe Dunkerquoise, Memoirs, *19* (1874-75), p. 429, pl. 2, fig. 2a to 2d.

Elphidium excavatum (Terquem) Parker, 1952, Bull. Mus. Comp. Zool., Harvard, *106*, no. 9, p. 412, pl. 5, fig. 8.

Cribroelphidium excavatum (Terquem) Scott et al., 1977, Can. Jour. Earth Sci., *14*, p. 1578, pl. 5, fig. 4.

Cribrostomoides crassimargo (Norman)

Halophragmium canariense (d'Orbigny) Brady (Part) 1884, Rept. Scientific Results Explor. Voyage H.M.S. Challenger, Zoology, *9*, pg. 310, pl. 35, fig. 4 (not fig. 1 to 3, and 5).

Haplophragmium crassimargo Norman, 1892, Museum NOrmanianum, pt. VIII, Rhizopoda, Durham, p. 17.

Haplophragmoides major Cushman, 1920, U.S. Nat. Hist. Mus. Bull., *104*, pt. 2, p. 39, pl. 8, fig. 6.

Labrospira crassimargo (Norman) Hoglund, 1947, Zool. Bidrag, Fran. Uppsala, Bd. 26, p. 141, pl. 11, fig. 1, text-fig. 121 to 125.

Alveophragmium crassimargo (Norman) Loeblich and Tappan, 1953, Smithsonian Misc. Coll., *121*, (7), pg. 29, pl. 3, fig. 1 to 3.

Cribrostomoides crassimargo (Norman) Vilks, 1969, Micropaleo. *15*, p. 44, pl. 1, fig. 16a, b.

Cyclogyra involvens (Reuss)

Operculina involvens Reuss, 1850, K. Akad. Wiss. Wien, Math-naturwiss, Cl. Denkschr., *1*, p. 370, pl. 46, fig. 30.

Cornuspira involvens (Reuss) Brady, 1884, Rept. Scientific Results Explor. Voyage H.M.S. Challenger, Zoology, *9*, p. 200, pl. 11, fig. 1 to 3.

Cyclogyra involvens (Reuss) Gregory, 1970, Distribution of Benthonic Foraminifera in Halifax Harbour, Nova Scotia, Canada (Unpublished Ph.D. Thesis, Dalhousie University, Halifax) p. 184, pl. 5, fig. 4.

Eggerella advena (Cushman)

Verneuilina advena Cushman, 1922, Contributions to Canadian Biology, No. 9, (1921), p. 141.

Eggerella advena Cushman, 1937, Cushman Lab. Foram., Res., Spec. Publ. *8*, p. 51, pl. 5, fig. 12 to 15.

Hemisphaerammina bradyi Loeblich and Tappan

Hemisphaerammina brady Loeblich and Tappan in Loeblich and collaborators, 1957, U.S. Nat. Hist. Mus., Bull., *215*, p. 224, pl. 72, fig. 2.

Crithionina pisum Gregory, 1970, Distribution of Benthonic Foraminifera in Halifax Harbour, Nova Scotia, Canada (Unpublished Ph.D. Thesis, Dalhousie University, Halifax), p. 165, pl. 1, fig. 6.

Miliammina fusca (Brady)

Quinqueloculina fusca Brady, 1870, Ann. Mag. Nat. Hist., London, England, Ser. 4, *6*, 47, pl. 11, fig. 2 and 3.

Miliammina fusca (Brady) Phleger and Walton, 1950, Am. Jour. Sci., *248*, p. 280, pl. 1, fig. 19a-b.

Pateoris hauerinoides (Rhumbler)

Quinqueloculina subrotunda (Montagu) forma *hauerinoides* Rhumbler, 1936, Foram. der Kieler Bucht, Teil II Ammodisculinidae bis Textulinidae, *1*, p. 206, 217, 226, tfs. 167, 208, 212.

Pateoris hauerinoides (Rhumbler) Loeblich and Tappan, 1953, Smithsonian Misc. Coll., *121*, p. 42, pl. 6, fig. 8 to 12.

Protelphidium orbiculare (Brady)

Nonionia orbicularis Brady, 1881, Ann. Mag. Nat. Hist. Mus., *8*, p. 415, pl. 21, fig. 5.

Nonion orbiculare (Brady) Cushman, 1930, U.S. Nat. Hist. Mus. Bull., *104*, p. 12, pl. 5, fig. 1 to 3.

Elphidium orbiculare (Brady) Hessland, 1943, Bull. Geologic Institute of Uppsala, p. 262.

Protelphidium orbiculare (Brady) Todd and Low, 1961, Contr. Cush. Found. Foram. Res., *12*, p. 20, pl. 2, fig. 11.

Quinqueloculina seminulum (Linne')

Serpula seminulum Linne', 1758, Systema naturae sive regna tria naturae, etc. Edn. XIII, by J.F. Gmelin, 10 vols., Leipzig, 1788 to 1793, p. 3439, no. 2.

Quinqueloculina seminulum d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, *7*, pg. 301.

Miliolina seminulum (Linne') Williamson, 1858, Roy. Soc. Publ., p. 85, pl. 7, fig. 183 to 185.

Quinqueloculina seminula (Linne') Cushman, 1929, U.S. Nat. Hist. Mus., Bull., *104*, pt. 6, p. 59, pl. 9, fig. 16 to 18.

Reophaz arctica Brady

Reophax arctica Brady, 1881, Ann. Mag. Nat. Hist., *8*, p. 405, pl. 21, fig. 2a, b.

Reophax scorpiurus Montfort

Reophax scorpiurus Montfort, 1808, Conchyliologie systematique et classification methodique des Coquilles, *1*, p. 330.

Remarks: This species is seen to be extremely variable and may include *R. dentaliformis* (as in Scott *et al.*, 1977, p. 22).

Reophax scottii Chaster

Reophax scottii Chaster, 1892, First Rept. Southport Soc. Nat. Sci., p. 57, pl. 1, fig. 1.

Saccammina atlantica (Cushman)

Proteonina atlantica Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 5, pl. 1, fig. 4.

Saccammina atlantica (Cushman) Gregory, 1970, Distribution of Benthonic Foraminifera in Halifax Harbour, Nova Scotia, Ph.D. Thesis, Dalhousie University, p. 162, 163, pl. 1, fig. 4.

Spiroplectammina biformis (Parker and Jones)

Textularia agglutiuans d'Orbigney var. *biformis* Parker and Jones, 1865, Philos. Trans. Roy. Soc. London, *155*, p. 370, pl. 15, fig. 23 and 24.

Spiroplecta biformis (Parker and Jones) Brady, 1878, Ann. Mag. Nat. Hist., *1*, (Ser. 5): p. 376, pl. 45, fig. 25 to 27.

Spiroplectammina biformis (Parker and Jones) Cushman, 1927, Cushman Lab. Foram. Res., Contr., *3*, p. 23, pl. 5, fig. 1.

Trochammina inflata macrescens Brady

Trochammina inflata (Montagu) var. *macrescens* Brady, 1884, Rept. Scientific Results Explor. Voyage H.M.S. Challenger, Zoology, *9*, p. 290 to 291, pl. 11, fig. 5a to c.

Trochammina macrescens Brady, Phleger, and Walton, 1950, Am. Jour. Sci., *248*, p. 281, pl. 2, fig. 6 and 7.

Jadammina macrescens (Brady) Murray, 1971, An Atlas of Recent British Foraminiferids. American Elsevier Publ. Co., New York, p. 41, pl. 13, fig. 1 to 5.

Trochammina lobata Cushman

Trochammina lobata Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. *12*, p. 18, pl. 2, fig. 10.

Trochammina squamata Parker and Jones

Trochammina squamata Jones and Parker, 1860, Geol. Soc. London, Quart. Jour. vol. 16, p. 304.