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ARCELLACEANS ("THECAMOEBIANS") IN SMALL LAKES OF NEW BRUNSWICK AND NOVA SCOTIA: MODERN DISTRIBUTION AND HOLOCENE STRATIGRAPHIC CHANGES

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ABSTRACT

Sediment-water interface samples from five lakes in New Brunswick and three lakes in Nova Scotia were quantitatively examined for both living and total populations of Arcellaceans. Two major assemblages (I and II) were recognized, both characterized by three main species: *Difflugia oblonga*, *Lagenodifflugia vas*, and *Pontigulasia compressa.* Assemblage I is divided into five sub-assemblages characterized by occurrences of minor species. Assemblage II basically has only three species with low abundances. The assemblage variations within Assemblage I are difficult to link with specific variables since we know relatively little about individual species. However, individual occurrences of two species can be linked to specific conditions: *Difflugia bidens* relates to increased sediment input and *Difflugia tricuspis* occurs with high concentrations of floating algae. The division between Assemblage I and II appears to be a function of seasonal temperatures. The high diversity Assemblage I occurs where summer temperatures reach values greater than 18°C (that is, above the thermocline) while Assemblage II occurs below the thermocline where temperatures do not exceed 6°C. Oxygen values in both assemblages are the same and, as in Lake Erie, low oxygen values do not appear to be a limiting factor.

To complement the surface studies, cores from six of these lakes were also examined. Most lakes were formerly marine basins when sea level was much higher and the marine freshwater transition demonstrated the sharpest assemblage changes. *Centropyxis aculeata* usually dominated the transition sections. Arcellacean assemblages illustrated few changes once freshwater conditions were established in New Brunswick even though climatic changes are known in the same interval. However, assemblages in the Nova Scotia lakes changed sharply below the surface with D. tricuspis becoming much more common; this indicates more floating algae in these lakes in pre-modern times.

Most of the species encountered here have been illustrated by us previously; however, three species found here were not illustrated in our Lake Erie study-*Lesquereusia spiralis, Difflugia urceolata elongata,* and <u>*Difflugia urens*</u>, n. sp.-and are fully illustrated here together with all the other species.

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INTRODUCTION

GENERAL STATEMENT

Testate rhizopods, or "Thecamoebians" (Loeblich and Tappan, 1964), are a large group of amoeboid protozoa in which the cytoplasm is enclosed within a discrete shell or test. Large populations are present in a wide variety of freshwater habitats, ranging from moss, soil, peat, and standing water, to sewage treatment works. They are also found worldwide, from tropical to polar regions (Ogden and Hedley, 1980) with an essentially cosmopolitan distribution of species.

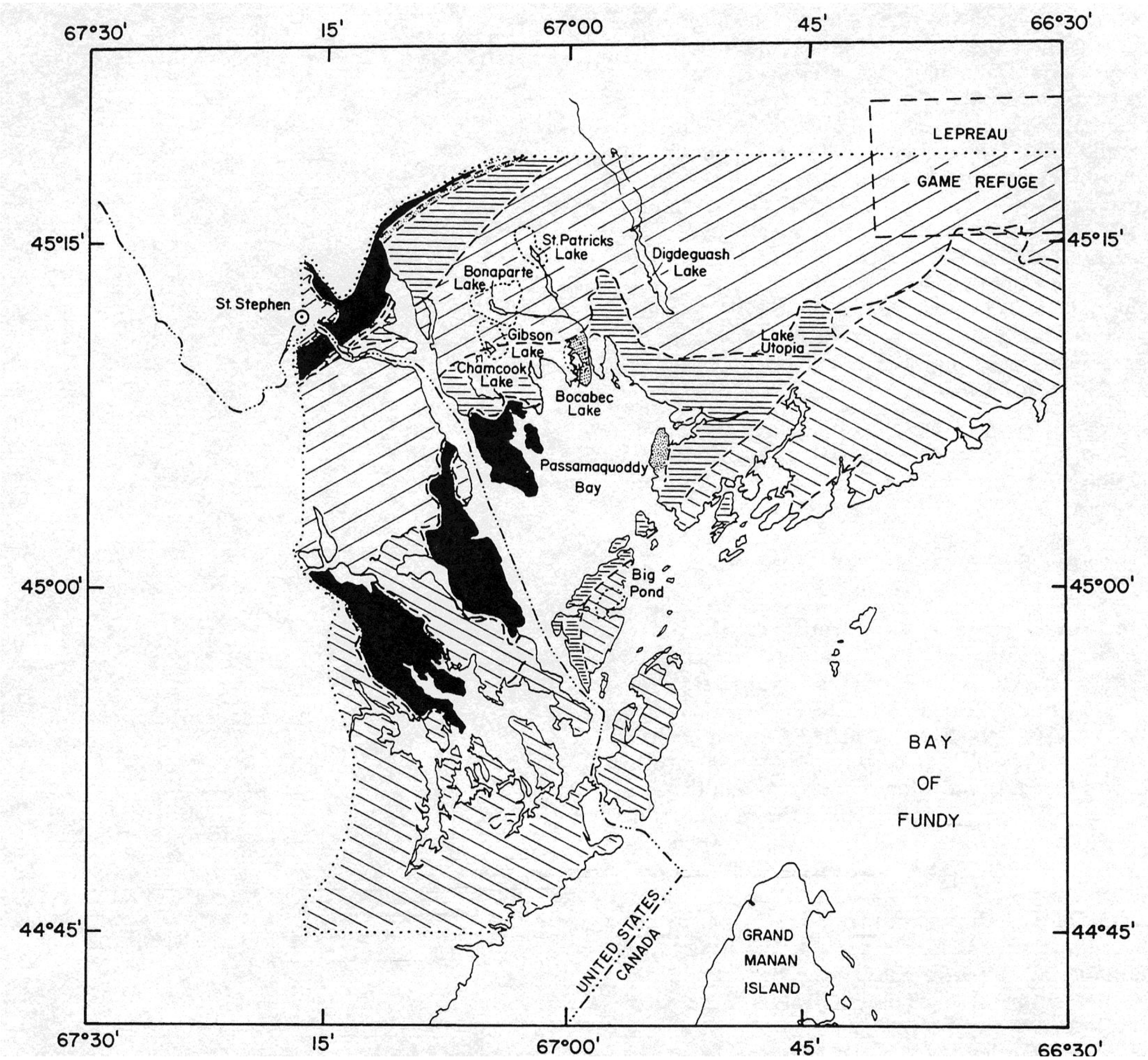
Although a large volume of literature concerns the group, it is scattered, resulting in taxonomic difficulties. Medioli and Scott (1983) have prepared a taxonomic review for Arcellacea from selected occurrences in eastern Canada. To date, the only known quantitative distributional study of a modern North American lake is a study of surficial and fossil arcellacean distributions in Lake Erie (Scott and Medioli, 1983).

Many freshwater microfossils (for example, ostracodes and molluscs), tend to dissolve in the low pH sediments of freshwater deposits, hence additional paleolimnological tools are required. Organic and siliceous fossils (pollen, spores, and diatoms) do not generally rellect conditions at the sediment-water interface. Arcellacean tests are agglutinated (with an organic matrix which is resistant to dissolution from low pH values), and, with one or two exceptions, benthic (that is, representative of bottom water conditions). Their high density populations also provide an adequate statistical base under most sampling conditions (Scott and Medioli, 1983).

Sediment-water interface samples from Gibson, Bonaparte, Bocabec, St. Patricks, and Big Pond (Deer Island) lakes in southwestern New Brunswick, and Journeays, Midway and Thibault Lakes in the Annapolis Valley, Nova Scotia, have been quantitatively examined to determine modern arcellacean surficial distributions (Figs. 1 and 2). This information has been used in a first order interpretation of fossil assemblages from several of these lakes.

The lakes were chosen as a follow-up to the Lake Erie study for a number of reasons and with a number of goals in mind:

1. to compare the diversity of this inter-lake study of small freshwater bodies with the results obtained from the intra-lake study of Lake Erie (a large freshwater body);



Base-map cartography with revisions by the Geographical Survey of Canada.1966,from maps published at 1:250,000 scale by the Army Survey Establishment. RC.E., 1953, 1955-57.

Mean magnetic declination 21°01' West, decreasing 0.6'annually.

Readings vary from 20°09', in the SW corner to 21°37' in the NE corner of the map.area.

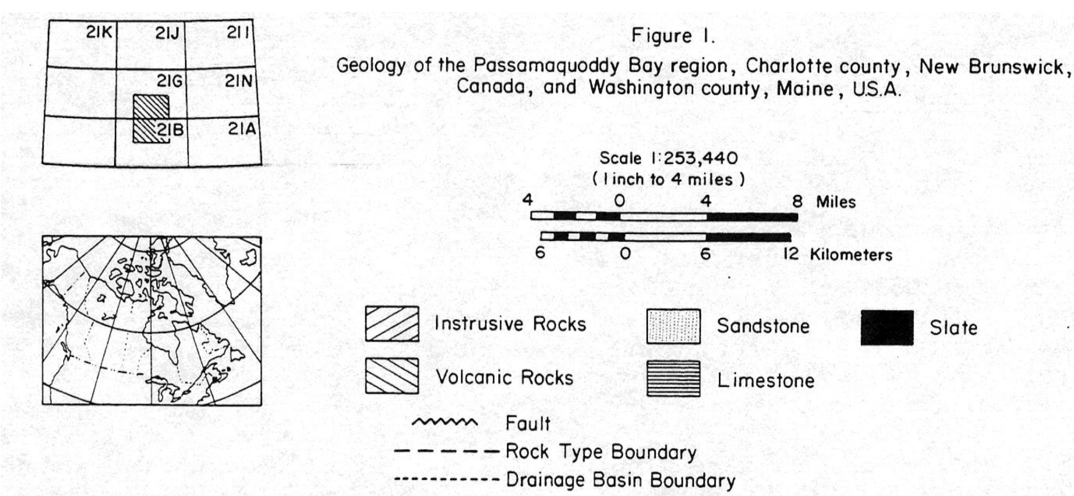


FIGURE 1 Location map of lakes in New Brunswick. Dotted lines around the lakes indicate the size of the drainage basin.

2. some of these lakes represent raised marine basins; previous examination and C^{14} dating of cores from several lakes have provided an accurate date for the emergence of the lake sills and hence an accurate sea level for that time (Scott and Medioli, 1980a); examination of the marine-freshwater transition (which is marked by the appearance of Arcellaceans in the cores) should provide a history of the appearance and evolution of arcellacean assemblages under continually freshening conditions;
3. lakes in such close proximity should display very similar distributional assemblages; if assemblages are not similar, they can probably be linked to known local features.

There is no previous work on arcellaceans in these lakes except for cursory examination of marine- freshwater transitions in some cores (Scott and Medioli, 1980a).

GENERAL PHYSIOGRAPHIC DESCRIPTION OF THE LAKES

On the Fundy Shore of New Brunswick, the maximum former marine limit has been determined to be approximately 75 meters above present mean sea level (Gadd and Lee in Walton and others, 1961; Lowden and Blake, 1976) and C^{14} dated at 13,000 years before present (ybp). This age has been revised downward to 16,000 ybp by Scott and Medioli (1980a). On the Annapolis-Fundy Shore of Nova Scotia, the marine limit is less well known but upper limits vary between 15-40 m above present (Hickox, 1962; Wightman and Cooke, 1978).

The freshwater sediment of the formerly marine basins is comprised of brown organic material (gyttja). This is underlain by an organic, grey brown silt, deposited under mildly brackish conditions. This is, in turn, underlain by a section of dark grey silt with some organic material, deposited under marine estuarine conditions. A grey silt with little organic material underlies this, while reworked glacial material is found at the base of these cores (Scott and Medioli, 1980a).

Post-marine sediment thicknesses vary from 290 cm in Bocabec Lake to 660 cm in Journeays Lake. Sedimentation rates have not been determined for any of these lakes.

VEGETATIONAL AND CLIMATIC CHANGES SINCE DEGLACIATION

Mott (1975) examined and radiocarbon dated sediment cores from two small lakes in this area. His pollen profiles reflect vegetational and climatic changes since deglaciation. However, the flora observed probably does not exactly mirror the climate of the time, due to migration lag. This would be particularly true if climatic change was rapid (Bryson and Wendland, 1967).

Following deglaciation, a flora of herbs and shrubs prevailed, indicating tundra conditions probably caused, in part, by the proximity of the retreating ice sheet. About 11,300 ybp an increase in pollen indicates the presence of more trees, probably climatically similar to that of north-central Quebec today (Mott, 1975).

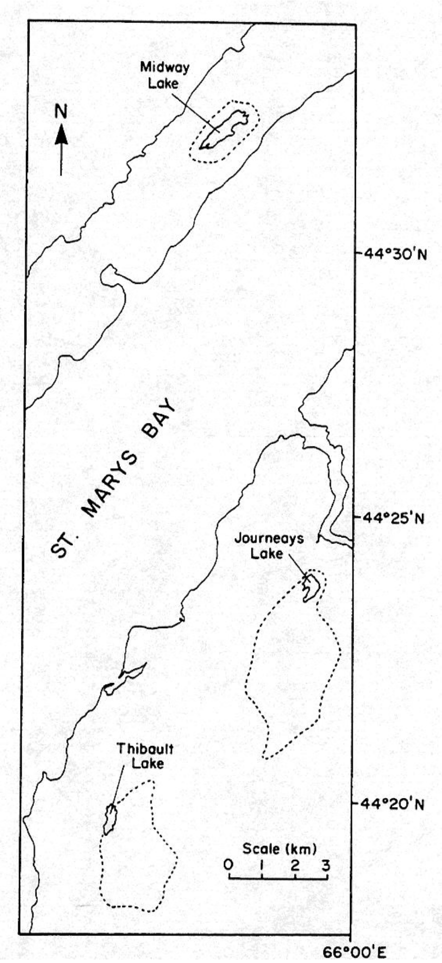


FIGURE 2. Location map oflakes in the Annapolis Valley of Nova Scotia. Dashed lines around lakes indicate the size of the drainage basin. Midway Lake sits in a basalt setting while the other two lakes are in Cambrian slates.

Another increase in pollen, particularly of pine, occurred about 9,500 years ago. From that time on, the hardwood component increased, beginning a trend which continued until about 1,000 years ago. Since then the climate of southwestern New Brunswick has returned to a cooler and more moist climate, indicated by an increase in spruce pollen, and a decline in hemlock and hardwood pollen (Mott, 1975). The same climatic trends can be inferred for Nova Scotia.

THERMAL AND SEASONAL FACTORS

One would expect the temperature curve of a lake to reflect the solar radiation absorbed by the lake. However, this does not seem to be the case. Direct stratification is observed, with dense cold water, lying beneath warmer layers, dividing the lake into three regions (Cole, 1979). The upper region, the epilimnion, is thoroughly mixed by wind to a more or less uniform temperature. The hypolimnion, the bottom region, is com-

TABLE 1. Percentage occurrences of Arcellacean species from surface stations in Deer Island Pond, New Brunswick; L=living,T=total population.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES FROM DEER ISLAND-BIG POND SURFACE STATIONS

Station Number		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
Water Depth (m)		5	5	10	10	4.5	4.5	8.5	8.5	3	3	10	10
Total No. of Species		12	12	10	12	11	9	9	8	12	11	9	10
Total Number of Individuals/10 ml	L	28	14	0	5	0	5	0	2	44	7	2	0
	T	724	677	60	212	1279	384	299	103	2266	756	83	79
Centropyxis aculeata	L												
	T	1.4	1	1.7	6.1	0.08	1	1	1.9	1	0.4	13.3	2.5
C. constricta	L												
	T	1.4	0.74	1.7	1.4	1.4	0.52	1.3		3.8	1.7		5.1
Difflugia corona	L										14.3		
	T	0.28	0.44	1.7	0.94	0.8		0.33	1.9	1.2	0.4	2.4	1.3
D. oblonga	L	35.7	42.9		40		40			54.5	71.4	50	
	T	34.5	42.4	38.3	20.3	45.3	45.8	39.1	33	64	66	37.3	38
D. protaeiformis	L												
	T	1.9	0.89	8.3	11.3	0.23		2	3.9	1.2	0.27	2.4	2.5
D. tricuspis	L		7.1										
	T	7.4	2.2	5	27.4	3.2	4.1	12.4	6.8	2	0.27	14.4	7.6
D. urceolata	L	14.3	14.3										
	T	2.5	1.5		1.9				0.97	0.13		1.2	3.8
D. urceolata f. elongata	L	14.3								2.3			
	T	2.5	1	1.7	2.8	5.6	10			4.2	3.3	1.2	2.5
D. urens	L									3.4	14.3		
	T	1.1	0.89		0.5	0.7	0.26	0.33		2.8	2.7		
Lagenodifflugia vas	L	14.3	7.1		60					4.5		50	
	T	14.4	12.7	20	17.9	1.8	1	22.7	24.3	12	20.7	20.5	16.4
Lesquereusia spiralis	L									4.5			
	T	0.83	0.44	1.7	1.4	0.6	0.52			4	0.53		
Pontigulasia compressa	L	21.4	28.6				60		100				
	T	31.8	35.7	20	8	40	36.7	20.7	27.2	3.7	4.5	7.2	20.2

posed of colder water little affected by wind action and usually termed stagnant. Separating these two major regions is the metalimnion, an intermediate zone where temperature drops rapidly with increasing depth.

Smith (1952) performed physio-chemical studies on some New Brunswick lakes over 30 years ago, but cores from the New Brunswick lakes indicate little or no change since then so that Smith's data should still be applicable to our study. Smith (1952) has data from Bonaparte, Gibson, and St. Patrick's Lakes in south-western New Brunswick. The largest inter-lake differences are with respect to bottom water temperatures. The shallower lakes (Gibson and St. Patrick's) do not develop a thermocline so that bottom water temperatures reflect atmospheric temperatures (that is, large seasonal ranges: 5-20°C). Bonaparte Lake does have a thermocline and bottom water temperatures below 7 m are always 3-6°C regardless of the season. A thermocline is usually associated with oxygen depletion of the bottom waters but Smith's measurements indicate that is not the case in Bonaparte even though oxygen depletion was recorded in some nearby lakes with thermoclines. Both Gibson and St. Patrick's lakes have high oxygen values at all depths. There appear to be few significant differences between lakes with respect to dissolved ions except that both Bonaparte and Gibson are high in dissolved $CaCO_3$ while St. Patrick's lake has no dissolved $CaCO_3$.

Cooper (1942) has studied the relationships between area and depth in 118 nearby Maine lakes to determine what type of stratification occurs. He found an average epilimnion depth of 5.5 m for lake areas of 14 to 40 hectares (ha), 9.0 m for lake areas greater than 810 ha. The bottoms of metalimnia averaged 12.8 m, and ranged from 10.1 m to 17.5 m in a study of 17 lakes carried out by Davis and others (1978). This would imply that Bonaparte Lake should have oxygen depleted bottom waters but it does not (Smith, 1952).

Davis and others (1978) also indicate for the same Maine lakes that summer stratification begins from late April to mid-June, with an average occurrence of early May, after a few days to a month of overturn. Stratification lasts from four to six months with the fall overturn beginning in late October to early November and lasting one to two months. Complete ice cover begins in late November-early December, lasting four to five months. The lakes in the Maine study were from southern to northern Maine, with the lakes of the New Brunswick study being, latitudinally, approximately at the median of Maine. Thus values for the New Brunswick lakes are probably at the median of the range given for the Maine lakes.

We have no data from the Nova Scotia lakes although two of the lakes (Thibault and Midway) are shallow and probably have no thermocline. Journeays Lake has some areas deeper than 10 m where a thermocline has probably developed.

GEOLOGICAL AND GEOGRAPHIC INFLUENCE ON WATER QUALITY OF THE LAKES

The five lakes of New Brunswick represent differing geological settings (Figure 1). St. Patrick's Lake and

TABLE 2. Percentage occurrences of Arcellacean species from surface stations in St. Patrick's Lake, New Brunswick; L= living, T= total population.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES FROM SURFACE SAMPLES IN ST. PATRICK'S LAKE, N.B.

Station Number		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B
Water Depth (m)		2	2	4.5	4.5	5	5	4.5	4.5	5	5	4.5	4.5	4.5	4.5	4	4	4	4	4	4
Total No. of Species		12	11	12	11	12	12	12	12	10	10	12	12	11	11	12	12	12	12	12	12
Total Number of Individuals/10 ml	L	316	470	173	0	83	1	0	4	4	0	0	0	0	3	228	5	0	0	6	28
	T	1972	3166	1442	744	1608	1500	594	1250	180	97	325	377	498	728	1760	453	775	841	963	955
Centropyxis aculeata	L	2.5	3.6	7.5		2.4										2.6					3.6
	T	1.8	4.3	4.8	4.4	3.3	2.8	2.5	4.2	1.1	4.1	2.5	3.2	3.2	4.9	3.6	1.5	5.2	3.2	5.5	5
C. constricta	L	2.8	10.8	19.1		4.8			75	25						15.4	20			16.7	25
	T	3.5	8.8	13.2	11.6	10.1	8.9	10.6	15.6	17.8	12.4	7.7	13.5	13.8	15.4	15.3	11.7	17.5	15	16.9	15.8
Difflugia corona	L	0.3	3.4	2.9		3.6									100	0.44					
	T	0.56	1.5	1.3	1.3	1.2	0.73	1.3	0.48		2.1	1.8	1.6	0.6	2.3	0.9	2	1.7	1.9	2.7	1.3
D. urceolata f. elongata	L	13.6	6.8	3.5		6										0.88					
	T	16.1	16.1	3.8	3.9	4.2	3.6	2.5	3.1	1.7		2.2	5		3.2	2.4	1.5	3.4	2.4	3.8	5
D. oblonga	L	44.4	36.6	40		51.8	100		25	75						57.4	80			33.3	39.3
	T	47	37	46.8	51.2	49	50.2	47.6	43.7	47.8	44.3	49.5	36.3	43.4	43.1	45.2	49.4	37.2	44.9	38.5	41.6
D. protaeiformis	L	0.63	0.42	0.58		3.6										1.3				16.7	
	T	0.46	1.5	2.8	2.8	2.9	4.3	5.1	5.6	5.6	8.2	7.1	5	5.4	2.6	2.2	4.6	7.4	3.6	5.1	4.1
D. tricuspis	L																				
	T	0.1		0.14	0.13	0.12	0.27	1.2	1.9	3.3	2.1	0.31	2.9	1.2	0.4	0.8	0.66	2.8	0.24	1.6	3.4
D. urceolata	L	3.8	5.5	2.3		9.6										2.2					
	T	2.7	2.9	0.76	1.7	3	2	2	1.8	1.7	1	0.92	0.53	1	1.5	1.3	1.5	1.7	1.7	1.1	0.73
D. urens	L	2.2	2.1			2.4										3.1				16.7	17.8
	T	1.5	1.2	0.28	0.54	0.87	1.1	1.7	0.24			0.92	0.53	0.8		0.9	1.3	0.13	1.1	1.6	1.5
Lagenodifflugia vas	L	4.7	6.2	2.3		1.2										2.2					3.6
	T	6.4	7.8	3.2	4	4.5	6.3	7.1	3.8	16.1	19.6	6.2	9	12.4	11.1	9.2	9.5	7.7	8	5.9	7.4
Lesquereusia spiralis	L		0.2													0.44					
	T	0.1	0.35	0.28		0.19	0.13	0.34	2.3	1.1	1	0.92	1.3	1.2	0.69	0.62	0.88	2.6	1.5	2.5	2.2
Pontigulasia compressa	L	25	24.3	22		14.4										14				16.7	10.7
	T	19.7	18.5	22.5	18.3	20.5	19.7	18	17.3	3.9	5.2	20	21	16.9	14.7	17.5	15.2	12.8	16.5	14.7	12

Bonaparte Lake are set wholly in granitic bedrock. Big Pond is entirely contained in a volcanic setting, while Bocabec rests on a sandstone-limestone contact, and Gibson Lake abuts a granitic and limestone unit (Cumming, 1964). The Nova Scotia lakes (Fig. 2) are set in either Cambrian slates and schists (Journeays and Thibault Lakes) or Triassic basalt (Midway Lake). Considerable amounts of glacial drift surround all the lakes as well.

The lakes vary considerably in mean elevation above sea level. In New Brunswick, Bonaparte Lake is at 49 m above sea level; Bocabec is at 10m above sea level; St. Patrick's Lake is at 70 m above sea level; Gibson Lake is at 35 m above sea level and Big Pond is at 5 m above sea level (data from Scott and Medioli, 1980a). In Nova Scotia, measurements were less precise but Joumeays Lake is 15-30 m above sea level, Thibault, 30-45 m above sea level, and Midway, 60-75 m above sea level.

Davis and others (1978) suggest that the chemistry

TABLE 3. Percentage occurrences of Arcellacean species from surface stations in Bocabec Lake, New Brunswick; L= living, T= total population.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES FROM SURFACE SAMPLES IN BOCABEC LAKE, N.B.

Station Number		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B
Water Depth (m)		2	2	3.5	3.5	6	6	9.5	9.5	8.5	8.5	3	3	4	4	2.5	2.5	2	2	3.5	3.5
Total No. of Species		12	12	12	12	13	14	11	13	14	14	12	12	12	12	12	12	13	12	12	13
Total Number of Individuals/10 ml	L	6	47	5	5	0	0	7	9	0	0	0	15	0	0	12	1	1	44	0	3
	T	951	994	864	563	1349	827	461	768	563	1461	694	655	208	346	1279	213	926	802	553	558
Centropyxis aculeata	L															16.7			2.3		
	T	6.3	5.7	4.1	5.5	2.2	1.9	0.65	0.65	0.71	1.2	6.8	5.6	7.7	2.9	27.1	18.8	7.9	11.7	4.7	3.05
C. constricta	L		2.1														100	100			
	T	1.6	3.6	4.5	4.1	2.5	1.9	3.2	2.2	1.4	2.2	5.8	6.1	3.8	3.7	1.02	1.9	3.1	1.7	3.2	3.2
Difflugia globulus	T	0.1					0.12			0.18	0.07							0.11			0.18
D. bidens	T					0.6	1.1	0.87	1.4	4.08	2.5										
D. corona	L															16.7			9.1		33.3
	T	2.9	1.5	1.9	1.8	0.22	0.6		0.26	0.36	0.27	0.29	0.3	2.9	1.4	19.8	24.4	10.6	9.1	3.4	1.8
D. urceolata f. elongata	L	16.7	23.4	20	20								6.7			16.7			13.6		33.3
	T	39.8	37.4	30.3	32	11	19.1	18.2	18.9	14.6	15.9	11.5	10.2	20.2	15.5	3.8	12.2	9.8	10.5	13.9	15.1
D. oblonga	L	66.7	56	20	40			57.1	33.3				20		33.3	33.3			29.5		
	T	35.6	35.9	38.5	37.3	18.4	17.4	47.3	39.4	45.1	49.5	49.1	42.9	41.8	50.1	14.9	18.8	44.5	45.9	53.7	56.4
D. protaeiformis	L								11.1												
	T	1.4	1.6	1.3	1.4	2.4	1.8	1.7	1.2	0.71	1.03	1.2	0.92	3.8	2	1.6	2.8	0.97	1.5	1.1	1.4
D. tricuspis	L								11.1												
	T	0.1	0.44	0.46	2	1.3	0.37	2.2	2.7	1.06	0.68	2.6	3.5	2.4	1.1	22	10.3	5.3	3.9	1.1	0.72
D. urceolata	L		4.7	20															2.3		
	T	3.6	3.2	3.5	2.1	0.22	0.12		0.13	0.18	1.2	1.2	1.4	0.48	2	0.23	0.47	0.65	1.1	0.9	1.08
D. urens	L	16.7	2.3	40				42.8					73.3			8.3			20.4		33.3
	T	1.8	0.44	1.5	1.2	1.04	1.1	0.87	1.4	2.7	2.6	2.3	5.2	1.4	2.9	0.31	0.94	2.1	1.7	2	3.6
Lagenodifflugia vas	L								11.1										6.8		
	T	1.9	2	1.2	1.6	55.4	50	14.5	18	13.1	4.1	5.04	5.5	5.3	3.2	1.8	3.3	6.3	4.6	7.05	2.9
Lesquereusia spiralis	L														33.3						
	T		0.55	0.46	0.36	0.9	0.37	0.87	1.2	0.36	0.07	2.2	1.4	1.4	0.57	3.7	1.4	1.2	1.4	0.36	0.72
Pontigulasia compressa	L		11.7		40				33.3						33.3	8.3			15.9		
	T	4.8	7.6	12.3	10.7	3.9	4	9.5	12.5	15.4	18.6	12.1	16.9	8.6	14.6	3.8	4.7	7.6	6.8	8.5	9.8

TABLE 4. Percentage occurrences of Arcellacean species from surface stations in Gibson Lake, New Brunswick; L =living,T=total population.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES FROM SURFACE SAMPLES IN GIBSON LAKE, N.B.

Station Number		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B
Water Depth (m)		5	5	5	5	5	5	4.5	4.5	4	4	5	5	5	5	5	5	5	5	4.5	4.5
Total No. of Species		12	10	11	12	12	12	9	6	11	12	12	12	11	10	10	12	12	12	12	7
Total Number of	L	0	27	0	1	13	1	6	0	117	316	22	21	12	6	0	0	70	32	44	2
Individuals/10 ml	T	606	262	383	1349	1241	956	251	60	1761	2854	2409	745	355	402	376	2327	1348	1263	825	150
Centropyxis aculeata	L					15.4				3.4	7.6				16.7				3.1	4.5	
	T	1.2	0.38	3.4	3.9	2	2.4	2		4.6	11.1	5.02	4.6	1.4	4	3.7	3.6	4.7	6.7	3.6	
C. constricta	L		18.5			30.8	100	33.3		3.4	19	22.7	9.5	8.3				7.1	6.25	4.5	
	T	5.8	9.2	16.7	18.2	13.4	11.1	9.6	5	3.7	17.7	23.7	16	9.6	13.7	11.7	19.5	18.5	17.5	8.1	0.67
Difflugia corona	L									0.85	1.9										
	T	0.33	0.38	0.26	0.44	0.81	0.52			0.34	0.60	0.62	0.8	0.84	0.25	1.1	1.5	0.74	0.54	0.36	
D. urceolata f. elongata	L							16.7		7.7	1.5									6.8	50
	T	1.6	0.38	2.6	3.2	1.8	2.6	0.8		4.6	7.2	1.95	0.94		0.25	1.1	0.77	1.04	1.8	7.6	7.3
D. oblonga	L		44.4		100	38.5		33.3		50.4	42.5	36.4	62	58.3	33.3			78.6	90.6	29.5	
	T	52.1	56.1	44.6	49.4	50	51.6	54.6	61.7	63.2	40.7	45.2	46	53	45.3	48.7	46.7	42.2	39	50.2	70.7
D. protaeiformis	L									0.85								1.4		2.3	
	T	1.5		2.3	2	3.2	1.05	0.8		0.06	0.7	2.2	1.3	1.1	0.75	0.53	2.5	5.04	5	4.1	
D. tricuspis	L					7.7												1.4		9.1	
	T	0.33	0.76	5.2	1.9	1.5	3.3			0.06	0.7	0.46	1.74	0.28		1.6	1.07	6	10.9	5.4	
D. urceolata	L							16.7		18.8	11.8	13.6	4.8	8.3				1.4		2.3	
	T	1.3	1.1	1.04	1.6	1.05	1.5	3.2	10	6	3.8	1.37	2.7	3.7	3.5	2.1	1.07	0.8	1.2	4.1	4
D. urens	L		11.1							6	6.8									4.5	
	T	0.82	1.5		0.74	0.08	0.3	1.6	3.3	3.9	2.1	0.3	1.3	1.7	2		0.47	0.15	0.15	0.24	
Lagenodifflugia vas	L		11.1							5.1	3.04	13.6	19	25	16.7			10		4.5	
	T	25.1	21.4	12	9.1	15.5	16.6	19.5	13.3	8.1	3.6	7.7	14.4	19	18.2	18.6	11.2	10	5.7	2.3	4
Lesquereusia spiralis	L																			2.3	50
	T	0.33		1.04	0.37	0.64	0.62				0.17	0.3	0.27	0.56			0.47	1.63	3.2	3.8	2
Pontigulasia compressa	L		14.8			7.7				3.4	5.7	13.6	4.8		33.3					29.5	
	T	9.6	8.8	10.7	9.2	10.1	8.4	8	6.7	5.3	11.5	11.2	10.1	9	12.2	10.9	11.1	9.2	8.3	14	11.3

of the bedrock exerts the strongest influence on lake water quality, largely determining the total natural dissolved load, much of the nutrient load, pH and alkalinity. These effects are direct if the bedrock is exposed or near the surface. The local bedrock is still important, even with an overburden of glacial till, since most of the tills in New England and the Maritimes are locally derived.

The geological setting of the lakes in the study area ranges from granite to limestone, that is poor to rich respectively, in supplying phosphorus for biological uptake. However, studies oflakes in Maine (Davis and others, 1978) also indicate that granite underlain lakes can have relatively high phosphorus levels and trophic state. Other parameters such as lake morphology, flushing rate, and the effects of man may be important.

Limestone, underlying two of the lakes in the study area, produces higher levels of phosphorus, resulting from the solution of apatite $(Ca_5)(PO_4)_3(OH)$ and also from the solution of $CaCO_3$ which usually has PO_3 present in solid solution. However, as Smith (1952) found, these lakes differ little in their dissolved ion load, despite the many types of bedrock that characterize individual basins.

TABLE5. Percentage occurrences of Arcellacean species from surface stations in Bonaparte lake, New Brunswick; X equals less than 1%; L = living, T= total population.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES IN SURFACE SAMPLES FROM BONAPARTE LAKE

Station Number		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	10A	10B
Water Depth (m)		8	8	10	10	13	13	15	15	12	12	18	18	13	13	8	8	10	13	13
Total No. of Species	L	1	4	3	3			2			1					3		3		2
	T	7	6	5	4	4	3	3	3	3	3	3	3	3	4	5	5	3	3	4
Total Number of	L	1	15	25	6	0	0	3	0	0	1	0	0	0	0	0	0	0	0	2
Individuals/10 ml	T	361	233	128	227	223	183	98	60	67	33	25	34	78	88	322	88	77	68	63
Centropyxis constricta	L																			
	T	x																		1
C. aculeata	L																			
	T	x	x	2												x	1			
Difflugia bidens	L																			
	T																			
D. corona	L																			
	T		x																	
D. oblonga	L		8	20	2						5					8				4
	T	57	43	66	75	61	53	46	52	46	61	48	47	52	49	59	64	59	46	41
D. protaeiformis	L																			
	T	1				x														
D. urceolata	L		8																	
	T	4	5	x	x										1	1	3			
D. urens	L																			
	T																			
Lagenodifflugia vas	L	1	4	26	3			7								16				
	T	20	31	21	14	19	23	15	13	12	6	12	29	22	11	20	22	14	9	8
Pontigulasia compressa	L		7	8	4			5								11				3
	T	17	19	10	10	20	24	39	35	42	33	40	24	26	39	20	10	27	45	50

TABLE 6. Percentage occurrences of Arcellacean species from surface stations in Thibault Lake, Nova Scotia; L = living, T = total population.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES IN SURFACE SAMPLES FROM THIBAULT LAKE, N.S.

Station Number		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
Water Depth (m)		2	2	2	2	2	2	2	2	1.5	1.5
Total No. of Species		11	13	10	12	10	12	11	10	11	11
Total Number of Individuals/10 ml	L	103	169	22	18	33	57	0	5	2	0
	T	384	1037	806	1070	589	1285	701	973	412	240
Centropyxis aculeata	L	1.9	3	4.5	5.6	3	3.5				
	T	1.3	2.1	2	2.7	2.2	5.1	3.7	3.4	3.2	2.5
C. constricta	L	2.9	2.4	9		3	10.5				
	T	3.6	3	2.2	3.45	1.5	8.9	4.1	3.6	2.7	4.2
Difflugia globulus	L	1	0.6								
	T	0.52	0.29		0.1						
D. corona	L	1					1.8				
	T	0.26	0.2	0.12	0.28		0.54	0.14		0.24	0.42
D. urceclata f. elongata	L		1.2	9		3	3.5				
	T	1.8	5.1	3.3	4.1	3.6	4.3	6.7	6.1	4.9	10.8
D. oblonga	L	50	50.9	31.8	44.4	42.4	47.4		80	50	
	T	52	54	56.3	55.3	46.5	45.5	36.4	39	43.4	45.8
D. protaeiformis	L		0.6								
	T	0.52	0.29	0.25	0.37	0.17	0.62	0.14		0.49	0.42
D. tricuspis	L										
	T		0.1		0.28	0.17	1.6	0.3	0.2		0.42
D. urceolata	L	15.5	20.1	13.6	11.1	6.1	1.8				
	T	8.1	7.8	5.2	5.1	4.2	4	6.6	7.5	4.4	3.8
D. urens	L	5.8	4.1	18.2	5.6	6.1					
	T	2.1	3.5	2.7	2.1	1.2	0.78	3.7	3.4	1.9	1.7
Lagenodifflugia vas	L	10.7	6.5	4.5	11.1	30.3	17.5			50	
	T	18.5	12.4	18.4	16.6	30	19.2	23.4	23	29	22.5
Lesquereusia spiralis	L		0.6								
	T		0.38				0.23		0.2	0.24	
Pontigulasia compressa	L	11.6	10	9	22.2	6.1	14		20		
	T	11.7	11	9.4	9.4	10.5	9.2	14.8	13.8	9.7	7.5

In addition, Davis and others (1978) indicate that the close proximity of lakes to the ocean (the case for all lakes in this study) may also playa considerable role in determining the levels of dissolved solids (Na^+, K^+, Ca^{++}, Mg^{++}, CH_4, H_4SiO_4). Cyclical salts injected into the atmosphere by sea spray are later precipitated as rain or snow. These salts may then constitute as much as half the dissolved salt load in coastal lake water. There is some evidence (foraminifera found in surface sediments) that Big Pond may be subject to direct marine incursion during severe stonn conditions.

METHODS OF COLLECTION AND PREPARATION

Sediment-water interface samples were collected at stations chosen to reflect the depth range of each lake. Due to the small size and lack of large scale maps for each lake, exact station locations were not recorded,

TABLE 7. Percentage Occurrences of Arcellacean species from surface stations in Midway Lake, Nova Scotia; L = living, T = total population.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES IN SURFACE SAMPLES FROM MIDWAY LAKE, N.S.

Station Number		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B
Water Depth (m)		2	2	3.5	3.5	3.5	3.5	3	3	3	3	1.5	1.5	2	2	1.5	1.5	1	1	1.5	1.5
Total No. of Species		11	12	12	10	10	9	9	8	9	9	11	12	9	7	12	8	13	11	11	10
Total Number of Individuals/10 ml	L	32	40	1	10	4	15	1	5	0	92	10	16	4	4	11	6	15	1	11	20
	T	210	323	166	64	218	90	82	30	272	270	187	242	80	34	222	146	966	203	581	189
Centropyxis aculeata	L		2.5		10								6.2	25	50	9.1					
	T	.5	1.5	0.6	4.7	3.7	2.2	1.2		0.74		14.4	0.4	22.5	23.5	2.2	0.7	0.62		0.52	
C. constricta	L																				1
	T	5.7	5.6	3.6		7.3	1.1	1.2				7.5	0.4	1.2	3	2.2	2	1.6	0.5	0.34	0.53
Difflugia globulus	L				10						2.2	10									
	T	.5	0.6	3	12.5					1.8	3	0.53	1.6					1.6	2.5	1.5	2.6
D. corona	L		2.5											25				6.7			5
	T	1	3.7	0.6	3.1	2.3	1.1	5	3.3	0.74	0.37	2.1	1.2	12.5	11.8	2.2	1.4	5.1	5.4	1.5	2.1
D. urceolata f. elongata	L	3.1				25	6.7		20		9.8							6.7		5	
	T	18.6	13.6	19.3	3.1	13.8	17.8	16	13.3	14.3	11.5		13.2	7.5	3	8.6	5.5	9.3	10	6.2	12.2
D. oblonga	L	25	17.5			50	6.7		60		42.4	40	50	50	50	54.5	33.3	53.3		27.3	25
	T	44.3	40.6	37.3	23.4	36.2	29	53.7	53.3	51	59.2	50	52.3	32.5	53	50	50.7	58.2	56.2	67	55.6
D. protaeiformis	L																				
	T	1	2.2	1.8	1.6	1.4			3.3			2.7	0.83		3	0.45		0.2	1.5	0.2	
D. tricuspis	L																				
	T											3.7	1.2	7.5		1.8		0.4	0.5		
D. urceolata	L		2.5				6.7				1.1	10	12.5								
	T	0.48	0.92	3	1.6	4.1	3.3	1.2		0.37	0.74	1.6	4.5	2.5		1.8	2	2.8	1	1.5	2.6
D. urens	L	72	70		80	25	40	100	20		37	40	31.2			36.4	66.7	13.3	100	72.7	65
	T	15.7	13	12	34.4	4.6	11.1	1.2	3.3	15.4	14	8.6	10.3			14.4	13	6.3	6.4	10.3	13.2
Lagenodifflugia vas	L		2.5				40				4.3							6.7			
	T	2.4	2.8	4.8	4.7	20.2	25.6	7.3	16.7	5.1	7.4		2.5	5		3.2		1	0.5	0.34	1.6
Lesquereusia spiralis	L										1.1										
	T		0.62	0.6				2.4	3.3		0.37	1.1				0.45		0.2			0.53
Pontigulasia compressa	L		2.5	100							2.2							13.3			
	T	10	15	13.2	11	6.4	8.9	9.8	3.3	10.3	3.3	8	11.2	8.8	3	12.6	24.6	12.6	15.8	10.5	9

TABLE 8. Percentage occurrences of Arcellacean species from surface stations in Journeays Lake, Nova Scotia; L = living, T = total population.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES IN SURFACE SAMPLES FROM JOURNEAYS LAKE, N.S.

Station Number		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B
Water Depth (m)		3.5	3.5	4	4	6	6	10	10	11	11	5	5	11	11	8	8	7	7	4	4
Total No. of Species		11	11	11	9	11	8	8	8	·9	10	7	8	9	11	8	10	7	9	9	11
Total Number of	L	22	308	138	251	243	242	7	0	0	22	113	370	10	8	33	29	97	224	464	760
Individuals/10 ml	T	1542	3000	1992	1226	958	698	143	104	94	279	1316	2090	141	337	326	280	168	721	2314	1864
	L		1.3		0.7	0.7		14.2				1.5									0.26
Centropyxis aculeata	T	0.52	0.8	0.6	0.4	0.3	0.23	4.2	1	4.2	1.8	0.26		1.4	2.1	0.75	1.1		0.4	0.09	0.32
	L	12.5	5.2	5.7	3.8	5.3	3.3	28.6			27.3			40	25	7.4	13.8	1	6.7		2
C. constricta	T	7	5.5	6.4	4.3	5.2	4	9.1	3.8	6.4	6.8		0.02	6.4	11.3	5.2	6.8	0.6	6	0.43	2.4
	L		3.9	1.9	4.4	1.3								10			3.4	1		1.3	
Difflugia corona	T	1.6	1.6	2	1.4	1.8	0.9	2.8		1.1	1.4		0.1	4.2	2.1		1.8	0.6	0.3	0.6	0.54
	L		14.3	11.3	16	19	22				9.1	10.4	11.9	10	12.5	18.5	17.2	24.7	26.3	13	37.7
D. urceolata f. elongata	T	20	15.1	22.8	19	14.7	15.4	25.2	29	38.3	23.3	23.6	7.6	33.3	23.4	28.5	19.3	20.2	21.8	33.4	41.5
	L	25	57.1	47	41.4	36.8	46.4	42.8			54	86.6	79	30	12.5	33.3	17.2	43.3	30	31.5	24.4
D. oblonga	T	36	46.4	39.4	48.3	40.4	42.7	41.2	48.1	34	50	67.4	80.4	38.3	45.4	37.8	36.4	40.5	33	36.2	27.1
	L			3.8		0.6	1.3										6.9	2.1	0.9		1
D. protaeiformis	T	0.52	0.4	1.7	0.4	0.5	0.9	0.7	1	2.1		0.4		0.7	0.9		2.5	1.8	1.1		1
	L	37.5	3.9	20.8	22.3	3.9	4						1.1			7.4			0.9	47.4	18
D. urceolata	T	9.4	4	5.2	8.6	1.5	1.4		1	2.1	0.7	0.5	0.3	0.7	0.3	0.75	0.36		0.28	18.4	8.6
	L			1.9		0.6															0.26
D. urens	T	0.52	0.3	0.5		0.16							0.05				0.36			0.09	0.2
	L				0.63								1.1		12.5				0.45	0.9	0.5
Lagenodifflugia vas	T	2.5	0.53	2	2.3	0.5		0.7		1.1	0.36	0.13	0.4	1.4	1.8	0.75		0.6	0.55	1.3	1.4
	L		1.3																		0.26
Lesquereusia spiralis	T	0.35	0.13	0.6		0.17					0.36	0.13			0.6	0.37	0.36				0.1
	L	25	13	7.5	10.8	31.6	23	14.3			9.1	1.5	7	10	37.5	33.3	41.4	28	35	6	15.6
Pontigulasia compressa	T	21.4	25.3	18.7	15.4	34.7	34.6	16.1	16.3	10.6	15	7.5	11	13.5	12.2	25.8	31	36	36.8	9.5	17

only water depths. An Ekman box corer (15 x 15cm) was used for interface samples with 10 cm^3 replicate samples being obtained at each station and the water depth recorded. Cores were obtained using a Livingstone square-rod continuous coring method. All cores were collected by Dalhousie personnel in 1978 and 1979 except the Gibson Lake core which was obtained from R. J. Mott of the Geological Survey of Canada.

The samples were sieved using a No. 35-mesh (0.5 mm) screen to retain coarse organics and shells and a No. 230-mesh (0.063 mm) screen to retain the arcellaceans. Fine organic material was removed by decantation. Care must be taken during this procedure as processing of arcellaceans is sometimes difficult, due to the fragility of the test. Although arcellacean tests can stand screened water pressure, they cannot survive any mechanical agitation. Since their tests are held together by organic cement, any chemical treatment or oxidization will destroy them. Decanting must also be done with care since arcellaceans have a lower specific gravity than most foraminifera.

Subsequent to sieving, a mixture of formalin and rose Bengal stain was added to the samples to detect specimens living at the time of collection. After standing overnight, the samples were rinsed and placed in denatured ethanol. Core samples were stored directly in denatured ethanol.

Scanning electron micrographs were taken using the Cambridge Stereo-Scan 180 scanning electron microscope located at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, using polaroid NP 55 film.

RESULTS-INTERFACE SAMPLES

Fourteen species were observed from 90 samples (46 stations) in New Brunswick and 15 species in 50 samples (25 stations) in Nova Scotia. Of these, all species had living representatives at the time of collection (Tables 1-8). Living populations were generally small in proportion to total populations, hence total populations were used to define assemblage zones. Total populations include both live and dead specimens; the latter having accumulated over several years. However, total population has been shown to be a good indicator of long-term as opposed to seasonal conditions (Scott and Medioli, 1980b).

NEW BRUNSWICK LAKES

Living Populations. Significant proportions of the populations were living in most of these lakes (Tables 1-5). Based on total populations, two primary associations were recognized, Assemblages I and II. Assemblage I can be further divided into three subdivisions not controlled by water depth. Only Assemblage II of Bonaparte Lake had an insignificant living population. This lake was also collected in June 1979, hence it is not clear why the living proportion differs so much from the other lakes. Percentage of the fauna living in these lakes was between 5% and 10% of the total, higher than observed in Lake Erie (Scott and Medioli, 1983).

Deer Island-Big Pond. Big Pond is dominated by Assemblage IA, found at all water depths, from 3 to 10 m (Table I). The assemblage is characterized by the dominance of *Difflugia oblonga,* with lesser percentages of *Pontigulasia compressa* and *Lagenodifflugia vas.* This is the only lake in the study where significant populations of *Difflugia tricuspis* are found in surficial sediments.

Total numbers are generally higher in shallow water (103-2,266 specimens/10 cc in 3 to 3.5 m), than in the deeper parts of the lake (60-212 specimens/10 cc at 10 m).

St. Patrick's Lake. This lake is dominated by assemblage IB, found at all water depths sampled, from 2 to 5 m (Table 2). It differs from Assemblage IA in the significant proportion of *Centropyxis constricta* pres-

TABLE 9. Average percentage occurrences of the five most common species in each lake together with average total and living numbers. X = mean and SD = one standard deviation.

General Assemblage Characteristics

Assemblage	Lake	Species	$\bar{X}$	SD
Assemblage IA:	Deer Island	D. oblonga	42%	12%
		P. compressa	21%	13%
		L. vas	15%	7%
		D. tricuspis	8%	7%
		D. urceolata F. elongata	3%	3%
		Total #	577	622
		Living #	9	13
Assemblage IB:	St. Patricks	D. oblonga	45%	5%
		P. compressa	16%	5%
		C. constricta	13%	4%
		L. vas	8%	4%
		D. urceolata F. elongata	4%	4%
		Total #	1011	719
		Living #	66	127
	Gibson Lake	D. oblonga	51%	8%
		P. compressa	10%	2%
		C. constricta	13%	6%
		L. vas	13%	6%
		D. urceolata F. elongata	2%	2%
		Total #	996	795
		Living #	34	70
Assemblage IC:	Bocabek Lake	D. oblonga	39%	12%
		D. urceolata F. elongata	18%	9%
		P. compressa	10%	4%
		L. vas	10%	15%
		C. aculeata	6%	6%
		Total #	792	338
		Living #	8	13
	Journeays Lake	D. oblonga	43%	12%
		D. urceolata F. elongata	23%	9%
		P. compressa	20%	10%
		L. vas	1%	1%
		C. constricta	5%	3%
		Total #	980	865
		Living #	168	196
Assemblage ID:	Thibault Lake	D. oblonga	47%	6%
		L. vas	21%	5%
		P. compressa	11%	2%
		D. urceolata	6%	2%
		C. constricta	4%	2%
		Total #	750	326
		Living #	41	52
Assemblage II:	Bonaparte Lake	D. oblonga	54%	9%
		P. compressa	28%	12%
		L. vas	17%	7%
		Total #	129	97
		Living #	3	6
Assemblage IE:	Midway Lake	D. oblonga	48%	11%
		D. urceolata F. elongata	11%	5%
		D. urens	10%	7%
		P. compressa	10%	5%
		L. vas	6%	7%
		Total #	229	207
		Living #	15	20

ent. *Difflugia oblonga* is dominant with lesser percentages of *Pontigulasiacompressa, Centropyxis constrieta, Lagenodifflugia vas,* and *D. urceolata elongata.*

Total numbers are high (97-3,166/10 cm^3) and indicate no depth relationship.

Bocabec Lake. Assemblage IC dominates this lake. It resembles both Assemblages IA and IE differing mainly in the large percentages of *Difflugia urceolata elongata.* Only in this lake has *Difflugia bidens* been recorded in surficial sediments (Table 3). The assemblage is dominated by *Difflugia oblonga;* however several species have significant percentage occurrences- *D. urceolata elongata, Lagenodifflugia vas,* and *Pontigulasia compressa.* Both *Centropyxis* spp. are relatively common.

Total numbers are moderate (213-1,461/10 cm^3), with no appreciable difference between shallower and deeper stations.

Gibson Lake. Water depth is fairly constant for all samples (4.5 m to 5 m) and Assemblage IE is found again (Table 4). *Difflugia oblonga* dominates, followed by *Lagenodifflugia vas, Pontigulasia compressa,* and *Centropyxis constrieta.* Total populations range from 60 to 2,854 specimens/10 cc in 4.5- to 5-m water depth.

Bonaparte Lake. This lake is characterized by Assemblage II (Table 5). It is dominated by *Difflugia oblonga*, followed by *Pontigulasia compressa* and *Lagenodifflugia vas*. Few other species are found in percentages greater than 1%. Significant living populations are found only in stations with water depths less than 10m.

Total numbers generally decreased from shallow water (72-361 specimens/10 cc in 8 to 10 m) to deeper water (25-223 specimens/10 cc in 12 to 18 m).

NOVA SCOTIA LAKES

Living Populations. Assemblages observed in these lakes were similar to those of New Brunswick. One lake (Journeays) had an Assemblage IC while the other two had slightly different ones (Thibault-ID, Midway-IE). Living populations in Thibault and Midway (5-10% of total) were comparable to New Brunswick values but Journeays Lake had significantly higher living percentages (17% of total). These samples were collected during the summer of 1979 so are directly correlatable to New Brunswick values.

Thibault Lake. Five stations were sampled in this small, shallow lake (depth range 1.5-2 m). Total numbers ranged from 240 to 1,285/10 cm^3 with no water depth trend (Table 6). The assemblage (ID) differs from that of other lakes, with *D. oblonga* dominating and *L. vas* subdominant followed by *P.compressa, D. urceolata* and C.*constrieta.*

Midway Lake. Ten stations were sampled in this shallow lake (depth range 1.5-3.5 m). Total numbers were lower here (30-966/10 cm^3) than in other lakes (Table 7), but living percentages were not particularly low, suggesting a higher sedimentation rate. Assemblage IE is characterized by *D. oblonga* dominating with *D. urceolata elongata, D. urens,* n.sp., and *P. compressa* all subdominants. This is the only lake with high numbers of *D. urens* in the surface sediments.

Journeays Lake. Ten stations were sampled in this moderately deep lake (3.5-11 m). Total numbers were high (94-3,000/10 cm^3) as was the living population (Table 8). This assemblage (IC) was virtually identical to that observed in Bocabec Lake, but lacked any *D. bidens* and had fewer *L. vas.* There is some indication that the three deepest stations (4, 5, 7) may be below the thermocline, since living and total populations here are lower, as in the deep areas of Bonaparte Lake.

Results from all the surficial samples in all the lakes are summarized in Table 9 with means and standard deviations of the top five species in each assemblage.

CORE RESULTS

Cores were examined from six lakes. Two other lakes (St. Patrick's, Deer Island) have been cored and are part of a separate study (Honig, 1984). Core data presented here are from Gibson, Bocabec, and Bonaparte Lakes in New Brunswick, and Thibault, Midway, and Journeays Lakes in Nova Scotia.

NEW BRUNSWICK

Gibson Lake. Assemblage characteristics change little in this core from 0- to 2l6-cm depth (Table 10,

TABLE 10. Percentage occurrences of Arcellaceans down core in Gibson Lake. x = less than 1%.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES DOWN GIBSON LAKE CORE
x = 1%

DEPTH IN CORE (cm)	10	20	30	40	50	60	70	80	90	100	110	120	130	145	155	165	175	194	204	214	224	226	245	255	264	274	284	294	314
TOTAL NO. OF SAMPLES	6	6	9	8	8	9	8	9	10	9	7	9	8	8	9	8	7	10	10	7	7	8	8	7	7	7	6	4	5
TOTAL NO. OF INDIVIDUALS/10 ml	115	20	74	122	103	386	394	418	317	471	556	463	498	90	699	666	326	411	1372	819	180	140	105	357	47	123	55	30	24
Centropyxis aculeata	3	10	8	2		3	4	x	8	3	2	4	1		x	2	1	x	x		1	3	x			1			4
C. constricta	12	15	18	25	22	36	22	27	24	23	30	22	23	3	10	22	7	8	15	17	14	15	10	19	13	2	5		
Difflugia bidens						x										x		3	3	x	x	x	x	3	2	2	7		
D. corona					3					x					x														
D. oblonga	37	35	22	36	51	38	52	27	39	42	46	44	32	73	65	28	42	65	52	43	51	44	34	47	53	68	58	63	80
D. protaeiformis	12	5	3	x	x	4	3	3	1	3	3	3	3	1	1			5	3	4	x	6	2						
D. tricuspis	12	5	5	x	2		x	4	2	x		1	1	2	x			2				5	5						
D. urceolata			4	4	3	1	1	3	3	x	x	1	5	2	x	7	1	x	3	3	9		15	1	4	3	5	3	8
D. urceolata f. elongata									x										x									6	x
D. urens																1	x	x	x					3	4				
Lagenodifflugia vas	24	30	27	14	9	8	13	27	12	23	12	15	23	12	10	23	33	6	15	27	21	23	31	14	17	10	16	30	4
Lesquereusia spiralis			5			x			x					1								2							
Pontigulasia compressa			8	16	9	8	4	8	11	6	7	10	12	6	11	17	16	9	8	6	3	2	2	12	6	12	7	3	4

Figure 3). The surface samples (10-30 cm) appear to have lower numbers than normal for this lake, possibly as the result of the upper part of the core oxidizing after collection (it was collected 10 years before our examination). The upper 2 m of core contains an assemblage identical to the surface assemblage of this lake (IB), except for isolated occurrences of *D. bidens* at 60 cm and 193-213 cm.

Below 216 cm, total numbers drop sharply. At 245 cm *P. compressa* and C. *constricta* percentages decline and *D. urceolata* and *D. oblonga* increase correspondingly down to 315 cm, where total numbers decrease further and *Centropyxis aculeata* becomes dominant. Between 375 and 400 cm sediments are barren of microfossils but a marine foraminiferal fauna appears at the 416 cm level (Scott and Medioli, 1980a).

Bocabec Lake. Total numbers are high in the upper 125 cm of the core (>1,000/10 cm^3, Figure 4, Table II). The assemblage in the upper section remains similar to that in the surface sediments except that *L. vas* decreases just below the surface. Below 125 cm, total numbers drop sharply (<200/10 cm^3). *Difflugia oblonga* remains dominant but *P. compressa* and *D. bidens* disappear. Below 225 cm, total numbers drop to less than 50 individuals per 10 cm^3 in many samples and assemblage distinctions are tenuous. However, *D. bidens* reappears and *Centropyxis* spp. (mostly C. *aculeata* in this section) become prominent and remain so into the marine sequence. The marine section is not shown here but is illustrated in Scott and Medioli (1980a) and is the same as Gibson Lake.

Bonaparte Lake. This is the longest freshwater sequence from New Brunswick presented here (Figure 4, Table 12). Total numbers in the core are generally higher than observed in the surface sediments. The assemblage is unchanged down to 475 cm where total numbers begin to fluctuate more, *D. bidens* appears in low numbers, and *L. vas* and *Centropyxis* spp. both increase slightly. Below 525 cm a short marine sequence occurs as described by Scott and Medioli (1980a), before the core bottoms in glacial material.

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Thibault Lake. Unfortunately only the lower 275 cm of this core was recovered for study so there is a 200-cm gap between the surface assemblage and the first core sample. The surface assemblage differs substantially from that of the first core sample at 200 cm (Table 13, Figure 5). First total numbers down core are considerably less than surface values and, although *D. oblonga* is still dominant, several other species are prominent at 2 m that are barely present in surface samples *(D. tricuspis, D. urens, D. urceolata elongata)* and *L. vas* drops significantly. Between 3.0 and 3.5 m total numbers increase, *L. vas* appears, and *Centropyxis* spp. also increase. Below 3.5 m, total numbers drop to less than 50/10 cm^3 and assemblage distinctions again are tenuous but *Centropyxis* spp. are the most prominent. The core grades into a hard sub-bottom with no marine material.

Midway Lake. This was a short core (upper 50 cm not available) but showed a trend similar to that observed in Thibault Lake (Table 14, Figure 5). Both *D. tricuspis* and *D. urens* increased in abundance in the subsurface but below 0.75 m in the core total numbers were so low that assemblages could not be determined reliably. *Centropyxis* spp. did not show the same trend as observed in the basal sections of the other lakes. The core grades into a hard sub-bottom with no marine sequence.

Journeays Lake. This contains the longest freshwater sequence presented here (6.6 m). The arcellacean assemblages indicate changes similar to those detected in Thibault and Midway Lakes (Table 15, Figure 6). Just below the surface (10 cm) the assemblage is enriched in *D. tricuspis* (which is not even present in surface samples) while *D. urceolata elongata* and *P. compressa* decrease markedly. Total numbers also increase markedly just below the surface and remain higher throughout the core down to 6.10 m. At 1.5 m the assemblage changes again as *P. compressa* becomes co-dominant and *D. tricuspis* decreases slightly. Below

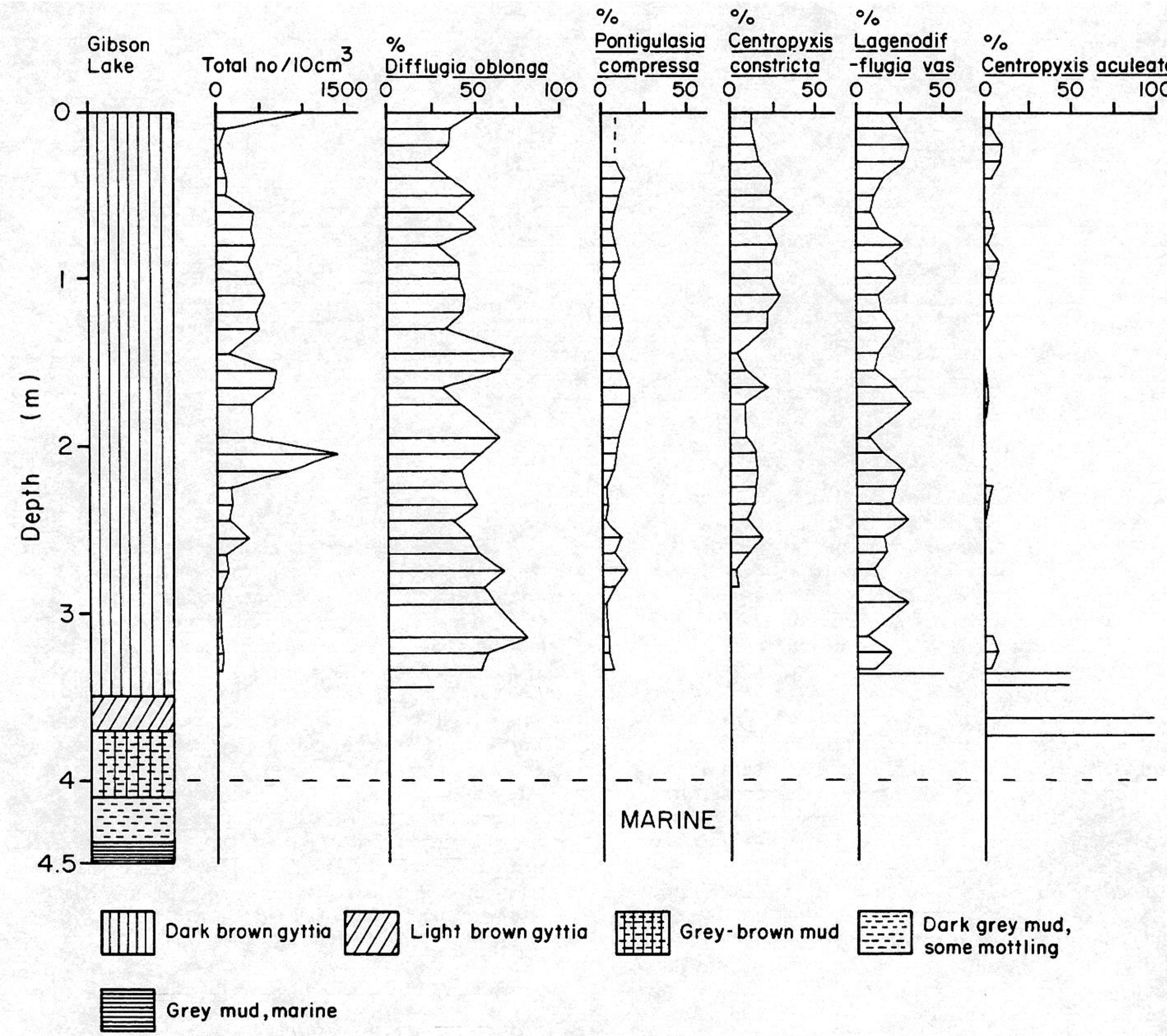

FIGURE 3. Lithology and biostratigraphy of Gibson Lake core. The lower section of the core (below 4.0 m) is marine and has been reported in Scott and Medioli (1980a).

5 m *Centropyxis* spp., particularly *C. aculeala.* become progressively more dominant down to 6.10 m where they are virtually the only species present. The core grades into a sandy base with no detectable marine sequence.

DISCUSSION

SURFICIAL SAMPLES

A summary of the data (Table 9) shows that *Difflugia oblonga* comprises at least 40% of all assemblages. Two other species, *Lagenodifflugia vas* and *Pontigulasia compressa.* are always among the five most abundant species. However all 14 species occur in all the lakes with varying percentages so that some sub-assemblages may be delineated. Most of the sub-assemblages are predictable, however, IC (with high *D. urceolala elongala* and IE (with high percentages of *D. urens)* have common species that are rarely reported in the literature and are not recorded in Lake Erie (Scott and Medioli, 1983). We had hoped to correlate assemblage variation.s and local geological setting, but found that lakes with similar geological settings commonly had different assemblages. Assemblage II may have been depth controlled, occurring in a lake where sample depths usually exceeded 10 m. Smith (1952) indicated that no oxygen depletion occurred in Bonaparte Lake but temperatures below the thermocline remained low all year. Similarly, the eastern basin of Lake Erie (the deepest part of the lake) has temperatures of 6°C all

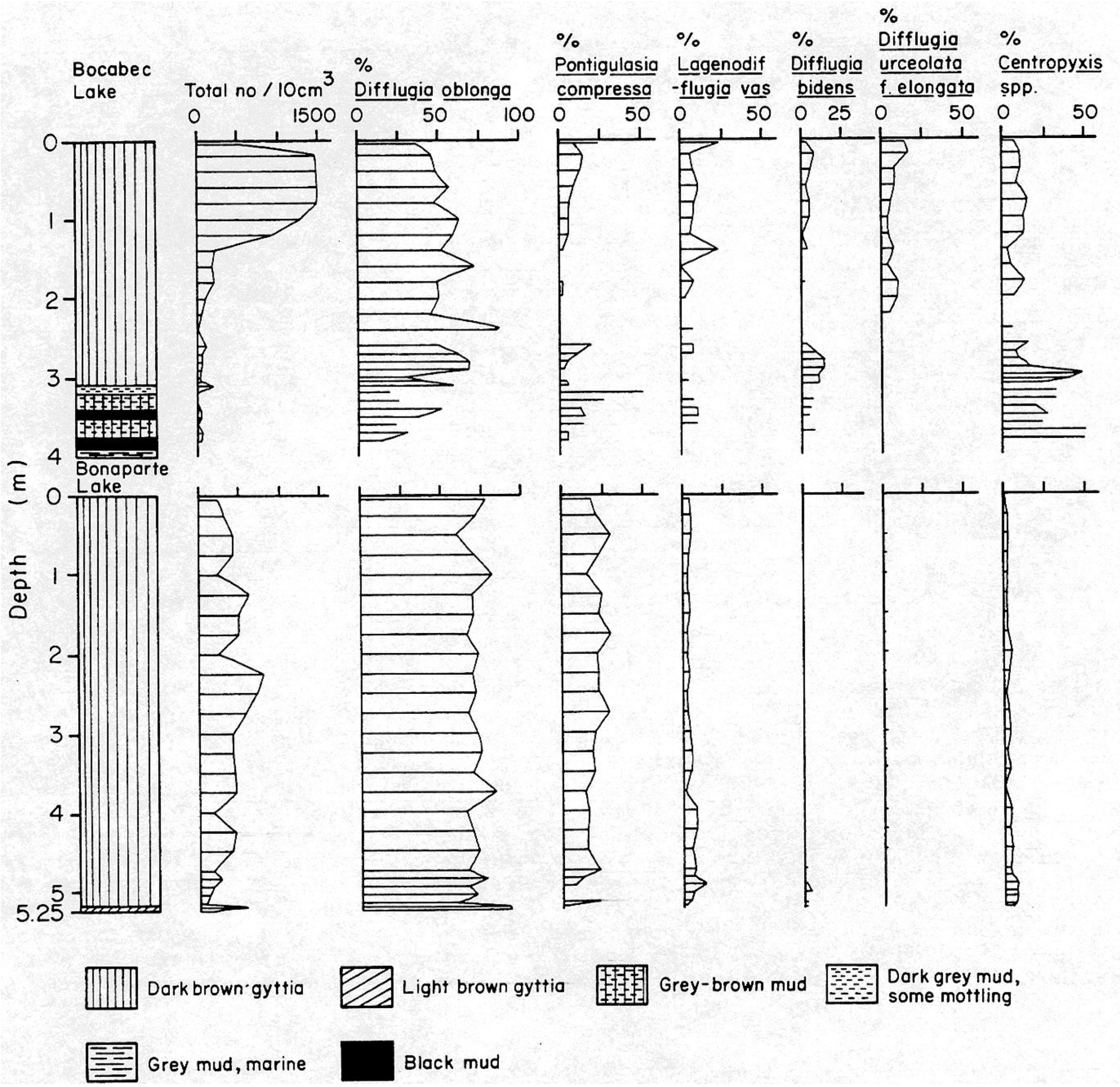

FIGURE 4. Lithology and biostratigraphy of Bocabec and Bonaparte lakes. In both lakes the lower sections (>4.0 m in Bocabec and >5.25 m in Bonaparte) are marine, as reported in Scott and Medioli (1980a).

year (Burns, 1976). Burns (1976) also notes that oxygen values are high in the deep bottom waters of Lake Erie. Both Bonaparte Lake and the eastern basin of Lake Erie have low total arcellacean populations (Scott and Medioli, 1983) and the similarity appears to be that neither bottom water mass ever warms above 6°C. Hence it appears that arcellaceans require high water temperatures at least part of the year to reproduce successfully, an observation already made for some shallow water foraminifera (Bradshaw, 1955, 1961).

The occurrence of one species, *Difflugia bidens*, even in its low numbers, can be linked to a high clastic input. The area around Bocabec Lake was subjected to deforestation by forest fire in 1970 and the area surrounding the lake contains easily erodable sandstone. Among lakes we have studied, only Lake Erie, which also has a high clastic input, has low percentages of *D. bidens* in the surface sediments (Scott and Medioli, 1983).

In these Maritime lakes the only large occurrence of *Difflugia tricuspis* (which lives in association with the floating alga *Spirogyra)* was in Deer Island Pond, significantly the only eutrophic lake sampled (that is, high planktonic algae content). The western basin assemblage in Lake Erie is dominated by *D. tricuspis* (Scott and Medioli, 1983) and this basin is also high in phy-

TABLE 11. Percentage occurrences of Arcellaceans down core in Bocabec lake.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES DOWN CORE FOR BOCABEC LAKE

Depth in Core (cm)	0-1	20-21	40-41	60-61	80-81	100-101	120-121	140-141	160-161	180-181	200-201	220-221
Total No. of Species	13	13	13	13	13	13	13	10	7	10	7	3
Total Number of Individuals per 10 cc	517	1482	2582	2264	1489	1314	989	209	176	217	85	24
Centropyxis aculeata	3.9	4.6	2.9	1.8	4.3	1.8	1.8	0.5	4	1.8	2.4	
C. constricta	2.9	6.5	8.8	5	11	9.8	10.2	1.9		10.1	4.7	
Difflugia bidens	1.7	5.7	5.2	2.6	5.1	3.4	0.1	1.9		0.92		
D. corona	0.58	0.27	0.31	0.22	0.8	0.9	0.9					
D. globulus			0.08		0.4	0.08	0.4					
D. oblonga	35.2	43.4	48.4	57	47.2	62.6	60	51.2	73.3	48.4	50.6	45.8
D. protaeiformis	1.9	0.4	1.1	0.75	1.3	0.38	1.1	1.9	1.7	1.4		
D. tricuspis	5.4	1.9	4.8	5	6.9	1.9	10	2.9	6.8	0.9		
D. urceolata	0.6	0.8	0.43	0.18	0.13	0.15	0.4					
D. urceolata f. elongata	13.7	16.7	7.3	8.04	5.7	3.3	3.7	7.7	2.8	9.7	8.2	4.2
D. urens	4.3	2.2	1.6	1.8	3.5	3.2	1.9	6.2	10.8	19.8	30.6	50
Lagenodifflugia vas	22.1	3.8	6.7	9.6	8.3	7.3	5.3	24.4	0.6	6	2.4	
Lesquereusia spiralis	0.97	0.6		0.09								
Pontigulasia compressa	6.8	13.1	12.3	8	5.3	5.2	4.1	1.4		0.92	1.2	

toplankton content (Munawar and Munawar, 1976). Schon born (1962) has shown that *D. Iricuspis* has a planktonic stage in its life cycle, hence requires food in the water column as well as on the lake bottom. Thus an abundance of *D. Iricuspis* indicates a lake in the eutrophic state.

Numbers of living individuals appear low in comparison with total numbers but this may reflect sedimentation rate rather than productivity. In most of these lakes 1 cm of sediment equals at least 10 years of deposition and presumably, with the living population, we are looking only at the last year. Hence living/total ratios of 1/10 are not low in the upper 1 cm of sediment. Where they are higher (Journeays Lake) sedimentation rates should be higher; in fact Journeays Lake did have the greatest thickness of sediment observed in any of the lakes.

Inter-station variation of percentage occurrences was low in most assemblages, at least for *D. oblonga* (as reflected by standard deviation (SD) in Table 9). It was higher for less common species. Variation in total numbers, however, was usually quite high between stations, sometimes with SD exceeding X (for example, Assemblage lA, Table 9). It is important to note that in all but two lakes, X for the total population exceeded $500/10\ cm^3$ which is more than adequate for statistical

TABLE 12. Percentage occurrences of Arcellaceans down core in Bonaparte Lake.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES DOWN CORE FOR BONAPARTE LAKE

Depth in Core (cm)	0-1	25-26	50-51	75-76	100-101	125-126	150-151	175-176	200-201	225-226	250-251	275-276	300-301	325-326	350-351	375-376	400-401	425-426	450-451
Total # Species	5	8	10	10	6	7	8	7	11	9	9	9	10	8	9	6	8	11	8
Total # Indivuduals/10cc	243	296	366	416	221	609	523	490	207	809	719	567	383	416	451	446	160	436	409
Centropyxis aculeata	0.4		0.8	1.2	1.4	0.66	0.76	0.2	1.4	0.6	0.28	0.53	2.3		1.8		3.1	0.9	1.2
C. constricta		0.68	1.36	0.24		0.66	0.76	1.2	1.9	1.1		0.53		0.48		0.22		1.1	2.9
Difflugia corona		0.68	0.27	0.24				0.6	0.48	0.12		0.7	0.26	0.72	1.8	0.9	0.6	1.1	1.7
D. globulus		0.68	1.6	1.9	0.45				0.48	0.12	0.14	0.35	0.52	0.24	0.22		0.6	0.46	
D. oblonga	77.8	72.3	59	70.4	81.9	70	70.4	66.7	73.4	70.3	73.7	66.1	72.1	75	70	85.2	65	70.6	73.3
D. protaeiformis		0.68		0.24							0.14		0.26					0.23	
D. tricuspis								0.2			0.14	0.35	0.52		0.89		6.25	2.8	3.2
D. urceolata				0.24					0.48		0.28								
D. urceolata f. elongata	0.4		1.6	0.96	0.45	1	0.76		0.48	0.87	0.83	0.35	1.3	0.48	0.44		1.25	0.46	0.73
D. urens		0.34	0.5				0.2		0.48							0.22			
Lagenodifflugia vas	2.9	3.7	3.8	1.9	1.4	3.1	3.1	2.4	1.9	4	1.2	2.3	2.9	5.8	4	0.22	6.9	6.9	2.7
Lesquereusia spiralis			0.27			0.16	0.2		0.48	0.12			0.26	0.24	0.22			0.23	
Pontigulasia compressa	18.5	20.9	30.6	22.6	14.5	24.5	23.9	28.6	18.4	22.7	23.2	28.7	19.6	17.1	20.8	13.2	16.3	15.1	14.2

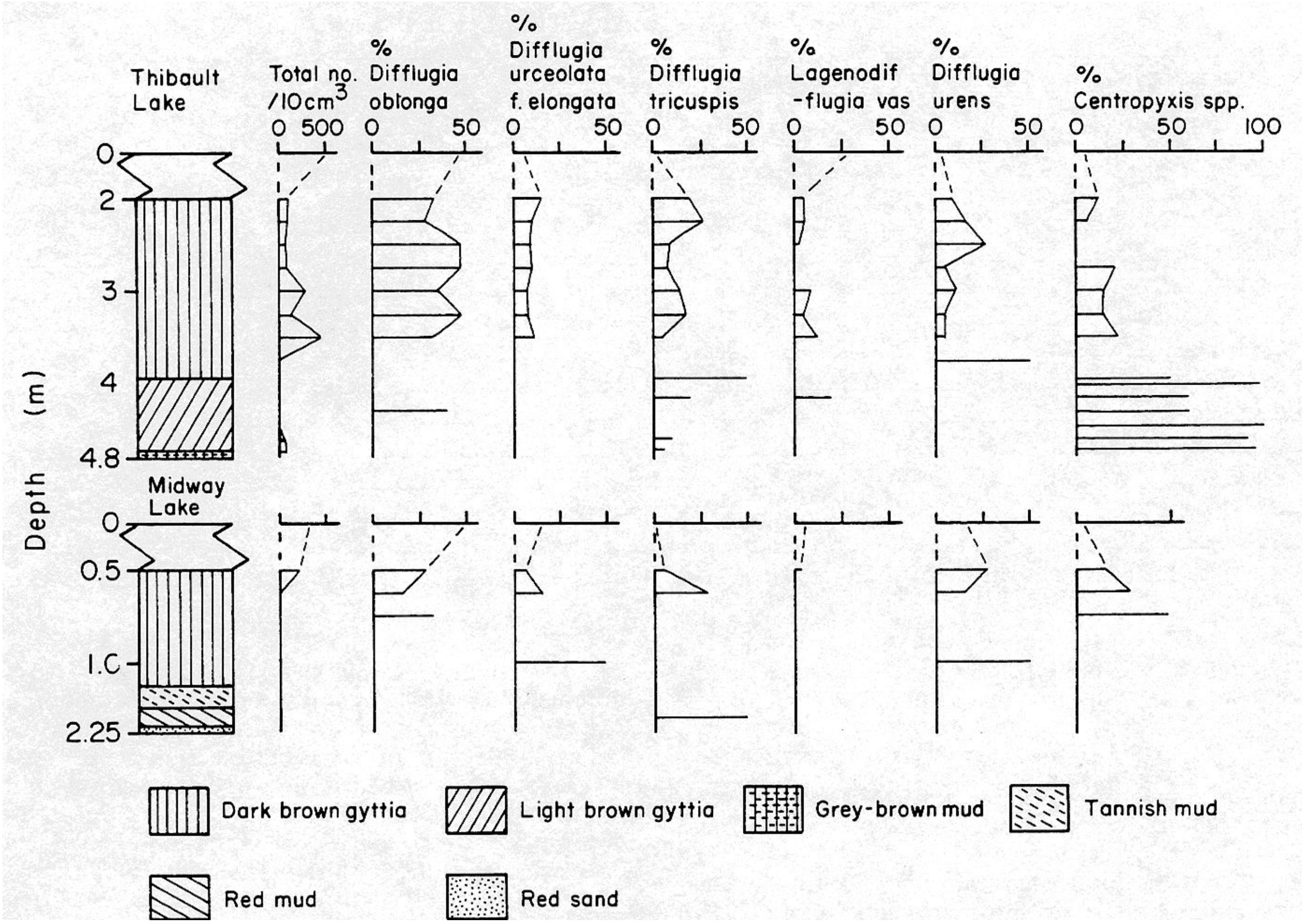

FIGURE 5. Lithology and biostratigraphy of Thibault and Midway lakes.

purposes, and is comparable with numbers observed in Lake Erie (Scott and Medioli, 1983).

Only one other quantitative study, comparable to this study, has been carried out in North America: a study in Lake Erie (Scott and Medioli, 1983). Assemblage variation observed there within the lake was greater than any variations observed between lakes here. *Difflugia oblonga* was the dominant form only in the central basin of Lake Erie; *D. tricuspis* and *D. urceolata* (dominates in parts of Lake Erie) are comparatively rare in New Brunswick and Nova Scotia. Arcellaceans do respond to environmental changes and the uniformity of assemblages in these lakes reflects the uniform nature of the small lakes in this region. More work must be done to determine if the small sub-assemblage variations in these small lakes can be associated with specific water characteristics. This will require extensive testing oflakes for a variety of characteristics, particularly those lakes with unusual faunas.

CORE STUDIES-NEW BRUNSWICK LAKES

The three cores presented here indicate that little change has occurred throughout the fresh bottom water interval of these lakes, particularly Bonaparte Lake. It may be significant that Bonaparte is the deepest lake and therefore buffered against radical seasonal-climatic variations. It is significant however that *D. bidens* occurs near the base of the freshwater interval in all three cores. This corresponds to the emergence of the basin out of the sea (Scott and Medioli, I980a); a time when the local area would have had little vegetation and higher clastic input to the basins. This is in accordance with a *D. bidens* correlation to high clastic input. The *D. bidens* occurence at 60cm in Gibson Lake may correspond to a forest fire in prehistoric times. The sustained occurrence of *D. bidens* in Bocabec Lake suggests this lake has always had a strong terrigenous input.

At the freshwater-marine transition of each of these cores, *Cencropyxis aculeata* becomes dominant, although in low numbers. This species appears to tolerate low salinitie's (probably >1-2%) as reported by nu-merous authors and observed by Scott and Medioli (1980c) in high marsh areas. Most other arcellaceans are exceedingly sensitive to even minimal changes in salinities, much more than their marine counterpart, the foraminifera, which commonly live in areas where salinity might vary by 20% on a single tidal cycle (Scott and others, 1980; Scott, 1977). Hence arcellaceans provide us with the link between extreme tidal conditions

TABLE 13. Percentage occurrences of Arcellaceans down core in Thibault Lake.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES DOWN THIBAULT LAKE CORE

Depth in Core (cm)	201-202	224-225	249-250	274-275	294-300	324-325	349-350	374-375	394-395	399-400	414-415	429-430	444-445	459-460	471-474
Total No. of Species	8	10	6	8	9	9	11	1	2	1	3	2	1	3	3
Total Number of Individuals/10 ml	71	78	34	31	255	94	465	2	2	3	5	10	1	19	36
Centropyxis aculeata	5.6	3.8		9.7	2.7	2.1	4.3		50	100	60	60	100	84.2	44.4
C. constricta	5.6	1.3		9.7	9.8	11.7	17.2							5.3	50
Difflugia corona		1.3		3.2	2.7	3.2	3.4								
D. oblonga	33.8	28.2	47.1	48.4	36.1	46.8	31.1					40			
D. tricuspis	18.3	25.6	8.8	6.4	12.9	17	5.6		50		20			10.5	5.6
D. urceolata							0.2								
D. urceolata f. elongata	14.1	11.5	8.8	9.7	7.1	7.4	11								
D. urens	8.5	16.7	26.5	3.2	11.4	4.3	3.6	100							
Lagenodifflugia vas	4.2	5.1	2.9		10.2	4.3	13.5				20				
Lesquereusia spiralis		1.3					0.22								
Pontigulasia compressa	9.8	5.1	5.9	9.7	7.1	3.2	9.7								

(high marsh) and fully freshwater conditions, a factor not detectable with most other microfossils.

CORE STUDIES-NOVA SCOTIA LAKES

In contrast to New Brunswick all three lakes investigated here show significant changes between surface assemblages and core assemblages. In all three cores, *D. tricuspis* increases significantly just below the surface. This suggests that mean amounts of suspended phytoplankton and/or nutrients were more abundant in the recent past. This factor has no obvious link with present conditions; in fact, with increased human population, more nutrients (pollution) would be expected now than in the past. In Thibault Lake, *D. urens* increases sharply in the subsurface so that the subsurface assemblage of this lake is closer to the surface assemblage of Midway Lake. Extensive work on these individuallakes will be required to determine the meaning of these assemblage changes. *Difflugia bidens* does not occur in any of these cores, suggesting either that it did not reach the area or, more likely, that vegetation cover around these lakes was well-developed before deposition started here.

In two lakes, Journeays and Thibault, C. *aculeata* is dominant in low numbers near the bottom of the cores, suggesting some salinity influence as observed in the known former marine basins of New Brunswick. These two lakes are at or below the suggested marine limit for the area and conceivably could have been influenced by the ocean even though no foraminiferal fauna is present below the freshwater material. Significantly, Midway Lake is distinctly above the marine limit, and has no significant occurrence of C. *aculeata* in the base of the core. A C^{14} date of 11,000 ybp at 636-659 3cm in the Journeays Lake core fits well with the suggested former high sea level of that time.

GENERAL OBSERVATIONS ON CORE MATERIAL

Pollen records (Mott, 1975) indicate that climate has changed significantly in this area during the last 8,000-11,000 years for this area. The arcellacean record shows no corresponding changes, and it appears that either the species and/or the lakes themselves (at least the bottom water) do not respond to climatic changes. This appears contradictory to the apparent temperature requirement for arcellaceans and leads to the conclusion

PLATE 1

1-3 *Difflugia urceolata elongata* Penard, 1902. 1. Side view of typical specimen; x :270. 2. Side view of another specimen; x 305. 3. Apertural view of same specimen; x 250. 4-12 *Difflugia oblonga* Ehrenberg, 1832. 4. Side view of specimen displaying a bifurcated neck; x 138. 5. Side view of laterally flattened specimen with many small spines; x 134. 6. Side view of specimen with wide neck and coarse. agglutination; x 223. 7. Apertural view of same specimen; x 223. 8. Side view oflaterally compressed specimen; x 155. 9. Side view oflaterally compressed specimen with lateral spines; x250. 10. Side view of typical specimen with spine; x223. 11. Side view of typical specimen; x160. 12. Side view of specimen with coarse agglutination in neck, tending towards *Lagenodifflugia vas;* x 143.

13-16 *Lagenodiffiugia vas* (Leidy), 1874. 13. Side view of specimen with prominent constriction; x 133. 14. Side view of typical specimen; x 154. IS. Side view of sped men with narrow neck; x 184. 16. Side view of specimen with pronounced constriction and narrow neck; x 167.

17,18 *Difflugia globulus* (Ehrenberg), 1848. 17. Apertural view of specimen with diatom incorporated; x 270. 18. Side view of two specimens attached to each other; x 200.

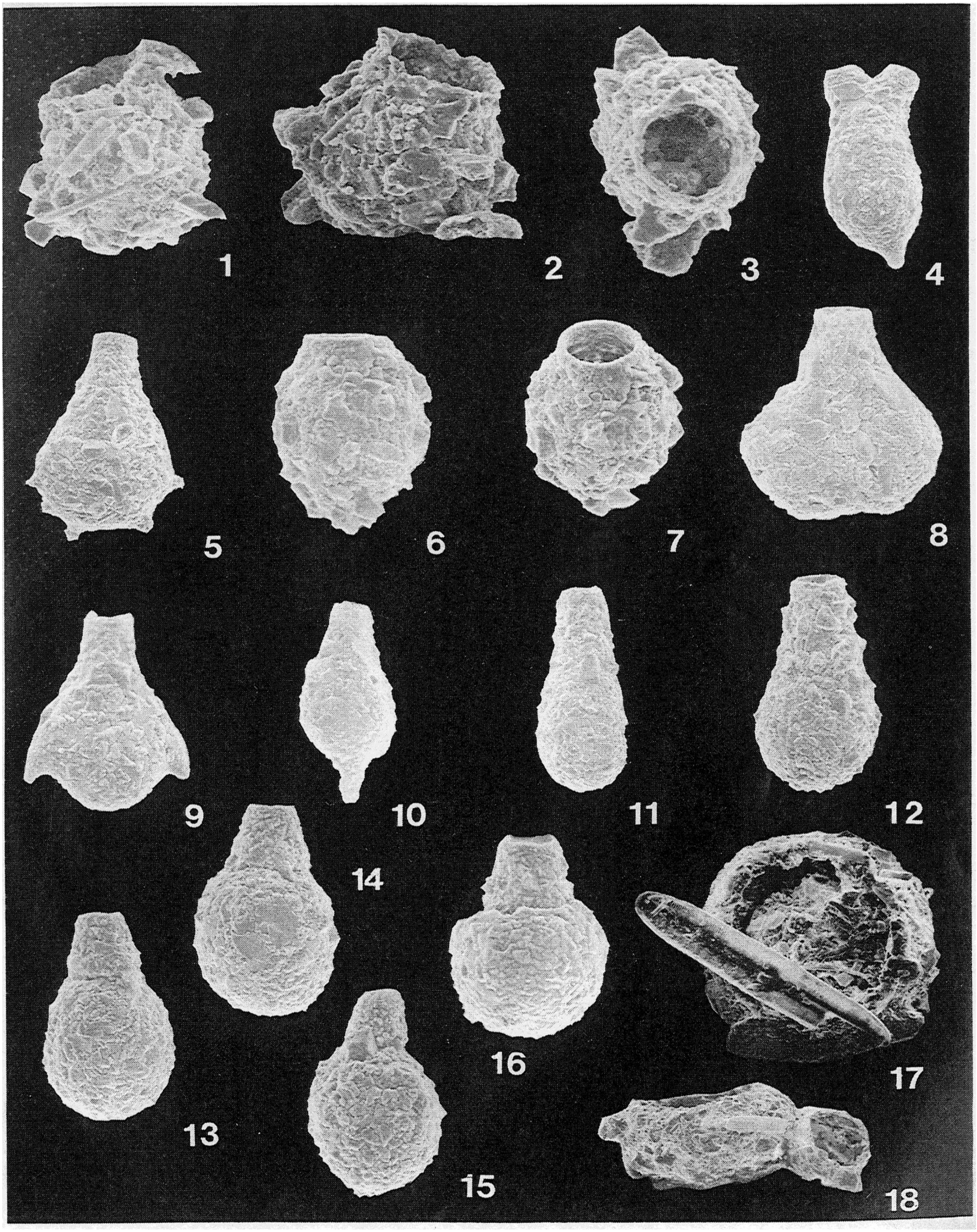
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TABLE 14. Percentage occurrences of Arcellaceans down core in Midway Lake.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES DOWN MIDWAY LAKE CORE

Depth in Core (cm)	51-52	74-75	99-100	124-125	149-150	174-175	199-200	214-215	224-225
Total No. of Species	9	5	3	0	2	0	0	1	0
Total Number of Individuals/10 ml	227	7	6	0	2	0	0	1	0
Centropyxis aculeata	15	28.6	50						
C. constricta	5.3								
Difflugia corona	3.5								
D. oblonga	28.6	14.3	33.3						
D. tricuspis	3.1	28.6						100	
D. urceolata f. elongata	4.4	14.3			50				
D. urens	27.3	14.3			50				
Lagenodifflugia vas	2.2								
Pontigulasia compressa	10.6		16.7						

that conditions in bottom sediments in these lakes are somewhat buffered from severe climatic changes.

A potentially important use of Arcellacean assemblages downcore would be the detection of the effects of "acid rain" on the lake environments. Although it is easy to measure the pH oflake water, it is impossible to directly measure pH in lakes prior to the period when "acid rain" is presumed to have started. Hence if arcellaceans were sensitive to pH, they would be invaluable in determining pH trends in a paleolimnological sense. At the time of sampling we made no pH measurements (such one-time measurements would not be particularly useful anyway) and do not know whether or not these lakes are acidic. However qualitative assessment oflake basins (that is, limestone vs. volcanics or granites) indicates that some lakes are probably acidic and others either neutral or alkaline, but no faunal trends can be associated with these bedrock differences.

ABBREVIATED TAXONOMY

Although this paper is not taxonomic in nature, all species discussed are illustrated here. A major taxo-

PLATE 2

1-6 *Difflugia corona* Wallich, 1864. 1. Side view of specimen with several spines; x266. 2. Apertural view of same specimen with 3 crenulations; x 227. 3. Apertural view of specimen with 4 crenulations; x 265. 4. Apertural view of specimen with 5 crenulations; x 220. 5. Apertural view of specimen with 13 crenulations; x 330. 6. Apertural view of specimen with 13 crenulations and diaphragm; x 270.

7, 8 *Pontigulasia compressa* (Carter), 1864. 7. Side view of specimen with typical v-constriction at base of neck; x 198. 8. Apertural view of same specimen; x 243.

9, 10 *Lesquereusia spiralis* (Ehrenberg), 1840. 9. Side view of specimen with short neck; x 336. 10. Side view of typical specimen; x 520.

11,12 *Difflugia urceolata* Carter, 1864. 11. Side view of specimen with well-developed apertural lip; x 152. 12. Side view of encysted specimen (test broken open); x 135.

13, 14 *Difflugia bidens* Penard. 1902. 13. Side view of typical specimen; x 167. 14. Side view of specimen with slightly developed neck; x 170.

15,16 *Difflugia tricuspis* Carter, 1856. 15. Side view of typical specimen; x510. 16. Apertural view of same specimen; x620.

PLATE 3

1,2 *Difflugia tricuspis* Carter, 1856. 1. Side view of specimen with slightly developed apertural lip; x460. 2. Apertural view of specimen with well-developed apertural lip; x 520.

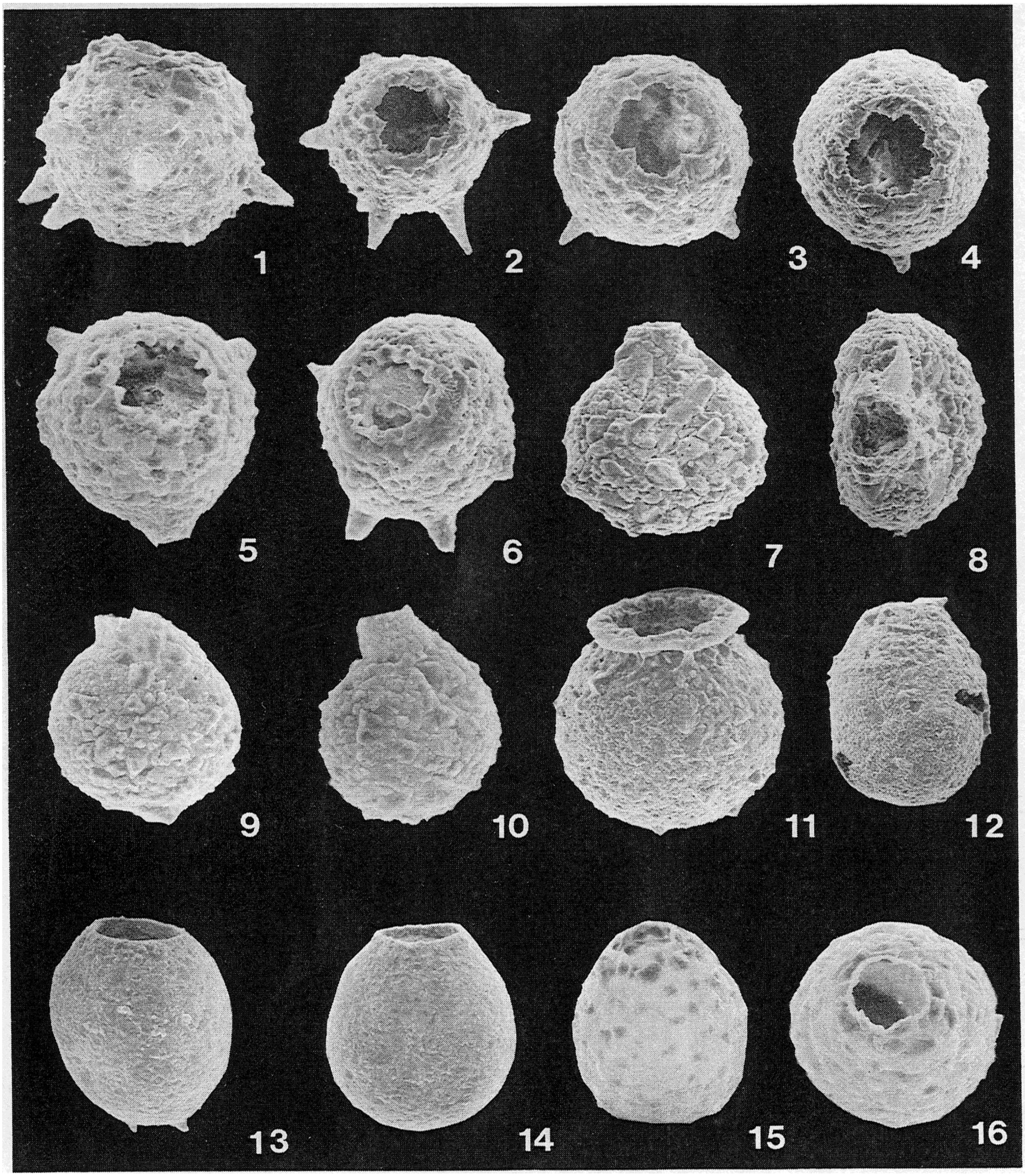
3, 4 *Difflugia protaeiformis* Lamarck, 1816. 3. Side view of specimen with coarse agglutination; x 184. 4. Side view of autogenous (Scott and MedioH, 1983) specimen; x 252.

5-14 *Difflugia urens*, n. sp. 5. Side view ofholotype with coarse agglutination (USNM 382217); x 249.6. Apertural view ofholotype showing apertural lip development; x 265. 7. Side view of paratype with diaphragm (USNM 382218); x 255. 8. Apertural view of same paratype; x277. 9. Side view of specimen with well-developed apertural lip; x201. 10. Side view of paratype (USNM 382219); x 235. 11. Apertural view of same paratype with diaphragm partly blocking aperture; x 206. 12. Apertural viewof para type (USNM 382220); x263. 13. Side view of same paratype with thickened apertural lip; x 194. 14. Side view of specimen with wide neck tending towards *Difflugia urceolata;* x 236.

PLATE 4

1-7 *Centropyxis aculeata* (Ehrenberg), 1832. 1. Dorsal view of specimen with a number of spines extending farther anteriorly than usual; x 181. 2. Dorsal view of specimen with 6 spines and little agglutination; x205. 3. Anterior view of same specimen showing the high angle of the spines to the horizontal; x 303. 4. Anterio-ventral view of broken specimen; x 310. 5. Ventral view of same broken specimen showing broken spines; x 272. 6. Side view of agglutinated specimen with an anterior depression; x 263. 7. Dorsal view of same specimen, which is almost circular; x217.

8-14 *Centropyxis constricta* (Ehrenberg), 1843.8, 12. Specimen with broken spines. 8, Ventral view; x291. 12, Anterior view; x41O. 9. Ventral view of multi spined specimen; x256. 10. Ventral view of specimen with 7 spines; x 290. II. AperturaI view of same specimen, not an invaginated aperture; x440. 13. Ventral view of specimen with 5 spines and slightly inclined aperture; x237. 14. Apertural view of same specimen, showing a ventral flattening more pronounced than usual; x 302.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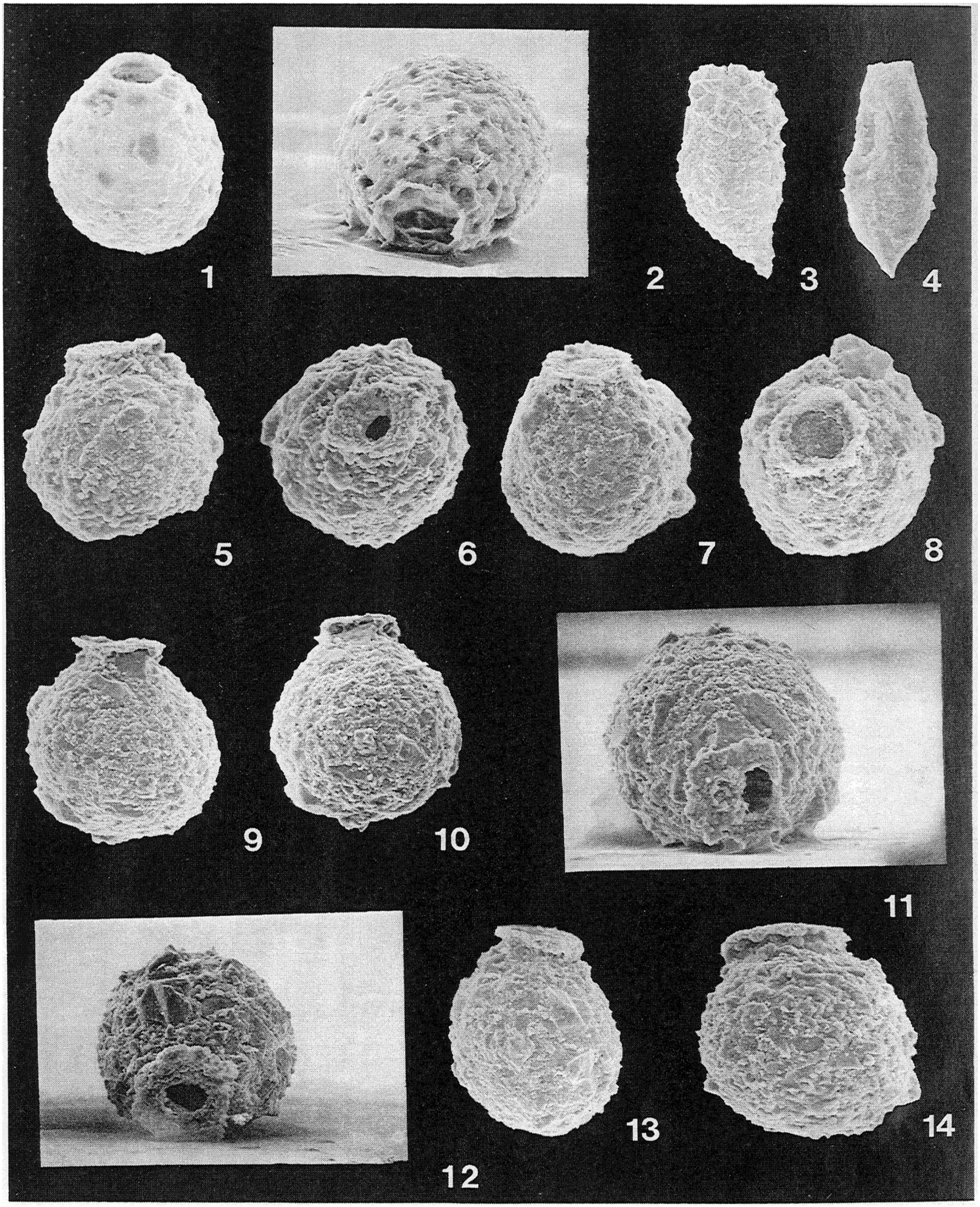
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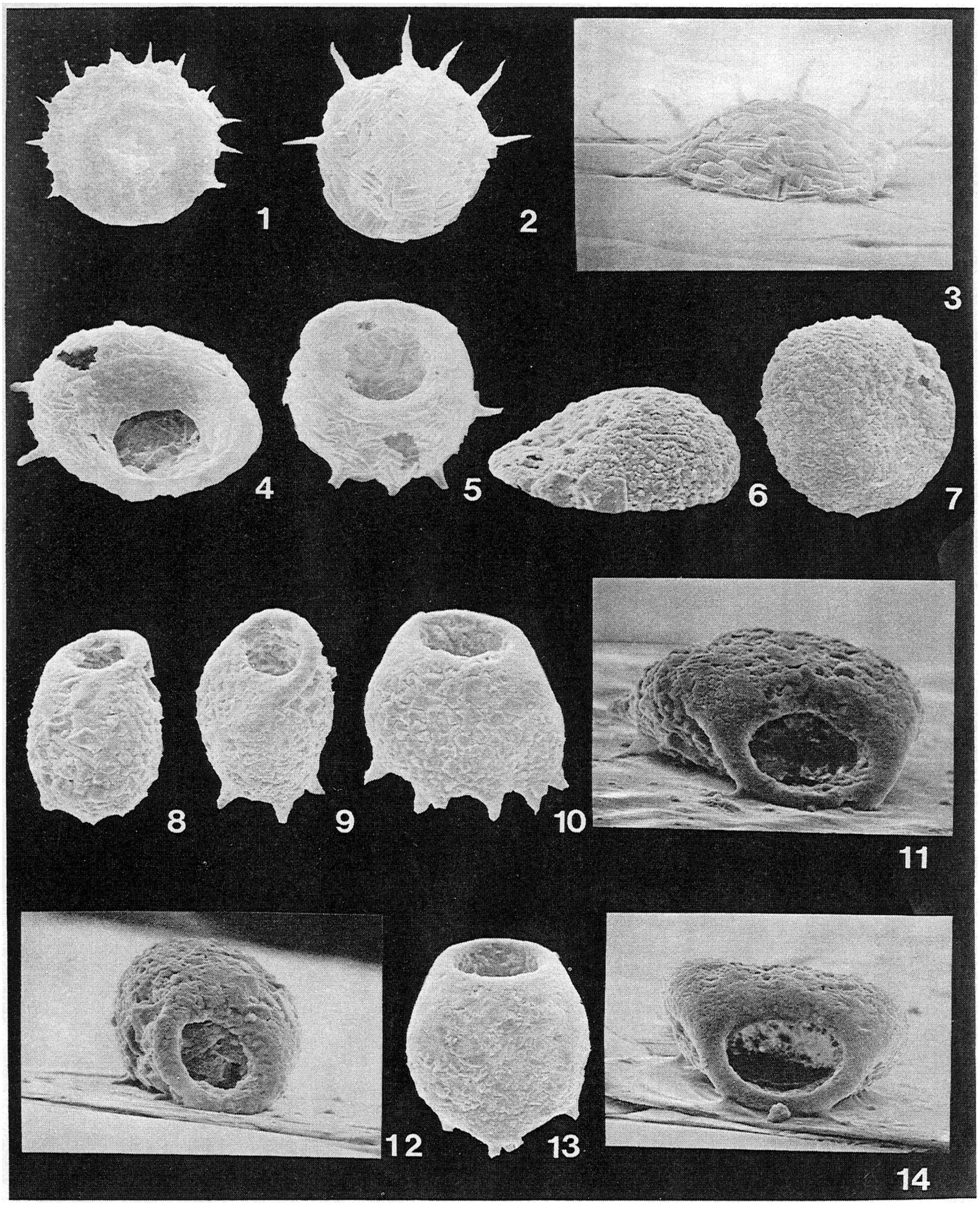
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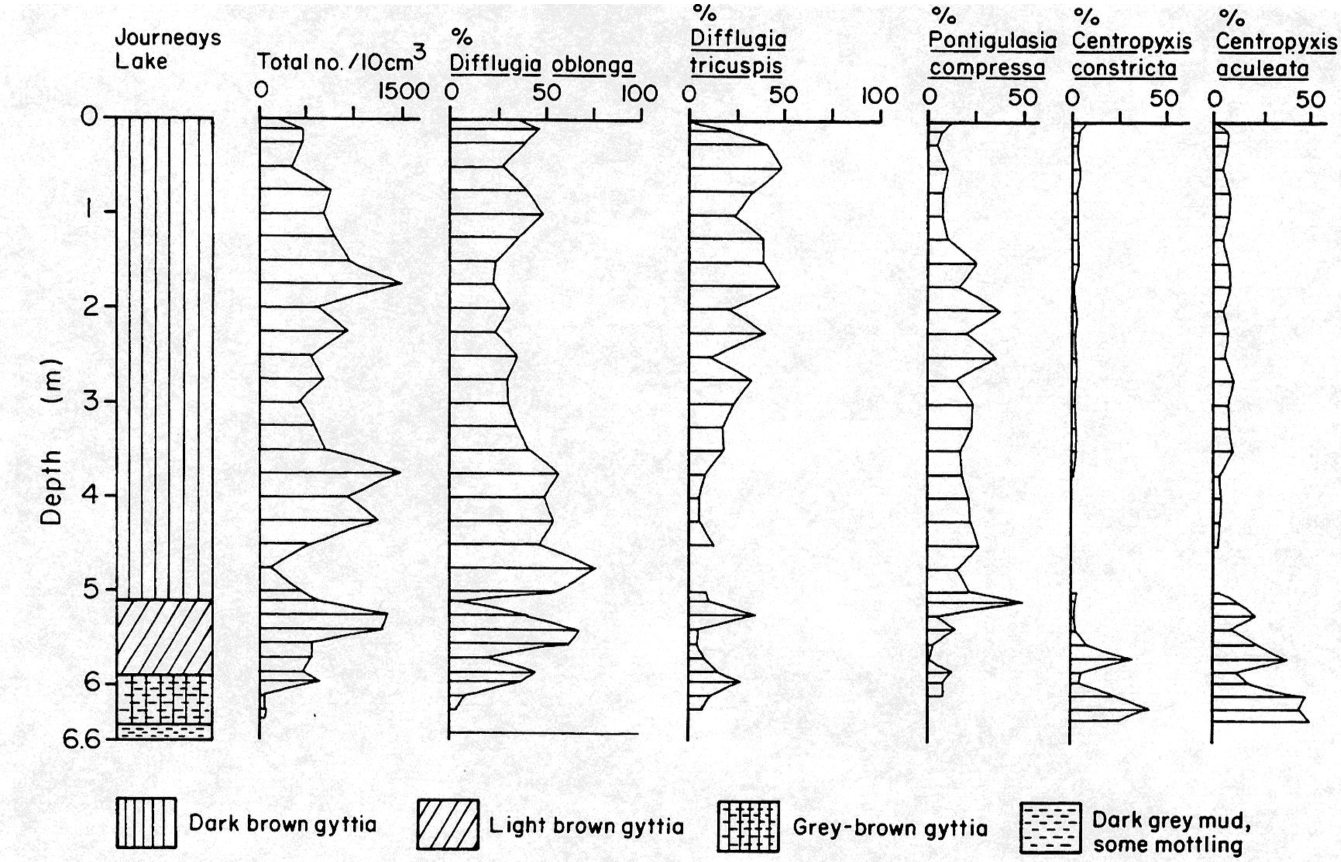

FIGURE 6. Lithology and biostratigraphy of Journeays Lake.

nomic study of Arcellacea from eastern Canada (Medioli and Scott, 1983) includes lengthy taxonomic discussions of each species, hence only the original species reference is presented here. However, three species herein were not illustrated by Medioli and Scott *(l983)-D. urens,* n.sp., *D. urceolata elongata* Penard, and *Lesquereusia spiralis* Ehrenberg.

Generic names are in accordance with Loeblich and Tappan (1964) and most species names are those used by Leidy (1879).

SYSTEMATIC TAXONOMY

Centropyxis aculeata (Ehrenberg), 1832
Pl. 4, Figs. 1-7

Arcella aculeata EHRENBERG,1832, p. 91.

Centropyxis constricta (Ehrenberg), 1843
Pl. 4, Figs. 8-14

Arcella constricta EHRENBERG, 1843, p. 410, pl. 4, fig. 35; pl. 5, fig. I.

Difflugia protaeiformis Lamarck, 18 16
Pl. 3, Figs. 3, 4

Difflugia protaeiformis LAMARCK, 1816, p. 95 (with reference to material in a manuscript by LeClerc, 1816).

Difflugia bidens Penard, 1902
Pl. 2, Figs. 13, 14

Difflugia bidens PENARD, 1902, p. 264, text-figs. 1-8.

Difflugia corona Wallich, 1864
Pl. 2, Figs. 1-6

Difflugia proteiformis (sic) Ehrenberg subspecies *D. globularis* (Dujardin) var *D. corona* WALLICH, 1864, p. 244, pl. 15, fig. 4a-c, pl. 16, figs. 19, 20.

Difflugia globulus (Ehrenberg), 1848
Pl.1, Figs. 17, 18

Arcella (?) *globulus* EHRENBERG, 1848, p. 379.

Difflugia oblonga Ehrenberg, 1832
Pl. 1, Figs. 4-12

Difflugia oblonga EHRENBERG, 1832, p. 90.

Difflugia tricuspis Carter, 1856
Pl. 2, Figs. 15, 16

Difflugia tricuspis CARTER, 1856, p. 221, pl. 7, fig. 80.

Difflugia urceolata Carter, 1864
Pl. 2, Figs. 11, 12

Difflugia urceolata CARTER, 1864, p. 27, pl. 1, fig. 7.

TABLE 15. Percentage occurrences of Arcellaceans down core in Journeays Lake.

PERCENTAGE OCCURRENCES OF ARCELLACEAN SPECIES DOWN JOURNEAYS LAKE CORE

Depth in Core (cm)	1-2	24-25	49-50	74-75	99-100	124-125	149-150	174-175	197-198	224-225	249-250	274-275	299-300	324-325	349-350	374-375
Total # of Species	10	9	9	11	9	10	10	10	10	10	10	10	10	10	10	11
Total # Individuals/100 ml	446	425	317	759	645	765	946	1517	592	923	527	626	412	596	702	1625
Centropyxis aculeata	6.5	6.1	3.5	8.7	7.9	5	6.2	6.7	4.4	6	5.1	9.4	7.3	7.7	10.3	2.2
C. constricta	1.8	1.9	2.2	1.7	1.1	0.78	0.84	0.46	1.4	0.76	1.5	0.64	0.73	1	2.8	0.25
Difflugia corona	1.3	1.6		1.2		1.3	0.53	0.4	0.84	0.3	1.3	1.3	0.48	0.84	1.1	1.05
D. oblonga	48	37.6	26.8	38.7	48.2	36	23.2	21	30	23.8	35.3	28.9	30.6	33.7	38.9	57.2
D. protaeiformis	6	5.2	2.2	2.8	3.7	2.5	0.74	2.2	2.4	1.4	1.7	3.5	1.7	3	2.7	5
D. tricuspis	19	39.3	49	34.1	23.6	37	38.2	49	17.4	40.2	10.1	32.3	24.3	18.4	17.8	8.1
D. urceolata				0.13			0.1	0.06								0.06
D. urceolata f. elongata	3.4		1.3	2.2	5	2.7	2.3	2	2.5	2.5	3.8	3.4	5.1	4	2.4	1.7
Lagenodifflugia vas	5.2	1.4	2.2	1.2	0.31	2.7			3.9	3	4.9	3.2	5.3	5.5	4.3	5
Lesquereusia spiralis	1.8	1.4	2.8	1.7	2.9	1.7	1.1	2	1.5	1.7	1.1	2.9	1.9	2.3	2.8	0.8
Pontigulasia compressa	7	5.4	10.1	7.5	7.3	10.2	26.8	16	35.5	20.3	35.1	14.5	22.6	23.3	16.8	18.7

Depth in Core (cm)	399-400	424-425	449-450	474-475	499-500	509-510	524-525	539-540	554-555	569-570	584-585	595-596	609-610	624-625	635-636	638-639	650-651	658-659
Total # of Species	10	10	10	5	9	9	10	11	10	7	10	10	5	6	3	0	1	0
Total # Individuals/100 ml	909	1264	480	90	378	690	1321	1283	525	269	429	670	53	63	50	0	2	0
Centropyxis aculeata	2.5	2	2.1		0.79	12.9	22.8	6.2	22.7	39.4	11	16.1	56.6	44.4	70			
C. constricta	0.66	0.32	1.04		2.1	2.5	0.9	1.9	6.7	33.1	4.4	5.4	24.5	42.8	28			
Difflugia corona	0.66	0.79	1.9	2.2	1.3		0.15	0.31	0.2		0.47	0.3						
D. oblonga	50	54.2	45.8	77.8	54	4.5	36.6	68.1	62.1	15.2	45.4	36.6	7.5	3.2			100	
D. protaeiformis	8.9	6.6	0.62			6.2	0.45	0.4	0.38		2.3	3.6						
D. tricuspis	5.2	5.2	12.9		9	10.7	34.2	4.7	5.5	8.9	16.3	26.1	9.4	6.3				
D. urceolata								0.08										
D. urceolata f. elongata	2.3	2	2.7		1.3	1.4	0.45	0.62	0.74	1.5	1.9	1.6		1.6				
Lagenodifflugia vas	5.1	4.7	4.8	2.2	6.3	8.1	2.4	1.3	0.57	1.5	2.8	1.6						
Lesquereusia spiralis	1	1.1	0.62	3.3	3.4	1.7	0.08	0.86	0.2		2.6	2.2	1.9	1.6	2			
Pontigulasia compressa	23.8	23.1	27.5	14.4	21.7	51.9	1.9	15.4	1.3	0.37	12.8	6.4						

Difflugia urceolata elongata Penard, 1902
Pl. 1, Figs. 1-3

Difflugia lebes var. *elongala* PENARD, *1902* p. 270, text-fig. 2, p. 271.

Remarks. We have placed this subspecies into *D. urceolata* since Medioli and Scott (1983) had already made *D. lebes* a junior synonym of *D. urceolata.* This subspecies was not observed in Lake Erie (Scott and Medioli, 1983) and does not appear often in the literature. It is relatively common in the Maritime Lakes and could be a local indicator species.

Difflugia urens, n. sp.
Pl. 3, Figs. 5-14

Difflugia urnula (Gruber), 1884. PATTERSON,1983, p. 29, pI. 3, figs. 5-14.

Holotype. One specimen from Midway Lake, Nova Scotia, Station 5, Pl. 3, Fig. 5, 6 this paper (USNM No. 382217).

Paratypes. Three paratypes are illustrated, all from Midway Lake, Nova Scotia, Station 5: USNM 382218 (Pl. 3, Figs. 7, 8); USNM 382219 (Pl. 3, Figs. 10, 11); and USNM 382220 (Pl. 3, Figs. 12, 13).

Type locality. Station 5, Midway Lake, Nova Scotia, Canada.

Trivial name. From the Latin verb: "uro," the secondary meaning of which is "to annoy, to make angry." "Urens" then means "'annoying-irritating."

Description. Test is brown and composed of mineral (usually quartz) fragments. Shape is subspherical, with a narrow circular aperture, bordered by an outward expanded flanged collar of variable width. A complete or partial diaphragm across the aperture may be present. In some specimens (not illustrated here) the aperture was completely obscured or absent.

Remarks. Initially this species was placed in *Ovulina urnula* Gruber (1884); however, re-examination of Gruber's paper indicated that he found his specimens only in a marine environment and what he reported was probably a foraminiferal species. The local occurrence of this species indicates that it may be a local indicator species similar to *D. urceolata elongata.*

Lagenodifflugia vas (Leidy), 1874
Pl.1, Figs. 13-16

Difflugia vas LEIDY, 1874, p. 155.

Lesquereusia spiralls (Ehrenberg), 1840
Pl. 2, Figs. 9, 10

Dijflugia spiralis EHRENBERG, 1840, p. 199.

Pontigulasia compressa (Carter) 1864
Pl. 2, Figs. 7, 8

Difflugia compressa CARTER, 1864, p. 22, pl. 2, figs. 5, 6.

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