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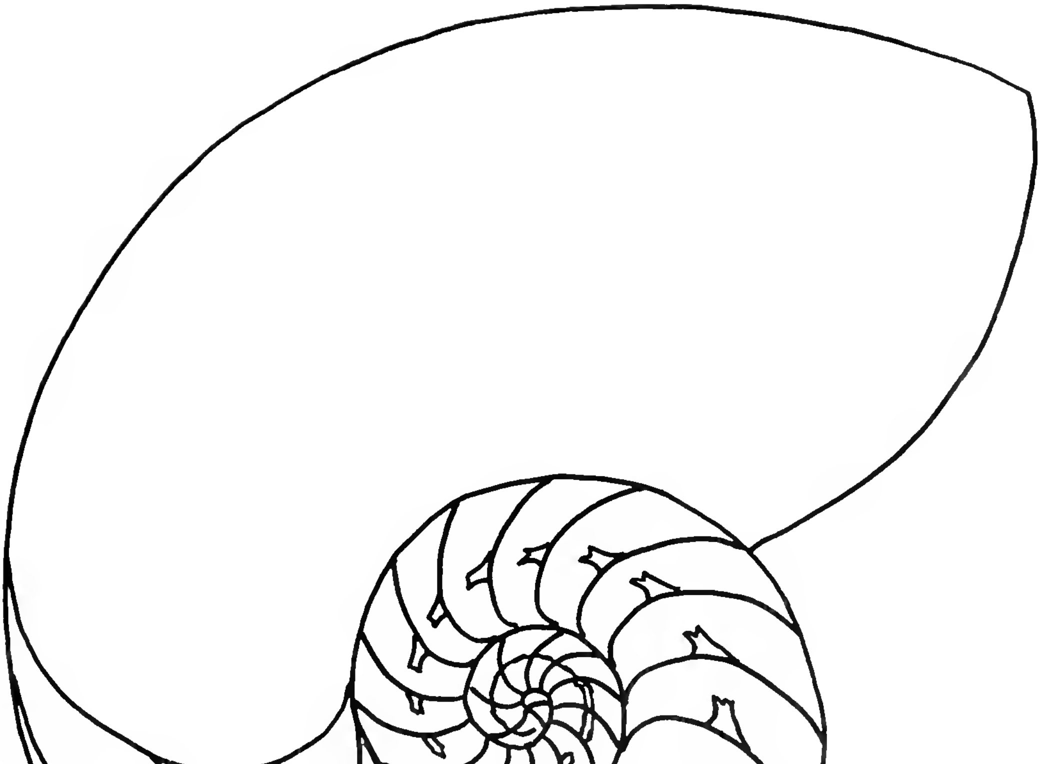

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CONTENTS

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(signed) R Tucker Abbott, Editor

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DIVERSITY AND DISTRIBUTION OF MUSSELS (BIVALVIA: UNIONACEA) IN A EUTROPHIC RESERVOIR, LAKE ASHTABULA, NORTH DAKOTA

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ABSTRACT

Lake Ashtabula, a 28-year-old eutrophic reservoir on the Sheyenne River in southeastern North Dakota, was surveyed for mussels by scuba diving during the summer of 1974. Belt transects, 20 m by 1.75 m and paralleling depth contours, were run at six stations at each meter depth, usually to 6 m. Four species, in order of decreasing abundance, were found in the lake: Anodonta grandis *Say,* Lampsilis radiata *(Gmelin),* Amblema plicata *(Say), and* Lasmigona complanata *(Barnes). Eight species are known in the river above the lake and 11 species below the lake. Lake individuals of* A. grandis *were conspicuously smaller than those in the river; most (82.7%) had about two or three winter rings, and the largest had about five. Individuals of* L. radiata*, however, were of a size about normal for those in the river; the largest individual had about seven winter rings. Most mussel individuals occurred at 3 m (46.9%) and 2 m (25.0%), fewest (3.1%) occurred at 6 m, and none was found at 5 m. The maximum density was 0.43 individuals/m^2 for* A. grandis *at 3 m. Individuals of* A. grandis *(collectively from all depths) decreased in numbers down the reservoir toward the dam. The average density (from 2 and 3 m) of* A. grandis *in the lake (0.27 individuals/m^2) was significantly ($P=0.10$) greater than that in the river below the lake (0.05 individuals/m^2) and about the same as that above the lake (0.32 individuals/m^2). The average density of* L. radiata *in the lake (0.05 individuals/m^2) was significantly ($P=0.10$) less than that above the lake (0.24 individuals/m^2) and about the same as that below the lake (0.07 individuals/m^2). Possible causes for fewer mussel species in Lake Ashtabula are alteration of normal mussel reproductive processes and periodic low levels of oxygen content.*

INTRODUCTION

It is well-known that the impounding of rivers generally has adverse effects on the mussel (Bivalvia: Unionacea) fauna of a natural drainage, but the reasons are not always clear (for summary of effects, see Fuller, 1974: 247-250). This paper reports the results of a study of mussels in a 28-year-old eutrophic reservoir on the Sheyenne River in southeastern North Dakota.

Cvancara *et al.* (1976) have recently summarized the mollusks in the Sheyenne River and Lake Ashtabula and reported only two mussels, from one station (fig. 1, station 6), in the lake. Peterka (1972) analyzed the concentrations and depth-occurrences of four snail and two pill clam (Sphaeriidae) genera in Lake Ashtabula and said (written communication, May 2, 1974) that five young "Anodontidae" were collected (by Ekman dredge) from 2-4 m at the mouth of Baldhill Creek (station 4, fig. 1) and at 2.1 km above the dam in July and August, 1966.

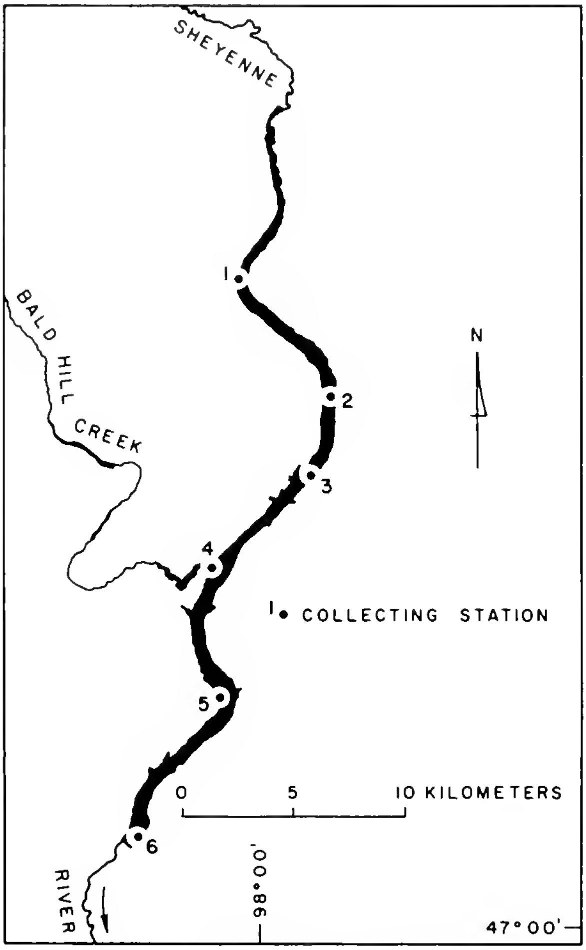

FIG. 1. *Map of Lake Ashtabula and vicinity showing mussel collecting stations.*

The generally north-trending Lake Ashtabula (fig. 1) is backed up by Baldhill Dam (NW 1/4 sec. 18, T. 141 N., R. 58 W. 47° 02′ N., 98°05′ W.), 8.4 km northwest of Valley City in Barnes County, North Dakota. The reservoir occupies the Sheyenne River Valley, whose floor is about 656 m below the surrounding terrain at the dam. Occupying a glacial meltwater trench (Aronow, 1963), the valley is cut into late Quaternary bouldery sand, silt, and clay (glacial till), sand and gravel (glacial meltwater deposits), and silty clay (glacial lake sediment) and Late Cretaceous shales (Kelly and Block, 1967; Merritt, 1966). The major tributary of the valley at the reservoir is Baldhill Creek (fig. 1). The bottom sediment of the reservoir is generally soft, organic mud beyond a depth of 1-3 m (Table 1).

Peterka (1972), Peterka and Knutson (1970), and Peterka and Reid (1969) have described the physical, chemical, and biological characteristics of Lake Ashtabula. The reservoir began storage in July, 1949; it is 43.5 km long at normal full pool and up to 0.97 km wide. The maximum depth, in the old river channel, is slightly over 15 m, and the mean depth is 4.0 m. At normal full-pool elevation the surface area is 2197.5 ha and the storage capacity is 8720.7 ha-m.

The water generally did not stratify (physical and chemical measurements from April 1966 to April 1967 unless otherwise stated (during ice-free periods. Dissolved oxygen concentration was 6.4-13.9 mg/1 during ice-free periods (at a single station) and nearly uniform throughout the water column. Supersaturated oxygen levels occurred often during April through September, 1966. During ice cover, oxygen concentrations dropped to lows of 8.2 mg/1 at the surface and 0.4 mg/1 at the bottom. Secchi disc transparency (at a single station) was 0.5-3.8 m, affected by both suspended sediment and phytoplankton. Transparency increased down-reservoir, was generally less than 1 m near station 2 (fig. 1), and averaged 2 m near the dam; this generally agrees with the results of Johnson *et al.* (1974: 16-17), obtained in July and August, 1974.

Total dissolved solids (at a single station) have varied from a little more than 200 mg/1 (April) to more than 600 mg/1 (February) (Peterka and Reid, 1969: fig. 5). Total alkalinity ranged from 140-160 mg/1 (April-May 1966) at all depths to 330 and 440 mg/1 (April 1967) at the surface and bottom. The pH values were 7.5-8.3 in April-May 1966, 8.8-9.2 in June 1966—January 1967, and decreased to about 8.0 in March-April 1967. Generally, fluctuations of sulfate, ammonia, nitrite, nitrate and total phosphate were similar to those of dissolved solids and alkalinity; low concentrations followed spring run-off and higher concentrations were reached just before ice break-up. The mean concentrations of total iron, total and ortho phosphate, and bicarbonate alkalinity (June 1967 to July 1968) were significantly less in the lower and middle reaches of the reservoir than in the upper part (Peterka and Knutson, 1970: 19). Conversely, the mean

TABLE 1. Estimated predominant bottom sediment and percentage of rooted aquatic plant cover for six stations in Lake Ashtabula in 1974 (stations are shown in fig. 1).

	Stations and dates of observations					
Depth (m)	(6/26) 1	(8/21-22) 2	(6/25-26) 3	(6/25) 4	(8/20) 5	(5/27) 6
1	Muddy sand[a] 85	Muddy sand 20	Sand 80	Gravelly sand 90	Sandy mud 90	Muddy gravelly sand 2
2	Mud 15	Mud 0	Muddy sand 1	Gravelly Muddy sand 60	Mud 0	Muddy sand 17
3	Mud 0	Mud 0	Muddy gravelly sand 0	Sandy mud 20	Mud 0	Sandy mud 8
4	Mud 0	Mud 0	Mud 0	Mud 0	Mud 0	Mud 2
5	--	Mud 0	Mud 0	Mud 1	Mud 0	Mud 0
6	--	Mud 0	Mud 0	Mud 1	Mud 0	Mud 0

[a] Estimate of bottom sediment made by generally following percentage limits of Shepard (1954).

concentrations of nitrate nitrogen and carbonate alkalinity were higher in the middle and upper reaches of the reservoir.

Lake Ashtabula is highly productive with an average annual gross primary productivity of 4.1 and 6.8 g 0_2/m²/day for 1967 and 1968. Heavy algal blooms occurred during the summer and autumn of 1967 and 1968 when *Aphanizomenon holsaticum* comprised about 90% of the blooms in numbers and volume (Peterka and Knutson, 1970: 59, 62-63). A band of submergent vegetation, largely of species of *Potamogeton*, occurred along the shores of the reservoir in water 0.6-2.5 m deep (Peterka and Knutson, 1970: 67). The existence of this vegetation band is partly reflected in Table 1. The total zooplankton dry weight standing crop was dominated by *Daphnia*, comprising 84% of the standing crop in 1967 and 81% in 1968; the average dry weight standing crop for *D. pulex* was 1110 mg/m² in 1967 and 2851 mg/m² in 1968 (Peterka and Knutson, 1970: 25, 28). The average standing crop of benthic invertebrates (spring and summer of 1967; single station 3.2 km north of the dam, fig. 1) was 7.2 g/m² and 2126 individuals. The total biomass consisted of mollusks (snails and pill clams), dipterans, annelids, ephemeropterans, and others (e.g., amphipods), in order of relative abundance. Most (90% by weight) of the invertebrates occurred at depths of 0-8 m (Peterka, 1972).

MATERIALS AND METHODS

During the summer of 1974, mussels were surveyed at six stations in Lake Ashtabula by scuba diving. The stations (fig. 1) were chosen so as to be distributed over most of the lake, be about equally spaced, and be in relatively undisturbed areas. No sampling was done above station 1 because Lake Ashtabula above this point is very shallow and largely a marsh. Belt transects, 20 m by 1.75 m and paralleling depth contours, were run at each meter depth to 6 m, except at station 1 where the maximum depth was less than 5 m. The transects were limited to 6 m because of extremely low lateral visibility; estimated values of visibility at 6 m for four stations were 0-0.4 m. (At 3 m, the estimated values at four stations were 0.6-1 m). To gain access to the 6-m depth, it was usually necessary to locate the former river channel; this was accomplished by use of a Lowrance Electronics Mfg. Corp. Fish-Lo-K-Tor. Each transect line was begun from a bearing normal to shore, established with an underwater compass. The transect line, a nylon cord 5 mm in diameter with lead weights, was held by a diver at one end while the other diver extended it along the desired depth contour by means of an underwater depth gauge. All mussels (alive and empty shells) that could be reached on either side of the transect line (a 1.75-m-wide belt or band) were placed in a numbered bag. Collecting was commonly done strictly by feel because of the generally low visibility. Observations on the estimated predominant bottom sediment and percentage of aquatic plant cover were made for each transect. More than 20 underwater manhours were devoted to this survey.

Shells were measured (to the nearest millimeter) for length (greatest distance parallel to the hinge line), height (greatest dorsoventral distance normal to the hinge line), width (greatest distance across both valves normal to a plane passing between them), and posterior length (greatest distance parallel to the hinge line from the beak to the posterior margin) in the field by use of a specially contructed measuring box with a sliding guide and by vernier calipers. The total weight (body and shell) and shell weight were measured to the nearest tenth of a gram. All excess moisture was removed before weighing live individuals, and shells were dried before weighing. Specimens used are encompassed within accession numbers A1203-1222 of the Department of Geology, University of North Dakota.

RESULTS

Four mussel species, in order of decreasing abundance, were found living in Lake Ashtabula (Table 2): *Anodonta grandis* Say, *Lampsilis radiata* (Gmelin), *Amblema plicata* (Say), and *Lasmigona complanata* (Barnes). Individuals of *A. grandis* were conspicuously small (Table 3); most (82.7%) had about two or three winter rings and the largest had about five. The ratios of posterior length/length, total weight/length, and shell weight/length of lake individuals of this species were less than those of Sheyenne River individuals. Individuals of *L. radiata* were of a size about normal for those in the river, and the largest had about seven winter rings. The male/female ratio of this species was 2. Too few

TABLE 2. Individuals of four species of mussels recovered from six stations in Lake Ashtabula.

Depth (m)	Anodonta grandis Stations 1	2	3	4	5	6	Total	Lampsilis radiata Stations 1	2	3	4	5	6	Total
1	0[a] (0)	1 (5)	1 (1)	5 (0)	0 (0)	0 (0)	7 (6)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	1 (0)
2	4 (5)	10 (17)	4 (0)	3 (0)	1 (0)	0 (1)	22 (23)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0 (1)	1 (1)
3	15 (11)	8 (7)	8 (16)	4 (4)	0 (0)	0 (1)	35 (39)	1 (0)	0 (0)	2 (1)	0 (0)	0 (0)	6 (0)	9 (1)
4	14 (5)	2 (0)	0 (0)	0 (0)	0 (0)	0 (0)	16 (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (1)	0 (1)
5	NS (NS)	0 (0)	0 (3)	0 (0)	0 (0)	0 (0)	0 (3)	NS (NS)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
6	NS (NS)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	NS (NS)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	1 (0)
Total individuals	33 (21)	22 (29)	13 (20)	12 (4)	1 (0)	0 (2)	81 (76)	1 (0)	0 (0)	2 (1)	1 (0)	1 (0)	7 (2)	12 (3)

Depth (m)	Amblema plicata Stations 1	2	3	4	5	6	Total	Lasmigona complanata Stations 1	2	3	4	5	6	Total
1	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2)	0 (0)	1 (2)
3	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
4	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
5	NS (NS)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	NS (NS)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
6	NS (NS)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	NS (NS)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total individuals	0 (0)	2 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2)	0 (0)	1 (2)

[a] Each entry represents the individuals (empty shells indicated by parentheses) collected from a 20-m by 1.75-m transect. NS = not sampled because the maximum depth was less than 5 m

TABLE 3. Statistical data of shell measurements, shell measurement ratios, weights, and weight-length ratios for *Anodonta grandis* Say and *Lampsilis radiata* (Gmelin) from six stations in Lake Ashtabula and 21 stations from the Sheyenne River above and below the lake.

	Lake			River[a]		
	Mean ±S.E.	N.	Range	Mean ±S.E.	N.	Range
Anodonta grandis Say						
Length	55±1.0	81	38-84	93±1.2	259	60-156
Height	33±0.6	81	23-50	53±0.7	259	37-87
Width	21±0.5	81	12-36	33±0.5	259	19-60
Height/length	0.60±0.003	81	0.55-0.67	0.57±0.002	259	0.51-0.74
Width/height	0.62±0.005	81	0.52-0.74	0.62±0.002	259	0.49-0.74
Posterior length	35±0.6	80	24-52	54±1.0	35	45-70
Posterior length/length	0.64±0.002	80	0.58-0.70	0.70±0.003	35	0.67-0.74
Total weight	18.4±1.1	78	5.2-69	98.3±6.5	157	17.4-355.3
Shell weight	3.3±0.2	80	1.1-11.5	20.6±1.3	130	7.6-146.9
Total weight/length	0.32±0.013	78	0.14-0.82	0.95±0.04	157	0.29-2.50
Shell weight/length	0.06±0.002	80	0.03-0.14	0.22±0.009	130	0.10-0.94
Lampsilis radiata (Gmelin)[b]						
Length	90±8.4	8	37-112	91±0.7	252	68-122
Height	53±5.1	8	23-71	53±0.4	252	40-85
Width	31±3.5	8	10-40	31±0.3	252	21-46
Height/length	0.60±0.014	8	0.52-0.65	0.59±0.002	252	0.48-0.79
Width/height	0.58±0.026	8	0.44-0.69	0.59±0.002	252	0.40-0.76
Posterior length	64±8.0	8	25-87	69±1.1	60	55-88
Posterior length/length	0.73±0.011	8	0.58-0.78	0.76±0.002	60	0.72-0.80
Total weight	95.6±22.0	8	4.3-168.7	92.9±2.8	168	29.6-233.2
Shell weight	43.7±8.1	8	1.3-75.6	45.3±1.9	144	10.5-123.1
Total weight/length	0.95±0.19	8	0.12-1.51	1.00±0.022	168	0.42-1.91
Shell weight/length	0.43±0.071	8	0.04-0.68	0.47±0.016	144	0.15-1.05

[a] River data were generated during the study of Cvancara *et. al* (1977).

[b] Only data for males are given.

lake individuals make comparisons with river individuals uncertain. The two individuals of *A. plicata* were 81 and 100 mm, 62 and 78 mm, and 29 and 39 mm in length, height, and width, and had about 4 and 7 winter rings. The single live *L. complanata* was 80 mm, 65 mm, and 28 mm long, high, and wide and had five winter rings. Oviferous individuals were found of *A. grandis* (stations 2 and 5 at 2-4 m; 20-21 August), *L. radiata* (station 5 at 2 m; 20 August), and *L. complanata* (station 5 at 2 m; 20 August).

Most (71.9%) mussel individuals occurred at 3 m (46.9%) and 2 m (25.0%), fewest (3.1%) at 6 m, and none was found alive at 5 m. Empty shells commonly occurred in numbers comparable to those for live individuals (Table 2). The maximum density was 0.43 individuals/m² for *A. grandis* at 3 m. The average densities (individuals/m²) for *A. grandis* and *L. radiata* at combined 2- and 3-m depths were 0.27 and 0.05. Total *A. grandis* decreased significantly (P<0.01) and linearly down the reservoir toward the dam (r = -0.96).

Densities of *A. grandis* and *L. radiata* in the lake did not show a consistent pattern as compared with densities in the river (Table 4). The average density of *A. grandis* in the lake was significantly greater than that in the river below the lake, but about the same as that above the lake. The average density of *L. radiata* was significantly less than that above the lake, but about the same as that below the lake. The relative abundances of the two species were about the same above and below the lake, but decidedly different in the lake.

TABLE 4. Density of *Anodonta grandis* Say and *Lampsilis radiata* (Gmelin) in Lake Ashtabula (from 2- and 3-m depths) and Sheyenne River above (three stations) and below (four stations) the lake.

Km above or below lake dam			*A. grandis* Density (individuals/m^2)			*L. radiata* Density (individuals/m^2)
250.0			0.14[a]			0.04
150.6		Mean	0.21		Mean	0.23
58.2		=0.32	0.60		=0.24	0.46
30.6	NS		0.54	S		0.03
23.6			0.51			0.00
20.1		Mean	0.34		Mean	0.06
14.2	S[b]	=0.27	0.20	NS	=0.05	0.00
8.0			0.03			0.03
0.5			0.00			0.17
3.0	S		0.01	NS		0.09
111.3		Mean	0.14		Mean	0.16
274.8		=0.05	0.00		=0.07	0.01
399.4			0.05			0.02

[a] Values are listed in downstream and downlake order. Lake values are underlined.

[b] S= compared means are significantly different (t-test; P=0.10). NS=compared means are not significantly different (t-test, P=0.10).

TABLE 5. Comparison of mussel species in Lake Ashtabula with those in the Sheyenne River above and below the lake

Species	Lake Ashtabula	River[b] above lake	River[b] below lake
1. *Amblema plicata* (Say)	1[a]	3	9
2. *Fusconaia flava* (Rafinesque)		2	7
3. *Quadrula quadrula* (Rafinesque)[c]			
4. *Anodonta grandis* (Say)	5	10	11
5. *Anodontoides ferussacianus* (Lea)		3	6
6. *Lasmigona complanata* (Barnes)	1	5	10
7. *L. compressa* (Lea)		3	1
8. *Strophitus undulatus* (Say)		1	4
9. *Lampsilis ovata* (Say)			6
10. *L. radiata* (Gmelin)	5	8	9
11. *Ligumia recta* (Lamarck)			2
12. *Proptera alata* (Say)			1

[a] Number of stations at which a species was found among totals of 6, 16, and 11 in the lake, above the lake, and below the lake.

[b] Data for the Sheyenne River are from Cvancara *et al.* (1976).

[c] Only empty shells of this species were found, in the river below the lake.

DISCUSSION

Considerably fewer mussel species were found in Lake Ashtabula than are known to exist in the Sheyenne River above and below the lake (Table 5). Those found in the lake are the same species as those found at most stations in the river. The chances of finding additional species in the lake can be estimated from the Poisson distribution, which fits the observed species distribution remarkably well. The Poisson probability of finding more than four species is 0.003 based on an extension of the observed data (Darnell, 1971: 189-193). One might ask, what would the mussel fauna be like if Lake Ashtabula were elsewhere on the Sheyenne River? If farther downstream, more species might occur since diversity is greater in the lower reaches of the river (Table 5). Other studies (summarized by Fuller, 1974: 247-250) have demonstrated the smaller number of mussel species in reservoirs as compared to those in the nonimpounded river. Shifts in the species composition may also occur, with commonly increased prominence of members of the Anodontinae. This was documented for reservoirs on the Tennessee River (Bates, 1962; Isom, 1969, 1971). Baker (1928), in a dammed-up creek system in Wisconsin, found that only two mussels out of eight remained in the man-made lakes—*Anodonta grandis* (including "*Anodonta marginata*") and *Lampsilis radiata*. *A. grandis*, an anodotine, was the dominant mussel found in Lake Ashtabula, followed by *L. radiata* (Table 2).

Possible causes for fewer mussel species in Lake Ashtabula are 1) alteration of reproductive processes and 2) periodic low levels of oxygen content. Since most mussels are dependent on a fish host for dispersal and development of the glochidial larva, fish species in Lake Ashtabula were checked (from Farmer, 1974 and from a list compiled by Dr. John B. Owen, Department of Biology, University of North Dakota and his students). Fuller (1974: 228-237) has compiled a list of host fishes for many mussel species from the literature. With the exception of *Anodontoides ferussacianus* (Lea), all mussels in the Sheyenne River with known fish hosts have one or more host fishes present in Lake Ashtabula. Therefore, there seems to be no problem with glochidial host availability. However, even though a suitable host is present, the level of infection by glochidia in reservoirs may be very low. Also, the reproductive process may be altered by loss of glochidia in the soft substrate or by increased attacks upon larvae by microorganisms, especially under conditions of high siltation and organic enrichment (summarized by Fuller, 1974: 222, 247, 252), as are present in Lake Ashtabula.

Periodic low levels of oxygen also may be responsible for low mussel diversity in the lake. Peterka and Reid (1969: 145) recorded a low of 0.4 mg/1 on the bottom (8 m) between stations 5 and 6 on 27 February 1967; Mr. James Ragan, of the North Dakota Game and Fish Department, reported (letter dated 4 August 1975) 0.5 mg/1 at 4.5 m depth at station 2 on 18 February 1970. The preponderance of *Anodonta grandis* in the lake suggests that this species is physiologically more adaptable to conditions of marginal oxygen. Isom (1971) attributed the sparse mussel fauna in Fort Loudon Reservoir on the Tennessee River to periodic insufficient oxygen resulting from organic enrichment entering the upper reservoir.

Individuals of *A. grandis* were conspicuously smaller in the lake than in the river (Table 3), not because of stunting, but because the lake forms were consistently younger, as mentioned under Results. It is possible that the preponderance of young individuals is due to significantly low water causing a dying off prior to their birth. The lowest levels (below normal reservoir level) during 1969-1974 were 8.22 feet (early April), 3.40 feet (early April), 4.34 feet (late March), 3.90 feet (early March), 2.79 feet (early March), and 8.49 feet (early April) (data from Mr. Melvin Rieman, Flood Control Dam Operator for the U.S. Army Corps of Engineers, 11 August 1975). The 8.22-foot drawdown in 1969 may be significant because most individuals of *A. grandis* were found at 2 and 3 m in 1974, and the time of the drawdown is close to the estimated time of birth of most of the individuals collected. Most of the adults may have died during the drawdown, and the shallow-water populations may have been dominated thereafter by juveniles developed after the water level rose. If reservoir level-lowering is significant, however, it is unclear why *Lampsilis* *radiata* was not represented primarily by young individuals. Also, the possible detrimental effects of the 8.49-foot drawdown in 1974 were not evident in either species.

The smaller posterior length/length ratio of lake individuals of *A. grandis* implies more centrally placed beaks, but may be the result of generally younger individuals in the lake than in the river. Clarke (1973: 69, 80) found high values of the anterior to beak length/length ratio (which correspond to low values of the posterior length/length ratio) in individuals of *A. grandis* from large lakes. He said such values imply a superior development of the foot for maintaining position better in lakes in exposed habitats and on shifting substrates (of sand). This explanation is questionable since one might expect currents in rivers, especially during flood stage, to affect a mussel's position on the bottom as drastically as does wave action.

The greatest concentration of individuals at 3 m differs notably from 1 m in Long Lake, a natural lake in northwestern Minnesota. However, the maximum density of 0.43 individuals/m^2 is similar to the 54 mussels/m^2 in Long Lake (Cvancara, 1972: 155). The scarcity of trees and long fetch at Lake Ashtabula are conducive to frequent, strong wave action that may result in more disturbance and fewer individuals at depths less than 3 m.

The fewer individuals with increasing depth in Lake Ashtabula also occurred in Long Lake. In both lakes, this may be because of decreased biological activity (slower metabolism, reproduction and growth) as related to lower temperatures (Cvancara, 1972: 157). In Lake Ashtabula, however, thermal stratification has generally not been observed (1966-1967) during ice-free periods, but does occur during such times in Long Lake. It may be, too, that periodic low levels of oxygen on the bottom result in fewer individuals with depth.

The decrease in numbers of individuals of *A. grandis* down the reservoir toward the dam may be due to a chemical factor. As mentioned under *Introduction*, total iron, total and orthophosphate, and bicarbonate alkalinity were less in the lower and middle reaches of the reservoir whereas nitrate nitrogen and carbonate alkalinity were higher in the middle and upper reaches. It is unclear, however, which chemical factor might be responsible and how it might relate to mussel density.

ACKNOWLEDGEMENTS

J. P. Bluemle and M. E. Bluemle, North Dakota Geological Survey and Department of Geology, University of North Dakota, aided in collecting river specimens of *Anodonta grandis* and *Lampsilis radiata* used in making comparisons with those in the lake. A. C. Lindem, Jr., Manager of Academic Systems at the University of North Dakota Computer Center, aided in the tabulation and analysis of shell and weight measurements. We wish to thank Mr. Samuel L. H. Fuller for his rigorous review of our initial manuscript.

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REDESCRIPTION OF *BITTIUM PROTEUM* (JOUSSEAUME, 1930) WITH COMMENTS ON ITS GENERIC PLACEMENT

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While examining cerithiid-type-material from the Museum d'Histoire Naturelle, Paris, I came across five lots of specimens from Aden that were described by Jousseaume in 1930 as *Cerithium proteum.* All of the specimens are less than 5.2 mm in length and have extremely variable sculpture that consists of intersecting axial and sprial cords. Jousseaume (1930) noted the conchological polymorphism and remarked that each individual could be construed as a separate species were it not for the intergradation of forms within a population. The type-shells have wide, shallow, short anterior siphonal canals and very weak anal sinuses that are indicative of the genus *Bittium* Gray, 1847 rather than *Cerithium* Bruguière, 1789.

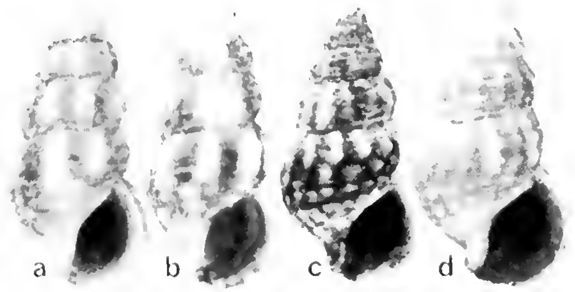
To my knowledge, *Cerithium proteum* was not mentioned again in the literature until 1971 when Biggs examined a series of small cerithiids collected in beach drift from the Dahlak Island, Ethiopia, by the Polish Expedition to the Red Sea ("Dar Opola"). Biggs (1971) was unable to identify the specimens or place them into any known genus; consequently, he proposed the genus *Dahlakia* which he suggested should be placed somewhere near the potamidid genera *Pirenella* Gray, 1847 and *Cerithidea* Swainson, 1840. He described four new species based on the material collected at the Dahlak Islands: *Dahlakia leilae* (type-species of the genus), *D. striata, D. jugosa* and *D. pirenelloides.* I believe these four species are conspecific with *Cerithium proteum* Jousseaume, 1930. Examination of Jousseaume's type-material, which consists about 100 specimens, shows that all of the characters used by Biggs (1971) to define his species exist in *C. proteum* and intergrade with each other, clearly indicating one extremely variable species. Some of Jousseaume's specimens were collected alive and still have their opercula and smooth protoconchs in contrast to the beach-worn specimens of Biggs. The operculum of *C. proteum* is thin, corneous and paucispiral with an eccentric nucleus characteristic of a cerithiid operculum. Biggs (1971) was thus mistaken in referring his specimens to the Potamididae.

Cerithium proteum seems to be a *Bittium* species, but there is much confusion and disagreement about the limits and subdivisions of this group. Many small cerithiid genera and subgenera are artificial groupings that do not reflect sound phylogeny and are impossible to use on a practical toxonomic level. I have commented on the nomenclature and usages of *Bittium* elsewhere (Houbrick, 1977) and suggest that *Dahlakia* Biggs, 1971 should be considered a synonym of *Bittium* Gray, 1847. A synonymy and redescription of *Cerithium proteum* Jousseaume, follow:

SYNONYMY

Subfamily Cerithiinae Fleming, 1828
Genus *Bittium* Leach in Gray, 1847

Bittium 1847 (Oct.), Leach in Gray, *Annals. Mag. Nat. Hist.* **20:**270 Type-species, *Murex reticulatus* Montagu, 1803 =*Strombiformis reticulatus* Costa, 1778), by subsequent designation, Gray, 1847 (Nov.), *Proc. Zool. Soc London* **129:**154.



FIGS. **a - d.** Bittium proteum *(Jousseaume, 1930) Lectotype (a) and representative paratypes from Djibouti, French Somaliland (b-d) showing variation in shell form and sculpture Measurements a) 5.4 × 2.2 mm; b) 5.9 × 2.4 mm; c) 4.9 × 2.3 mm; d) 6.3 × 2.8 mm*

Dahlakia 1971, Biggs, *Journ. Conch.* **27:**221 Type-species, *Dahlakia leilae* Biggs, 1971 (=*Cerithium proteum* Jousseaume, 1930), by original designation.

Bittium proteum (Jousseaume)

(Figs. a - d)

1930 *Cerithium proteum* Jousseaume, *Journ. de Conchyliol.* **74:** 283-284, fig. 1. Djeddah, Hodeidah, Aden, Djibouti (type-locality here restricted to Djibouti, French Somaliland). Lectotype, Mus. Hist. Nat., Paris, not registered. (5.4 × 2.2 mm)

1971 *Dahlakia leilae* Biggs, *Journ. Conch.* **27:** 221, pl. 7, fig. 3. Entedebir I., Dahlak Archipelago, Red Sea. Holotype: Zool. Inst. Polish Acad. Sci., Warsaw.

1971 *Dahlakia striata* Biggs, *Journ. Conch.* **27:** 222, pl. 7, fig. 1. Entedebir I., Dahlak Archipelago, Red Sea. Holotype: Zool. Inst. Polish Acad. Sci., Warsaw.

1971 *Dahlakia rugosa* Biggs, *Journ. Conch.* **27:**222, pl. 7, fig. 2 Entedebir I., Dahlak Archipelago, Red Sea. Holotype: Zool. Inst. Polish Acad. Sci., Warsaw.

1971 *Dahlakia pirenelloides* Biggs, *Journ. Conch.* **27:** 222, pl. 7, fig. 4. Entedebir I., Dahlak Archipelago, Red Sea. Holotype: Zool. Inst. Polish Acad. Sci. Warsaw.

RE-DESCRIPTION

Shell tiny (3.7 - 5.2 mm in length; 1.7 - 2.5 in width), turrited, elongate, consisting of 7-9 moderately inflated whorls having an apical angle of 28-45 degrees. Whorls sculptured with slanted axial ribs, numerous thin spiral cords and striae of variable number. Intersections of axial ribs and spiral cords usually beaded. Whorls sometimes lacking axial ribs sculpture and with reduced sprial sculpture. Protoconch smooth, 2-2.5 whorls. Suture deeply incised. Aperture ovate, columella concave with slight callous. Outer lip convex, thin, weakly crenulate. Anal canal very small. Anterior siphonal canal short, broad and shallow, very slightly reflexed backwards. Shell color tan to dark brown, axial ribs usually flecked with white. Aperture yellowish brown. Operculum thin, corneous, tan, ovate, paucispiral with eccentric nucleus. Radula and soft parts unknown.

REMARKS

As Jousseaume (1930) remarked, this species is exceedingly variable in sculpture and form (see figs. a-d). Although *Bittium proteum* is characterized by its inflated whorls and by slanting axial ribs and riblets, some individuals are almost devoid of sculpture and others are rather elongate. Elongate individuals were named *Dahlakia* *pirenelloides* and *D. leilae* by Biggs (1971). *Bittium proteum* is normally more stocky than *B. reticulatum*, the type-species of the genus, and is closest in shape to several Tertiary species from Venezuela described by Weisbord (1962) and referred to a new subgenus, *Brachybittium* Wesbord, 1962; *Bittium caraboense*, *B. venezuelanum*, *B. salinae*, and *B. palitoense*. These fossil species are also variable in sculpture and I question the taxonomic necessity of a new subgenus to accomodate them because good supraspecific characters are, in my opinion, lacking.

Jousseaume (1930) did not designate a holotype and I have been unable to find a paratype that exactly matches the figure given in his paper; thus, I herein select a lectotype (fig. a, this paper, 5.4 × 2.2 mm) and restrict the type-locality to Djibouti, French Somaliland.

Bittium proteum most likely occurs throughout the Red Sea but may be overlooked by collectors due to its small size. It is not well-represented in American museum collections: The National Museum of Natural History, Washington, D.C. has only two lots, from Jidda, Saudi Arabia and Port Sudan, Sudan. Bigg's material is from the Dahlak Ids., Ethiopia and the original type-material of Jousseaume was collected in French Somaliland and Aden. Thus, *Bittium proteum* may have a larger geographic distribution extending into the Indian Ocean.

ACKNOWLEDGMENTS

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A NEW SPECIES OF *ASHMUNELLA* (PULMONATA: POLYGYRIDAE) FROM THE DAVIS MOUNTAINS, TEXAS

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ABSTRACT

Ashmunella sprouli *Fullington and Fullington is the third species of this genus described from the Davis Mountains, Jeff Davis County, Texas. The type locality is a localized colony in an igneous talus slide above No. 10 Spring, Hell's Canyon, on the R. E. Sproul Ranch.*

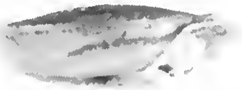
Ashmunella sprouli
Fullington and Fullington, spec. nov.
(Figures 1 to 3)

Holotype description - Shell light-brown, slightly convex above (although 5 of the 41 collected specimens were dorsally flattened or even concave), and moderately umbilicate (umbilical width, 3.41 mm; contained 3.4 × in shell diameter). Whorls, 5 1/2, tightly coiled; suture lines slightly indented. Periphery sharply carinated and the last whorl is deflected downward immediately behind the peristome. The peristome thin and expanded, but not flanged. Two parietal teeth; the upper is shorter, more degenerate than the larger, s-shaped lower parietal. The larger parietal tooth bends toward the upper parietal at its upper end. The peristome contains 3 palatal teeth. The uppermost is elongate, and rests very obliquely across the nearly converging parietals. Basally, two laterally compressed teeth are connected by a small, raised ridge slightly below the peristome. The two teeth are equidistant externally but strongly diverge as they continue 1.4 mm into the aperture. They may be observed as two white lines through the thin shell. The expanded peristome is continuous across the parietal wall and slightly elevated. The upper shell surface is marked by fine, curved spiral striae evenly spaced from the protoconch until the penultimate whorl where they become irregularly spaced and larger, resembling wrinkles more than striae. Ventrally, the striae are fine, evenly spaced to the peristome and continue to the umbilicus. The entire surface is covered by rows of structures termed cuticular scales by Clench and Miller (1966:2). The scales are embedded only in the periostracum.

Measurements (mm):

	Diameter	*Height*
Holotype	12.65	1.82
Paratypes	12.17	3.70
	12.69	4.10
	12.00	3.75
	11.82	3.81
	12.29	3.74
	11.30	3.65
	11.51	3.71

Genitalia: The genitalia of *Ashmunella sprouli* (fig. 10) are similar to those of *A. bequaerti* as described by Clench and Miller (1966:3). However, they differ in several respects. The penial retractor muscle is attached to the epiphallus much higher than the attachment site on *A. bequaerti* and the epiphallus itself is much shorter, but the flagellum is much longer. The most obvious difference is in the length of the prostate gland. In *A. bequaerti*, it travels the entire length of the uterus touching the albumen gland. In the new species, it extends only half the length of the uterus. Externally, the peristome of *A. sprouli* is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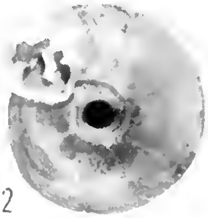
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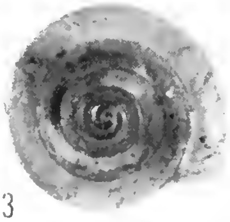
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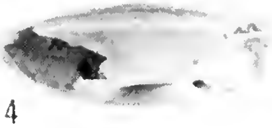
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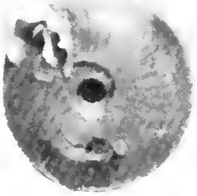
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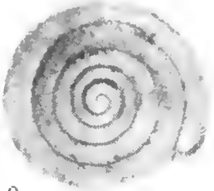
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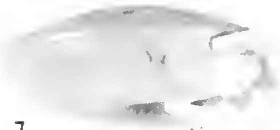
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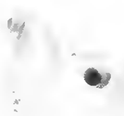
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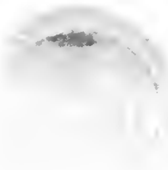
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FIGS. 1-3. Ashmunella sprouli *Fullington and Fullington, new species. Holotype, ×2.1.* FIGS 4-6. A bequaerti *Clench and Miller, 1966; Topotype: ×2.1;* FIGS. 7-9. A mudgei *Cheatum, 1970 Holotype ×1.8.*

continuous forming a raised shelf across the parietal wall and the umbilical diameter is smaller. Although, the two species are externally similar with the exception of the peristome, we feel that the new species merits specific rank based upon the several differences in the two reproductive systems.

Structure	*bequaerti*	*sprouli*
Penis	5.0	5.14
Ephiphallus	21.0	10.35
Flagellum	1.5	1.73
Penial retractor	1.3	not measured
Spermatheca & duct	31.0	not dissected from sac
Vagina	4.0	2.61
Free oviduct	2.5	1.28
Atrium	1.0	1.14

Deposition of Specimens: holotype, Dallas Museum of Natural History (DMNH 5355); paratypes deposited California Academy of Sciences, Delaware Museum of Natural History (no. 119484) and United States National Museum.

Type Locality: Davis Mountains, Jeff Davis County, Texas. Spring No. 10 on north wall of Hell's Canyon just west of junction with Frazier Canyon 30° 40′ 10″ N Lat., 103°5′ 15″ W Long. (U.S.G.S. map, Casket Mountain Quadrangle, 1972); Elev. 5500′; R. E. Sproul Ranch.

Habitat: On 24 July, 1975, forty-one (11 living) specimens of the new species were collected in a small talus slope just above the small spring emerging from a sheer igneous cliff face. The cliff is located in Hell's Canyon on the R. E. Sproul Ranch just north of Fort Davis, Texas. The colluvium is surrounded by dense, low vegetation, large Red Oak trees *(Quercus gravessii)*, Ash *(Fraxinus cuspidata)*, Walnut *(Juglans microcarpa)* and Buckeye *(Aesculus* sp.). Maidenhair fern *(Addiantum* sp.) was abundant on rocks by the spring. Water from the spring cascaded almost 100 feet to the canyon floor. Specimens were dug from under leaf covered rocks. Rain was falling at the time of collection, but no live specimens were observed above ground. The collecting party consisted of the Dallas Museum staff members: Steven Runnels, Charles Meister, Ray Garza and the senior author.

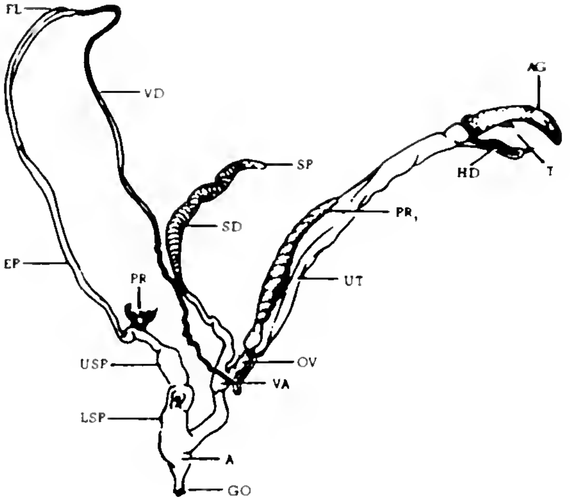

FIG 10 Ashmunella sprouli *Fullington and Fullington, new species, Genitalia of paratype (DMNH 5356)*

GO - Genital Orifice
LSP - Lower Sac of Penis
PR - Penial Retractor Muscle
EP - Epiphallus
VD - Vas Deferens
T - Talon
OV - Oviduct
UT - Uterus
HD - Hermaphroditic Duct

A Atrium
USP - Upper Sac of Penis
SP - Spermatheca
FL - Flagellum
VA - Vagina
AG - Albumen Gland
SD - Spermathecal Duct
PR - Prostate

COMPARISONS

This new species is the third *Ashmunella* to be described from the Davis Mountains; *Ashmunella mudgei* Cheatum (1970) (fig. 7 to 9) from Sawtooth Mountain on the west side and *Ashmunella bequaerti* (fig. 4 to 6) Clench and Miller (1966) which occurs in Goat Cave Canyon located ten miles north of Hell's Canyon. *A. mudgei* is a large, smooth shelled *Ashmunella* and bears no resemblance to *A. bequaerti* or to this species, although Bequaert and Miller (1973:39) considered *A. mudgei* a subspecies of *A. bequaerti*. Specifically, *A. bequaerti* and the new species are similar in external morphology and probably evolved from a single parental stock.

The colony of *A. sprouli* appears to be relatively small and extremely isolated as the canyon was investigated for some distance on either side of the spring and no additional specimens were collected. This situation is typical of the larger-sized land mollusks that inhabit the narrow steep-sided canyons in the Davis Mountains. Genetic studies will probably indicate that the whole Davis Mountains *Ashmunella* are interrelated but with extreme localized allelic fixation. Preliminary electrophoretic data on the *Humboldtiana* complex in the Trans-Pecos Mountains by Fullington and Zimmerman indicates that this is the case.

This species is named in honor of Mr. R. E. Sproul a rancher who has been an amateur naturalist most of his life. He has long encouraged and assisted in scientific studies of the Davis Mountains flora and fauna.

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POTENTIAL BIOLOGICAL CONTROL OF SCHISTOSOMIASIS INTERMEDIATE HOSTS BY HELISOME SNAILS[1]

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ABSTRACT

Helisoma, *an American planorbid genus of mainly northern freshwater snails, is represented by only one or two species in Central America and certain Caribbean islands. Their distribution overlaps that of the neotropical and medically important snail,* Biomphalaria glabrata *in only Puerto Rico and Guadeloupe. Results of laboratory studies point to possible use of helisome snails as competitors against adult* B. glabrata. *The snails could also function to reduce the reproductive potentials of* B. glabrata *and also act as decoys in absorbing miracidia of the human schistosome* Schistosoma mansoni.

Interest in biological control of medically important snails has intensified in recent years, to serve as an alternative of, or in addition to, chemical and engineering measures. The reason for this has been the gradual opposition to the application of chemical molluscicides, and the possible side-effects of these compounds. Among the reviews of the use of biological control have been Malek (1956, 1958), Michelson (1957), Mandahl-Barth (1965), Ferguson and Ruiz-Tiben (1971), Ferguson (1972), and Berg (1964, 1973).

Investigations on certain species of snails as biological control agents against medically important snails include those on *Marisa cornuarietis* (Linné, 1758) (Ferguson and Palmer, 1958; Oliver-Gonzales and Ferguson, 1959; Demian and Lutfy, 1965; Ruiz-Tiben *et al.*, 1969; Jobin and Berios-Duran, 1970); on *Pomacea* spp. (Paulinyi and Paulini, 1972); and on *Helisoma duryi* (Abdalla and Nasr, 1971; Rasmussen, 1974).

MATERIALS AND METHODS

An albino NIH strain of *Biomphalaria glabrata* was used. *Helisoma duryi normale* Pilsbry, 1931, from near Tallahassee, Florida were supplied by Dr. Robert B. Short, and *Helisoma trivolvis lentum* (Say, 1834) were collected from swamps near New Orleans, Louisiana. Aquaria used for the experiments were filled each with 12.5 liters of dechlorinated tap water, and had a small amount of gravel on the bottom, but were without vegetation and aeration. The design of the experiments to test the effect of the presence of the helisome snails on adult *B. glabrata* is shown in Table 1. Each set of aquaria, for example, 1 and 2, 3 and 4, and 5 and 6 were quite identica as to maintenance and diet for the snails.

Experiments on the effect of helisomes on the viability of eggs of *B. glabrata* were undertaken at a temperature of 22-24° C in plastic boxes, 17 × 12.5 × 6 cm in size with 800 ml of water. Four boxes were used, in each of which 5 *Helisoma trivolvis lentum* were kept for 3 weeks without change of water, before introduction in each of the dishes of 10 newly-laid egg clutches. Susceptibility of *B. glabrata* to infection with a Puerto Rican strain of *Schistosoma mansoni* in presence of *H. trivolvis lentum* was tested in 4 boxes similar to those used for the effect on the eggs. Medium-size, about 6 mm in diameter, albino *B. glabrata*, and the helisomes about 10

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TABLE 1 Experimental Design to Test the Effect of Helisome Snails on *Biomphalaria glabrata*. The capacity of each aquarium was 12.8 liters

Aquarium	*Biomphalaria glabrata*		*Helisoma duryi*		*Helisoma trivolvis lentum*	
	Number	Diameter mm	Number	Diameter mm	Number	Diameter mm
1	16	14.3				
2	8	12.5	8	14.1		
3	28	11.0				
4	14	12.5			14	15.2
5	50	4				
6	25	4.5			25	18

mm in diameter were used for this experiment according to the following protocole: box 1) 10 *B. glabrata* and 20 helisomes. 2) 10 *B. glabrata* and 10 helisomes. 3) 10 *B. glabrata* and 3 helisomes. 4) 10 *B. glabrata* alone. In each container 6 miracidia of *S. mansoni* per snail *(B. glabrata)* were introduced. Replicates of each of the 4 experiments were done.

RESULTS

The rate of growth of *Biomphalaria glabrata* was slightly greater when associated with *Helisoma duryi* (aquarium no. 1), than when raised alone (aquarium no. 1). This indicates that there were no ill effects upon adult *B. glabrata* when maintained with *H. duryi*. However, there was a vast difference in the number of young; there were 364 offspring in aquarium 1, and only 20 in aquarium 2 in which *B. glabrata* coexisted with *H. duryi*.

Replicates of the above experiment, but using *Helisoma trivolvis lentum*, from Louisiana, and different numbers of the component snails, gave similar results. Table 2 shows that the reproductive capacity of *B. glabrata* was hampered by the presence of *H. trivolvis lentum*. Such a drastic effect can be deduced by comparing the number of offsprings in aquarium No. 3 and 4, and also No. 5 and 6. During the first month of the experiments *B. glabrata* laid eggs when in association with the helisomes in aquaria 4 and 6, but many of the eggs failed to hatch, and there was mortality among the hatched embryos. Beyond the first month, egg laying by *B. glabrata* was minimal. As to growth rate of *B. glabrata* the snails grew normally in greatest diameter during the first two months, but beyond this period their growth was slow or was arrested.

In the experiments to test the susceptibility of *B. glabrata* to infection with *S. mansoni* in presence of *H. trivolvis*, the infection rates in the 4 groups were as follows: 10%, 20%, 50% and 90%. Replicates of these experiments resulted in the following infection rates in *B. glabrata*: 0%, 10%, 40%, and 90% respectively. Thus the increase in the infection rates of *B. glabrata* was proportional to the decrease in the number of *H. trivolvis* present in each experiment (group), pointing to the possible use of the latter snails as decoys in absorbing miracidia of the schistosome.

DISCUSSION

The fact that there were no deaths among *Biomphalaria glabrata* in aquarium 2 and that

TABLE 2. Growth Rate and Reproduction of *Biomphalaria glabrata* when maintained alone or in association with Helisome Snails. D = average diameter in mm; O = number of offspring

Aquarium	Biomphalaria glabrata											Helisoma trivolvis lentum										
	0 mo.	1		2		3		4		5		0 mo.	1		2		3		4		5	
	D	D	O	D	O	D	O	D	O	D	O	D	D	O	D	O	D	O	D	O	D	O
1	14.3	17.0	-	17.1	364																	
2	12.5	16.8	-	17.1	20																	
3	11.0	13.2	148	15.8	266	17.4	380	18.0	120	18.6	482											
4	12.5	14.8	18	15.9	20	16.2	32	16.8	32	17.0	10	15.2	17.0	48	18.5	90	19.1	180	19.4	210	19.5	312
5	4	6.8	64	9.5	312	11.8	420	14.5	548	16.0	820											
6	4.8	6.5	10	8.8	56	9.2	60	9.2	70	9.4	78	4.8	6.0	12	8.2	82	10.5	100	14.0	310	15.3	360

these snails grew, more or less, at the same rate as those in aquarium 1 indicate that there were no ill effects upon adults of *B. glabrata* due to the presence of *Helisoma duryi*. However, there was a vast difference in the breeding rate of *B. glabrata* in the two aquaria. This difference was also confirmed in the other two sets of aquaria. Evidently, breeding of *B. glabrata* was considerably affected in the presence of either species of the helisomes. The detrimental effect of the helisomes on the egg clutches of *B. glabrata* in other experiments was also evident, as was observed by Abdalla and Nasr (1971). This might suggest that excretions or secretions from the helisomes affect the reproductive potential of *B. glabrata*. In the experiments on the susceptibility rates of *B. glabrata* to *S. mansoni* there was a consistent reduction of these rates as the number of helisome snails increased. This points to the fact that helisomes absorb a good number of the miracidia of the schistosomes possibly acting as decoys, as has already been suggested by Chernin (1968), and Rasmussen (1974).

Although results of laboratory experiments should not always be indicative of what happens in natural habitats there is evidence of competition between helisome snails and *B. glabrata* as indicated by the data from the literature and our own observations of the geographical distribution of helisomes and the susceptible snail hosts of *S. mansoni* in the neotropics. Observations on the natural geographical distribution of *Helisoma* spp. point to their possible use as biological control agents of medically important snails such as *Biomphalaria* spp. in Africa and the neotropics and of *Bulinus* spp. in Africa and the Middle East.

Although most species of *Helisoma* are temperate climate snails in North America, a few species are adapted to and occur in the subtropics and tropics of the Americas. The genus is not represented in Africa or Asia. In the neotropics species of *Biomphalaria*, such as *B. obstructa*, *B. riisei*, *B. albicans* and *B. fieldii*, share habitats with a few species of *Helisoma*. However, helisomes do not occur in the geographical zone of distribution of the medically important neotropical *B. glabrata*, *B. straminea* or *B. tenagophila*, except in a small overlap zone in the Caribbean, and probably Venezuela. In Puerto Rico, Harry and Hubendick (1964) reported *B. glabrata* co-existing with *Helisoma foveale* (Menke, 1830) in two habitats. The senior author has collected *Helisoma* spp. from Panama, El Salvador, Colombia, and Mexico. He did not encounter helisomes on Saint Lucia (Malek, 1976) nor on Grenada, but helisomes are known to occur on Guadeloupe and Martinique. *Helisoma duryi* a species common in Florida has been introduced into the Distrito Federal and two other habitats in Brazil (Paraense, *personal communication)*.

Other snails which have been advocated for biological control of *Biomphalaria glabrata* are *Pomacea* spp., and *Marisa cornuarietis*. However, both *Pomacea* and *Marisa* are neotropical and in certain habitats they occur together with *B. glabrata*. The senior author encountered several localities in western Bahia in Brazil, where large numbers of *Pomacea* and *B. glabrata* co-exist. In Africa species of the genus *Pila*, an ampullarid closely related to *Pomacea* co-exist with *Biomphalaria* spp. and *Bulinus* spp., hosts of *S. mansoni* and *S. haematobium* respectively.

In addition to helisomes acting as competitors against the medically important biomphalarids and bulinids they can also serve as decoys in absorbing a large number of the miracidia as demonstrated in this study, and as reported by other workers. It has been demonstrated by us and by other workers that helisomes cannot act as suitable hosts for the schistosomes. Helisomes certainly deserve to be considered as biological control agents either by being competitors, intoxicators or decoys. Other suggested forms of competitive displacement of the medically important *B. glabrata* has been by the use of other species of *Biomphalaria*, such as *B. tenagophila* and *B. straminea*, and in this case the competition is termed interspecific competitive displacement (Barbosa, 1973). Observations by the senior author in Bahia, Brazil, support the apparent displacement under natural conditions of *B. glabrata* by *B. straminea*. Interest in such forms of biological control has arisen from the fact that these measures are inexpensive to apply. They require minimal training of the personnel, no equipment and have no chemical side effects. Thus while we are making use of the information which has been gained about chemical control of snails for the last 2 or 3 decades, we should also be considering effective biocontrol.

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NESOVITREA SUZANNAE, A NEW ZONITID LAND SNAIL FROM COASTAL SOUTHERN TEXAS

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ABSTRACT

Nesovitrea suzannae *Pratt is a new zonitid land snail from leaf litter in live oak groves of Aransas County, Texas. It is distinguished from other North American* Nesovitrea *species by its diameter of 2.25 to 2.5 mm, umbilicus 16% to 21% of diameter, lack of spiral sculpture, and pinkish brown color.*

In April of 1974 a field party of the Fort Worth Museum of Science and History, making general natural history collections in southern Texas, collected a casual leaf litter sample in Goose Island State Park. When sorted some months later the sample proved to contain a small series of an undescribed land snail of the family Zonitidae. Later sampling of the same locality provided more material, including living specimens.

Nesovitrea (Perpolita) suzannae

new species

Diagnosis: a small *Nesovitrea*, 2.5 mm or less in diameter, translucent pinkish brown in color, with fewer than four whorls, umbilicus less than 22% of diameter, and without spiral sculpture.

Description: shell depressed heliciform, whorls 3 1/2 to 3 7/8, slowly increasing, periphery rounded, aperture ovate-lunate, lip simple; diameter 2.25 to 2.5 mm, height 47% to 51% of diameter; umbilicate, the umbilicus 16% to 21% of diameter. Irregular growth striae strongly developed above periphery, barely discernable on base, shell otherwise smooth, without sprial sculpture. Fresh shell translucent pinkish brown.

Atrium long, simple; penis strongly clavate, apex bluntly rounded, the slender and delicate penial retractor muscle inserted well below the apex, slender atrial end of penis without internal folds, internal walls of swollen apical half with complex internal folds forming a reticulate pattern; a membranous sheath visible at insertion of epiphallus; epiphallus entering penis will below apex, walls of epiphallus simple, without glandular thickening; vagina short; spermotheca a clavate sac, tapering slightly toward insertion. Length of penis .6 mm, length of epiphallus .6 mm. Body of living snail light gray.

Holotype: United States National Museum of Natural History, (USNM 711140); *type locality:* Goose Island State Park, 1 mile east of Lamar, Aransas County, Texas. Sifted from leaf litter in grove of coastal live oak (*Quercus virginiana* L.), 19 April 1974, W. L. Pratt, W. R. Barber *et al.*

Paratypes: deposited in the Fort Worth Museum of Science and History (FWMSH 3201), the Dallas Museum of Natural History (DMNH), and in the author's collection (WLP 1528). Additional paratypes collected on 1 December 1974 at the type locality have been deposited in the author's collection (WLP 1529) and will be distributed to major natural history museums.

Measurements:

Diameter *(mm)*	*Height* *(mm)*	*Umbilicus*	*Whorls*
(Holotype)			
2.5	1.25	.45	3 1/2
(Paratypes)			
2.15	1.2	1	3 7/8
2.45	1.15	.4	3 7/8
2.5	1.2	.5	3 7/8
2.35	1.2	15	3 3/4
2.45	1.15	15	3 7/8
2.25	1.15	.45	3 3/4
2.25	1.15	4	3 1/2

(All specimens fully mature; all measurements by ocular micrometer.)

FIGS. 1, 2 and 3. Nesovitrea suzannae *Pratt, new species. Holotype, diameter 2.5 mm.*

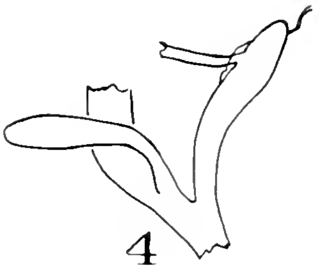

FIG. 4. Nesovitrea suzannae *Pratt, new species. Outline drawing of the anterior genitalia of a paratype, scale line equals 0.1 mm.*

Discussion: Nesovitrea dalliana (Pilsbry and Simpson) of Florida and coastal Georgia differs from *N. suzannae* in color, has more whorls (4 to 4 1/2), a wider umbilicus (22.5% to 27% of diameter), and is larger (2.66 to 3.35 mm). *N. subhyalinia* (Pfeiffer) of Mexico is larger with a more depressed shell and weak spiral striae. *N. electrina* (Gould), known from the Texas Pleistocene, and *N. binneyana* (Morse) are northern species, both much larger with somewhat wider umbilicus and different color. The penial retractor is inserted on the apex of the penis in both *N. electrina* and *N. binneyana*, in addition to numerous other differences in detail (Baker, 1930); neither of the other American *Nesovitrea* has been dissected.

A single Texas species, *Glyphyalinia roemeri* (Pfeiffer), might be confused with *N. suzannae* in drift material. *G. roemeri* is larger, with closely-spaced, regular radial grooves; fresh material is translucent yellowish white. *G. roemeri*, so far as presently known, is restricted to the uplands of central Texas, well away from the coastal range of *N. suzannae*, but might be found in river or beach drift.

Nesovitrea suzannae is known only from the type locality. The minute snails of the region are poorly known, however, and *N. suzannae* is probably widespread in the live oak groves of the Texas coastal prairie. Living snails in the original sample had been mostly young juveniles with a few lingering adults, suggesting that the species probably breeds in late winter and early spring. An additional collection made in early December, 1974 was composed of large juveniles and young adults, strengthening the evidence for a late winter breeding season. At the type locality *N. suzannae* inhabits leaf litter of a grove of coastal live oak (*Quercus virginianus* L., s. str.) with a dense understory of yaupon (*Ilex vomitoria* Ait.) and red bay (*Persea borbonia* (L.) Spreng.). The litter forms a layer about 4 cm thick on Pleistocene beach sands with little or no development of soil horizons.

Nesovitrea suzannae is named for my wife, in recognition of her assistance in the field and her patience at home.

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ASPECTS OF THE REPRODUCTIVE CYCLE IN *MACOMA BALTHICA* (BIVALVIA)

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ABSTRACT

The reproductive cycle and sex ratio by size in a population of Macoma balthica *at Rand harbor, Falmouth, MA, were determined by dissecting live, measured animals taken from monthly samples (October 1969 to August 1970) and examining the gonads. Several specimens, representative of the stages of gonadal development observed macroscopically, were fixed for histological study. The histological appearance of gonadal development is very similar to that reported by Caddy (1967) and Lavoie (1970). There appears to be but one, annual reproductive cycle in* M. balthica *at Rand Harbor, with spawning occurring in May. Gonadal regeneration starts by late fall an gonadal growth continues throughout the winter. There appears to be no significant deviation from a 50:50 sex ratio at any size at Rand Harbor.*

In molluscan species with extensive latitudinal ranges, spawning in widely separated localities occurs at different times (Lammens, 1967; Giese, 1959). For example, populations of *Mya arenaria* (Ropes and Stickney, 1965; Shaw, 1965), *Spisula solidissima* (Ropes, 1968), and *Mercenaria mercenaria* (Porter, 1964, cited in Ropes, 1968) spawn once a year in the northern portions of their range, but twice a year to the south.

The reproductive cycle in *Macoma balthica* (L.) has been studied at several localities: Bay of Mecklenberg, Baltic Sea (von Oertzen, 1972); Den Helder, the Netherlands (Lammens, 1967); the Thames estuary at Whitstable, Kent, England (Caddy, 1967); the Saint Lawrence estuary, Cacouna-est, Quebec, (Lavoie, 1970); Malpeque Bay, Prince Edward Island (Sullivan, 1949); the Saint Croix estuary and Birch Cove in Passamaquoddy Bay, Saint Andrews, New Brunswick (Battle, 1933); and the Tread Avon River in the Chesapeake Bay, Maryland (Shaw, 1965). I studied the reproductive cycle of *M. balthica* at Rand Harbor, Falmouth, Massachusetts, intermediate between the Canadian and Maryland sites, to clarify latitudinal patterns.

METHODS

Samples of *M. balthica* and water-column temperatures were taken at approximately monthly intervals from October 1969 to August 1970 from the zone of greatest abundance in the intertidal area at Rand Harbor. Spadesful of mud were washed through a 2 mm mesh sieve and the animals removed and taken to the laboratory. Sex and gonadal condition were examined after removal of the left shell valve and mantle lobe. Sex is easily determined by the color of the gonad: ovaries are gray to gray-orange and testes are white (Battle, 1933; Lammens, 1967; Caddy, 1967). Eggs are also often visible through the body wall. As a histological check on the visual determination of gonad condition, 25 specimens (total) were chosen as representative of all stages

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TABLE 1. Date, water temperature and number (ΣN = 228) of *M. balthica* examined at each collection at Rand Harbor.

Date	Water temperature (at low tide)°C	Number examined
October 24, 1969	—	15
November 13, 1969	11	22
December 5, 1969	2	27
January 9, 1970	frozen	—
February 8, 1970	0	21
March 12, 1970	3	34
April 22, 1970	12	36
May 11, 1970	12	40
June 1, 1970	16	21
August 14, 1970	25	12

of gonadal development from the animals examined in March, May, June and August. The visceral masses of these specimens were fixed in Rossman's fluid, imbedded in paraffin, cut at 5-10μ, mounted on slides and stained with hematoxylin and eosin.

RESULTS

The gonad was observed to invest the visceral mass in a slightly different pattern from that detailed by Caddy (1967), so a different system of classification was used to chart the development of maturity. The gonad was first visible just below the pedal retractor muscle (fig. 1a,), but sexing was not possible at this time (immature stage). The gonad then grows down among the coils of the hindgut and through the central portion of the foot (Stage A), and finally appears dorsal and anterior to the stomach (Stage B; fig. 1a). Stage C (pre-spawning) is marked by a striking swelling of the visceral mass due to a rapid increase in the volume of the gonad. For up to two months after spawning, the visceral mass is in the "spent" condition. It appears flaccid with a glassy hyaline surface and contains visible gonadal remains. As the animals recover from spawning, the gonad remains are resorbed and the gut becomes clearly visible through the body wall (undifferentiated stage); sex is again indistinguishable at both the macro- and microscopic levels.

Histologically, the cycle is basically the same as reported by Caddy (1967) and Lavoie (1970). I was unable to confirm Caddy's observation that the gonia were concentrated near the pedal ganglia after spawning. Rather, the observed pattern of gonadal proliferation (fig. 1a) supports Lavoie's findings that the germinal cells are first found around the genital pores near the internal dorsal pallial cavity.

Fig. 1b presents the percentage of animals in each stage of development throughout 1969-70 at

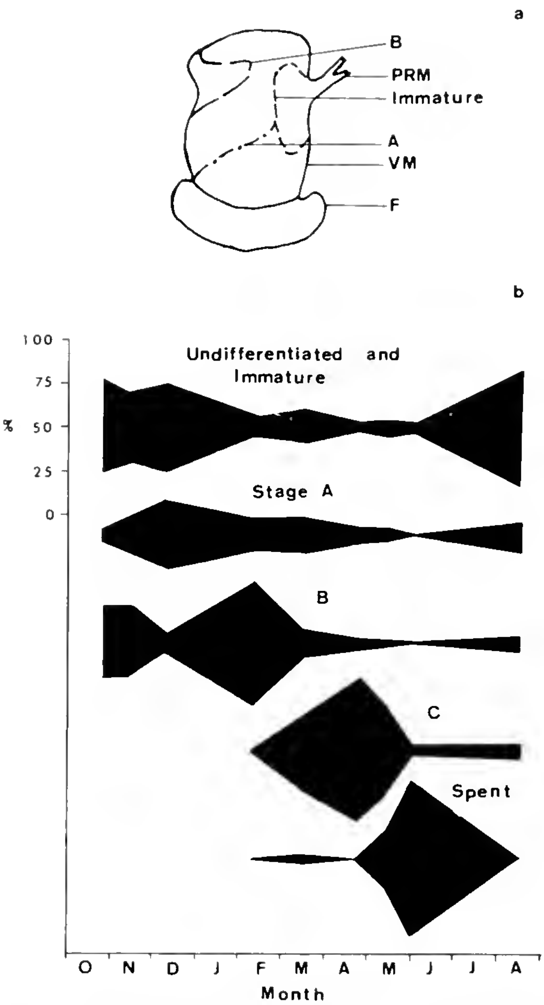

FIG. 1. **a.** Diagram showing the several stages of gonadal maturity of *M. balthica* at Rand Harbor. Lines labeled A, B show the dorsal extent of the gonad at stages A and B; F, foot; PRM, pedal retractor muscle; VM, visceral mass. Anterior is to the left.

b. Percentage (N = 228) of *M. balthica* in each stage of gonadal maturity during 11 months at Rand Harbor. Stages A and B are as diagramed in 1a, see text (p. 22) for the description of the remaining stages.

Rand Harbor. There was clearly only one reproductive cycle, with spawning occurring largely in May and finishing by early June. Recovery occurs over the summer and into the fall, and gonadal regeneration starts by late fall. Gonadal growth progresses slowly and steadily until February, when it speed up in preparation for spawning.

Table 2 presents the percentage of male, female and undifferentiated individuals in each size category (5 to 13+ mm) for all animals examined. Individuals become sexually mature at about 8 to 10 mm in length, i.e. at the end of their first year (Gilbert, 1973). Although Caddy found that small (4 to 10 mm) specimens are predominantly male with the sex ratio approaching 50:50 as animals become larger, there appears to be no significant deviation from a 50:50 sex ratio at any size at Rand Harbor. This discrepancy may be due to the fact that very few *M. balthica* are 4 to 6 mm in length at the end of their first year at Rand Harbor.

DISCUSSION

As in the pelecypod species mentioned in the introduction, *M. balthica* appears to have but one spawning season in the northern part of its range and two in the southern portion (fig. 2). The timing of these seasons varies, but seems to be tied to the annual periods when the seawater ranges from 7 to 14°C. In Passamaquoddy Bay (Saint Croix and Birch Cove; Battle, 1933), the water warms much more slowly and evenly than in other localities and reaches a peak of only 12-14°C by late summer, explaining the delayed spawning season there. Sullivan's (1948) data show that planktonic larvae are only found for three o four weeks at temperatures warmer than 15°C, implying that spawning occurred during the immediately preceding period when temperatures rose from 10-15°C within a week. Lammens (1967) concluded from laboratory and field observations that the critical temperature conditions may indicate hospitable conditions for larval survival; and both the coincidence of spawning with neap tides (Battle, 1933; Caddy, 1967) and the rapid rate of development at low

TABLE 2. Percentages of male, female and undiffertiated *M. balthica* in each size category collected throughout one year.

Sex	Size (mm) 5-7 (N = 7)	 8-10 (N = 47)	 11-13+ (N = 174)
male	0	30	42.5
female	0	21	42.5
undiffereniated and immature	100	49*	15

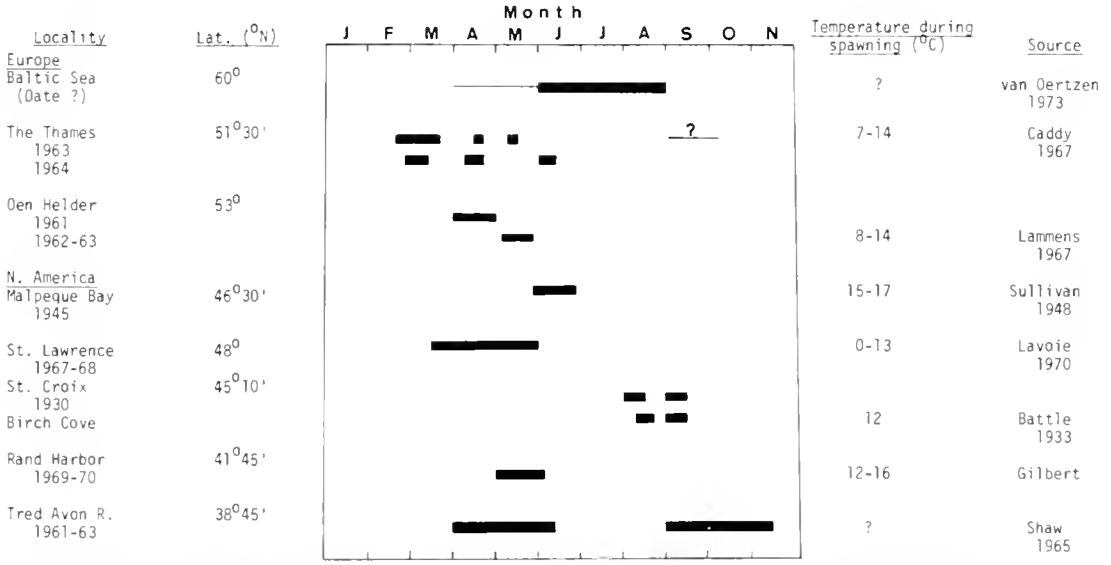

FIG. 2. *Dates and temperatures of the water during spawning seasons of* Macoma balthica *at various locations.*

temperatures (Gilbert 1975) may be adaptations to help ensure return of the larvae to the adult locality.

Two characteristics of this species' reproductive cycle emerged. First, gonadal growth occurs throughout the winter (fig. 1; Caddy, 1967; Lammens, 1967; Lavoie, 1970). As Lammens points out, since *M. balthica* feeds on the substrate, its food source is available throughout the year. Second, there is an alternation of growth in size and gonadal development: the annual period of rapid increase in length (Gilbert, 1973) occurs during the gonadal recovery period (fig. 1b). Lammens and Lavoie also observed such an alternation for animals at Den Helder and Cacouna-est (Saint Lawrence), respectively.

The age of sexual maturity does vary. On the Thames it occurs during the second year (at 5 to 6 mm length; Caddy, 1967), whereas in the Netherlands first year animals larger than 4 mm contained gonads during the spawning season (Lammens, 1967). At Cacouna-est, sexual maturity is not achieved until the second year (mean length of 3.57 mm), as first year animals (2.34 mm) did not spawn their sexual products (Lavoie, 1970). Considering that the growth rate varies widely among different populations of *M. balthica* (Gilbert, 1973), this species may mature sexually during the second year, regardless of size, and during the first year if a certain size (4 mm) is reached.

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EFFECTS OF POLLUTANTS ON NATALITY OF *MUSCULIUM SECURIS* (BIVALVIA: PISIDIIDAE)

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ABSTRACT

Laboratory experiments show that natality of Musculium securis *is significantly reduced below 10°C and above 25°C with optimum reproduction close to 18°C. Road salts consisting of sodium chloride have a greater adverse effect than similar concentrations of salts consisting of calcium chloride on the natality of laboratory reared* M. securis. *Natalities are significantly less in sulfate concentrations exceeding 100 mg/1. When reared in the field, reproduction of* M. securis *is reduced immediately below pulp and paper outfalls and sewage and slaughter house waste discharges. It is concluded that natality is a good index for the assessment of water quality. Guidelines are given to standardize techniques for calculating a natality index from naturally occurring populations of sphaeriids.*

A plethora of indices using benthic organisms for the assessment of water quality has been developed in recent years. Nearly all require species identifications of several groups of benthic organisms. Perhaps the oldest and most commonly used are the pollution indicators (e.g. *Tubifex tubifex* and *Chironomus plumosus*) whose presence in large numbers usually indicate organic enrichment (Gaufin 1973). Long lists have been published of plants and animals classified as indicators of different degrees of pollution (Kolwitz and Marsson 1908, 1909; Richardson 1929; Sladacek 1973). Lists of groups of indicator organisms have been made for calculating biotic indices, such as the Trent Biotic Index (Woodiwiss 1964) and the Beak Biotic Index (Beak 1965). Use of diversity indicies based on information theory (Wilhm and Dorris 1968; Pielou 1967, 1969) are being used in assessment of water quality with increasing frequency in the literature.

All extant biotic indices require good quantitative samples to be able to calculate accurate population sizes for each taxon. However, there are numerous sources of error that are inherent in the various methods needed for accurate population estimates (Cummins 1962). For example, there are no sampling devices that sample all communities on all substrates equally well resulting in selectivity of gear for certain benthic groups (Flannagan 1970). There is usually loss of some organisms through conventional sieves during washing procedures (Jonasson 1955; Reisch 1959; Mackie and Quadri 1971). The methods that have been developed for separating the organisms from the debris are invariably selective for certain groups (e.g. flotation, Anderson 1959, Whitehouse and Lewis 1966; fluorescent dyes, Hamilton 1969; elutriation, Moon 1935). Finally, the taxonomy of some groups, especially of larval chironomids at the species level, is poorly known and the identification of all taxa within a community is time consuming and often requires confirmation or identification by experts.

Clearly, there is need for a biotic index that does not require quantitative samples nor identification of species within numerous taxa. These obstacles largely can be reduced with the use of natality data from a single group of organisms. Natality is a useful parameter because it is a measure of population increase under an actual specific environmental condition varying with the size and composition of the population and the physical environmental conditions (Odum 1971). The prerequisites for choice of organisms are (a) they should be cosmopolitan in distribution, and (b) they should be viviparous or ovoviviparous (i.e. bear living young) since oviparous organisms usually lay numerous eggs (often uncountable) that are often hard to find. The most cosmopolitan benthic organisms are oligochaetes, chironomids, and sphaeriids, and of these, only the sphaeriids are ovoviviparous and bear living young.

The objectives of the present study are to determine the effects of some common pollutants, temperature, road salts, sulfate, domestic and slaughterhouse wastes, and pulp and paper effluent on the natality of a sphaeriid, *Musculium securis*, and to assess the use of sphaeriid natality as an index for assessment of water quality. The effects of substratum and competition on natality of *M. securis* are described elsewhere (Mackie and Qadri, *in press; Mackie*, Qadri, Reed, *in press). Musculium securis* was chosen as the test animal because it is cosmopolitan in distribution and grows and reproduces relatively quickly in the laboratory (Mackie 1973).

MATERIALS AND METHODS

Natality in sphaeriids is relatively easily determined by one of two methods. The simplest method is to place one to five newborn clams into growth containers, allow them to grow and reproduce under a specific set of environmental conditions either in the laboratory or in the natural habitat, and count the number of newborn produced after a definite interval of time. For *M. securis* this interval of time is the life of the clam (60 to 80 days) since the parents usually die after producing a litter of newborn. For multivoltine species the containers must be examined at more frequent intervals. Mean natality is determined by dividing the total number of newborn produced in the containers by the number of parents (i.e. adults that reproduce).

Since the first method requires at least eight weeks to obtain results (from *M. securis*) the second method is preferred where natality data is needed in one or two days. However, a knowledge of larval development in sphaeriids is required. A brief description follows but detailed descriptions of life history of *M. securis* are given by Mackie, Qadri, and Clarke (1975, 1976) and of other species by Heard (1965, 1977).

In sphaeriids there are four arbitrarily defined stages of larval development that occur on the inner gill; these are embryos, fetal larvae, prodissoconch larvae, and extra-marsupial larvae. Embryos are contained within single-walled primary sacs and include all stages from the zygote through gastrulation. When the shell begins to form the larvae are known as fetal larvae and the enveloping brood sac forms a second wall to become a secondary brood sac. The prodissoconch larva is the third developmental stage including formation of the shell up to but not including escape from the double-walled tertiary sacs in which they are incubating. The shelled larvae that have broken free from the tertiary sacs are known as extra-marsupial larvae and they are contained within the marsupium prior to birth. All four larval stages may be found on an inner gill in species of *Musculium* but only one developmental stage is usually found at one time in species of *Pisidium* and *Sphaerium*.

There is usually some mortality between each larval stage with more mortality occurring between fetal and prodissoconch larvae than between prodissoconch and extra marsupial larvae. There is very little or no mortality at the extra-marsupial stage and more than 99% of these larvae are viable at birth in *M. securis* (Mackie, Qadri, and Clarke 1976). Therefore, in the second method it is important to account for extra-marsupial larvae. Care must be taken, when examining a sample, to ensure that none of the extra-marsupial in a litter have been born (i.e. newborn are not present in the sample). Counts of prodissoconch larvae are also useful since they can be used to determine numbers of extra-marsupial larvae in a litter if amount of mortality between these two stages is known. A sample of 50-100 specimens of a species is sufficient for calculating a reliable estimate ($P<0.05$) of mean natality.

After trying several methods, I found that a combination of soil (from a willow-elm forest), leaves, and water was the best medium for maintaining *M. securis* in the laboratory. Newborn *M. securis* were obtained from Carp Pond (Mackie, Qadri and Clarke 1976) and grown in 100 mm dia × 50 mm ht

"Pyrex" dishes (= growth dish) containing 50 g (oven-dry basis) of air-dried soil, (from Carp Pond), 2 g of air-dried black willow or white elm leaves, and enough distilled or deionized water to fill each dish. One day was allowed for equilibration, and then usually five newborn *M. securis* were added. These were allowed to grow, reproduce, and die (60-80 days). Dishes were topped daily with distilled or deionized water and examined every two weeks to determine how many adults were bearing larvae (shells are transparent enough to see if larvae are present). Dishes were otherwise left undisturbed, e.g. without aeration. At the end of the experiment, when at least 75% of the parents (usually 100%) were dead, the numbers of newborn produced within each dish were determined.

Temperature - To determine the effects of temperature on the natality of *M. securis*, adults were grown in constant temperature rooms at 5°C, 10°C, 18°C, and 25°C. Other conditions, such as light intensity, appeared to be similar in each room but were not measured. Three dishes with five newborn in each were maintained at each temperature.

Road salts - To determine the effect of road salts on the natality of *M. securis*, newborn were grown in various concentrations of rock salt, calcium chloride ($CaCl_2$), and sodium chloride (NaCl). The rock salt was obtained from the storage sheds of the Ontario Department of Highways. The chemical composition (by weight) of the rock salt as specified by the Ministry of Transportation and Communications of Ontario (pers. comm.) had a moisture content of less than 0.5%, a sodium chloride content of more than 96.0%, and insoluble matter of less than 4.0%. Concentrations of 200, 400, 600, 800, and 1000 mg/1 of each salt were made using deionized water. Growth dishes were prepared as described above but in replicates of three and using the solutions of different salt content rather than distilled water. Three control dishes (i.e. soil, leaves, and deionized water) were also prepared with five newborn clams in each.

Sulfate - The effect of sulfate on the natality of *M. securis* was determined by maintaining adults in sulfate (in sulfuric acid) concentrations of 0, 20, 40, 60, 80, 100, 200, 300, 400, and 500 mg/1. Natality of *M. securis* was determined as described earlier but in replicates of three for each concentration of sulfate solution. The final sulfate concentration in each dish was taken as the concentration of sulfate added plus that which went into solution from the soil used in the growth dishes. Sulfate concentration was determined on water samples taken from each dish using a modification of the turbidimetric technique of Toennies and Bakay (1953). These modifications are described elsewhere (Mackie 1973).

Organic and Industrial Pollutants - Growth tubes were made to maintain *M. securis* above and below municipal sewage and industrial outfalls. The tubes were made out of 35 mm dia × 60 mm ht plastic vials with snap-on caps. Two 1 cm × 4 cm rectangular holes were cut from the lower sides and covered with nylon mesh to permit flow of water through the tubes. Twenty growth tubes, each containing one newborn *M. securis* from Britannia Bay of the Ottawa River near Ottawa, were placed at each distance of 50 m, 330 m, 700 m, and 1000 m below the outfalls of a pulp and paper plant in the Ottawa River. Another twenty tubes were placed immediately upstream of the outfalls as controls. Twenty tubes were also placed 1.6 km below a slaughterhouse and several raw sewage outfalls; growth tubes placed in Britannia Bay were used as controls. All growth tubes were placed in less than one meter of water. The number of young produced by parents in each tube was recorded at the end of the experiment.

RESULTS

Temperature

Of the four temperatures tested, the greatest natality occurred at 18°C (Table 2). The optimum temperature for reproduction was between 10 and 25°C, probably close to 18°C.

Road salts

Increased concentration of rock salt and pure sodium chloride had greater adverse effects on the natality of *M. securis* than did calcium chloride (Table 2). Natalities were greater in control dishes than in experimental dishes containing rock salt or sodium chloride. Lower natalities occurred in high concentrations of CaCl than in control dishes but differences were not significant primarily because of the large variations in natality that occurred among dishes.

Sulfate

The following table gives the pH and sulfate contents of the test solutions before and two weeks after adding sediments. The results show that the pH decreased with increasing concentration of sulfate. Also, the increase in pH after adding sediment indicates the high buffering capacity of the soil in the dishes. The amount of sulfate that went into solution from the sediment tended to decrease with increasing concentration of sulfate, in the prepared solutions.

TABLE 1. Changes in the pH and sulfate concentrations of water after adding Carp Pond soil to the growth dishes.

Before adding soil		*Two weeks After adding soil*	
pH	sulfate mg/1	pH	sulfate mg/1
7.00	0	6.80	80
3.90	20	6.60	92
3.10	40	6.40	108
2.75	60	6.30	118
2.60	80	6.16	128
2.45	100	6.10	144
2.25	200	5.65	230
2.15	300	5.45	333
2.00	400	5.15	427
1.90	500	4.70	515

Concentrations of sulfate less than 100 mg/1 had no significant effect on the natality of *M. securis* (Table 2). Significant reductions in natalities occurred in concentrations exceeding 100 $mgSO_4/1$. Most clams in these concentrations formed blackish shells.

Raw sewage and slaughterhouse wastes

There was no reproduction of *M. securis* in a creek carrying raw sewage and slaughterhouse wastes (Table 2). The qualities of the waters in the creek and control stations are given in Table 3.

Pulp and paper wastes

Natalities of *M. securis* were significantly greater ($P<0.05$) above the outfalls than below the outfalls and tended to increase with increasing distance below the outfalls (Table 2).

As many as eight leeches of the species, *Helobdella stagnalis*, were present in the growth chambers above the outfalls. The mortalities of *M. securis* in the chambers were low and most produced young so that the leeches had little effect on the production of first litters of young. Most *M. securis* adults died by the end of August in the control tubes but it is not known whether they died of natural causes or leech predation.

High mortalities of *M. securis* occurred in growth tubes below the outfalls. No leeches occurred in the growth tubes below the outfalls. Premature deaths of adults were probably attributable to chemicals or other properties of the effluents. Table 4 gives some physical and chemical properties of the water at various distances from the outfalls during the study period.

DISCUSSION

Effects of Pollutants

Mackie (1973) showed that growth of *M. securis* at 10°C in the laboratory was minimal and that in the natural habitat growth did not appear to begin until about 8°C. Similar results have been reported for other sphaeriids, e.g. *M. partumeium* (Thomas 1965) and *S. corneum* (Thiel 1927; Mitropolskji 1966) and several freshwater gastropods (van der Schalie and Berry 1973). These results suggest that many sphaeriids should be absent or depauperate in waters where the mean temperature is less than 10°C, although some (e.g. *Pisidium conventus* and *Sphaerium nitidum)* are seldom found in temperatures above 10°C, Herrington 1962).

Mackie (1973) also showed that the upper threshold of tolerance for *M. securis* was less than 30°C and the present study would indicate that reproduction probably ceases between 25 and 30°C. Other species, e.g. *M. partumeium* (Thomas 1959) have even lower thresholds, close to 21°C. These results suggest that many sphaeriids would be absent in waters where the mean temperature exceeds 25°C.

High concentrations of rock salt and sodium chloride have a greater adverse effect on the reproduction of *M. securis* than do high concentrations of calcium chloride. Smaller natalities occur with increased concentrations of rock salt and sodium chloride, particularly in concentrations greater than 200 mg/1. The results obtained using calcium chloride are more difficult to explain.

Clams show higher natality with increased concentration of calcium chloride but natality in all concentrations studied are less than those observed in the control dishes. The reasons for this are not clear but it is possible that chloride has an adverse effect while calcium has a stimulating effect on the reproduction of *M. securis*. If this interpretation is correct then the adverse effects of chloride are more pronounced at low calcium chloride concentrations and the stimulating effects of calcium are more pronounced at high concentrations.

The results also indicate that road salts could be a major factor in limiting the distribution of *M. securis*. This is particularly true in northern latitudes where sodium chloride is used in the winter months to remove ice from roads. The effects of road salts on growth, reproduction and distribution of other sphaeriids have not been reported in the literature.

The present study indicates that natalities of *M. securis* are not significantly affected by sulfate until exposed to concentrations exceeding 100

TABLE 2. Mean natalities of *Musculium securis* adults showing the effects of temperature, rock salt, sodium chloride, calcium chloride, sulfate, pulp and paper waste and raw sewage and slaughterhouse wastes. Means side-scored by the same lines are not significantly different at P = 0.05. Standard deviation of the mean in parentheses.

Variable	Mean Natality	
Temperature (C)	per growth dish	
25	14.7	(3.1)
18	49.7	(4.2)
10	0	
5	0	
Rock Salt mg/l	per growth dish	
0	54.3	(5.1)
200	33.7	(2.5)
400	19.3	(3.2)
800	8.3	(2.7)
600	3.0	(1.5)
1000	0	
Sodium Chloride mg/l	per growth dish	
0	54.3	(5.1)
200	28.7	(2.1)
400	22.0	(7.6)
600	8.7	(4.1)
800	5.0	(5.6)
1000	0	
Calcium Chloride mg/l	per growth dish	
0	54.3	(5.1)
800	40.7	(8.1)
600	31.3	(5.1)
1000	30.3	(7.5)
200	28.7	(2.1)
400	22.0	(8.5)

Variable	Mean Natality	
Sulfate mg/l	per growth dish	
40	52.0	(9.2)
20	43.1	(7.0)
0	43.6	(5.6)
60	43.3	(9.2)
80	40.7	(1.2)
100	39.7	(0.6)
200	21.0	(15.6)
300	10.7	(2.9)
400	10.3	(5.7)
500	0	
Pulp and Paper	per growth tube	
Above outfalls	3.8	(1.6)
1000 m below	2.1	(0.6)
700 m below	1.8	(1.1)
300 m below	0.8	(1.3)
50 m below	0	
Sewage and Slaughter	per growth tube	
Above outfalls	9.8	(2.4)
Below outfalls	0	

TABLE 3 The means and ranges of several factors of the water below a slaughterhouse and several raw sewage outfalls. Each mean is based on five water samples taken at approximately two week intervals in the summer of 1971. All values are in mg 1 unless otherwise indicated.

Parameters	Below Outfalls		Britannia Bay - Control	
	Mean	Range	Mean	Range
Temperature °C	17.6	8.0-22.5	20.0	17.0-21
Alkalinity	28.8	24.0-36.0	30.4	28.0-35.0
Conductivity micromhos/cm	70.2	62.0-80.0	65.4	63.0-68.0
Dissolved oxygen	5.5	3.0- 8.0	8.4	8.0- 9.0
Hardness (calcium)	35.6	28.6-53.2	18.0	16.0-20.0
Hardness (total)	46.4	48.7-72.3	26.2	22.0-32.0
pH	6.7	6.5- 7.0	7.0	7.0- 7.2
Sulfate	11.8	7.0-25.0	8.0	5.0-10.0
B.O.D. (5 days, 20^{0}C[a]	3.8	0.6-16.5	1.1	0.4- 3.0
Total coliform bacteria (MPN/100cc)[b]	322200	43000-2400000	760	21-9300

[a] Biochemical oxygen demand – given in Mackie (1973).

[b] MPN = Most Probable Number - given in Mackie (1973)

$mgSO_4/1$. However, as the sulfate concentration is increased, the pH decreases. Therefore, it is difficult to determine whether pH or sulfate is the limiting factor. Since the same inverse relationship usually exists between pH and sulfate in the natural habitat, it can only be concluded that high sulfate concentrations would have either a direct or indirect effect on the reproduction of *M. securis*.

High concentrations of sulfate may also limit the distribution of *M. securis* although specimens have been collected near Sudbury, Ontario (see collection in National Museum of Canada, #NMC 28610) where sulfur dioxide is a serious atmospheric pollutant (Rao and Leblanc 1967). In the presence of moisture, sulfur dioxide forms sulfurous acid which is slowly oxidized to sulfuric acid; the acid in turn is converted to sulfates such as amonium and calcium sulfate (Johnstone and Coughanow 1958). The effects of sulfate on the growth and reproduction of sphaeriids, and indeed on other mollusks, have not been reported in the literature.

It is apparent that *M. securis* cannot tolerate gross chemical and/or organic pollution of pulp and paper, slaughterhouse, and raw sewage effluents. It is not possible to identify those factors in the effluents that affected the reproduction of *M. securis* although the water quality data indicates that large B.O.D.'s and coliform bacteria counts may be important factors. Since *M. securis* often is exposed to very low oxygen levels (less than 1 ppm) in temporary aquatic habitats (Mackie 1973), it is doubtful that oxygen was a limiting factor in the growth of *M. securis* below the outfalls. Thomas (1965) also concluded that oxygen was not a limiting factor in the growth of *M. partumeium.*

The effluent below the pulp and paper mill carried large quantities of wood fibers but very little entered the chambers in which *M. securis* adults were maintained. Therefore, growth of *M. securis* below the pulp and paper outfalls probably did not represent the added effects of wood fibers.

The increase in reproduction of *M. securis* with increased distance from the pulp and paper outfalls indicates that the species could survive in recovery zones. However, as indicated above, the environment in the growth chambers may not have been representative of the environment in the "natural" habitat below the outfalls. Wurtz (1956) suggest that *M. securis,* as well as several other sphaeriids, "can survive, at least to some degree, in the zones of degradation and recovery". Ingram *et al* (1953) conclude that *Sphaerium striatinum (*as *S. solidulum)* cannot tolerate intensive pollution from domestic sewage but that it may respond to a slight fertilization effect from domestic sewage by increased productivity. Kehr *et al* (1941) and Purdy (1930) consider the Sphaeriidae as a group of sewage-tolerant organisms while many others (Morgan 1930; Carpernter 1928; Baker 1922) associate them with clean waters.

Use of Sphaeriid Natality as an Index of Water Quality

The results of the pollution studies indicate that natality of *M. securis* is generally either directly or inversely related to the intensity of the concentration of a pollutant. This implies that the natality of *M. securis* is potentially a good index of environmental stress. However, before natality of sphaeriid species can be used as an index of water quality, the effects of various pollutants must be determined for several species (especially for common species such as *Sphaerium striatinum, Pisidium casertanum, Pisidium compressum, Pisidium nitidum,* and all *Musculium* species) since some, e.g. *S. striatinum,* respond to slight fertilization by increased productivity (Ingram *et al* 1953) and others by decreased productivity. Also, because of the heterogeneity of the natural habitat and the multiplicity of interacting factors (e.g. sediment texture, competition, temperature, etc.) experiments should be done in the field on natural populations. Stations should be established above

TABLE 4. The means and ranges (in parentheses) of several factors of the water at various distances above and below a pulp and paper outfalls. The values are based on five water samples taken at approximately two wek intervals. All values are in mg/l unless indicated otherwise.

Parameters	Above outfalls	Below outfalls			
		50 m	300 m	700 m	1000 m
Temperature °C	17.6 (8.0-22.5)	18.6 (9.0-24.5)	17.8 (8.0-22.5)	17.6 (8.9-22.5)	17.6 (8.0-22.5)
Alkalinity	25.0 (18.0-30.3)	22.2 (18.0-26.0)	24.7 (18.0-28.0)	24.5 (18.0-29.0)	24.4 (18.0-29.6)
Conductivity µmho/cm	62.2 (48.2-80.0)	60.4 (43.2-72.1)	64.7 (46.7-75.0)	67.3 (50.0-78.5)	65.1 (48.5-78.2)
Dissolved oxygen	8.5 (7.0-12.0)	6.5 (5.0- 9.0)	7.5 (6.0-11.0)	7.5 (7.0-12.0)	7.5 (7.0-12.0)
Hardness (calcium)	32.0 (25.2-36.3)	43.6 (35.3-64.4)	30.1 (27.3-34.4)	38.6 (27.1-45.5)	39.5 (23.1-46.0)
Hardness (total)	49.7 (42.4-54.7)	61.3 (53.0-83.2)	47.8 (44.0-54.8)	53.4 (42.1-60.0)	55.3 (41.7-60.0)
pH	6.9 (6.5- 7.5)	6.7 (6.5- 7.0)	6.7 (6.5- 7.0)	6.7 (6.5- 7.0)	6.7 (6.5- 7.0)
sulfate	17.8 (10.0-23.0)	30.4 (10.0-62.0)	32.3 (10.0-55.0)	18.6 (10.0-20.0)	15.6 (10.0-20.0)
Biochemical oxygen demand (5 days, 20^0C^a	1.6 (0.5- 4.0)			6.8 (0.4-29.4)	
Total coliform bacteria (Most probable number per 100 cc)[a]	(2300-21000)			(9300-2400000)	

[a] Values determined by Mackie (1971)

(= control) and at several distances below the outfalls. Habitat characteristics should be similar, except for those features altered by pollution, and natalities should be compared with those in the control stations. It is essential that at least two control stations be established to detect differences that may occur from one site to the next in the unaltered habitat. Also, control stations account for variations in natality that may occur from one year to the next and among different bodies of water.

If these criteria are met, then any changes in water quality would be accompanied and be detected by changes in the natality index. Values significantly less than those obtained in the control station would indicate deterioration in water quality. Values significantly greater than those obtained in the control station would indicate that the species responds to the ambient conditions by increased productivity. The habitat that supports the highest natality would probably be the habitat most characteristic of the species. Therefore, if a species is more prolific in organically enriched areas, it is probably an indicator of those conditions.

Applying the index to the Ottawa River, the highest natality in the natural population of *M. securis* in 1972 was obtained in Britannia Bay, the control station (2.44, Table 2). Although a small sample size (12), the mean natality of *M. securis* below the pulp and paper outfalls (off east end of Kettle Island, Mackie and Qadri 1973) in 1972 was 1.70 young per parent (standard deviation = 0.55). This is significantly less ($P<0.05$) than that obtained in Britannia Bay, indicating a deterioration in water quality.

The advantage of using natalities as indices of water quality are far reaching. Most significant is that quantative estimates of population sizes are not necessary and samples of sphaeriids need not be obtained with quantitative sampling techniques; it is necessary only to obtain a sufficient number of any species of sphaeriid that has a portion of the population in the process of reproduction. The number of extra-marsupial larvae (shelled larvae lying free in the marsupium and ready for birth) or prodissoconch larvae are determined for each parent and the mean natality per parent is then calculated as described in materials and methods. Enumeration of other larval stages provides other important criteria such as per cent viability of larvae and larval mortality rates (Mackie, Qadri and Clarke 1976). Another advantage is that water quality can be assessed long before conditions become aggravated if sphaeriid species common in cleaner water are examined. This is in direct contrast to pollution indicator organisms that diagnose water already grossly polluted.

Although this study indicates that natality is potentially a good index for assessment of water quality, considerably more studies are needed before its validity can be fully assessed. For example more data is needed to show variations in natality within several species taken from several different kinds of habitats. It is not known if species that require two and three years to complete their life cycles can also be used for natality indices. Studies are needed to determine if natality indices can be used to characterize different degrees of pollution, i.e. subpollution, gross pollution. Undoubtedly, many more questions will be asked as more problems are solved.

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RANGE EXTENSION OF MOLLUSKS FROM THE MIDDLE ATLANTIC BIGHT

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ABSTRACT

New northern and southern range and depth extensions off Eastern United States of 67 species of mollusks collected alive by R/V DELAWARE Cruise 60-7 are reported, including 3 scaphopods, 30 gastropods and 34 bivalves. Cylichna linearis *Jeffreys (Opisthobranchiata: Cylichnidae) is reported in Western Atlantic waters for the first time.*

The U. S. Bureau of Commercial Fisheries[4] conducted a routine cruise (R/V DELAWARE Cruise 60-7) in the middle Atlantic Bight from Cape Cod, MA, to Cape Hatteras, NC, during 11-21 May 1960. Eight major transects with selected stations between the transects were made; in all, 113 stations were occupied in depths of 26 to 146 meters (fig. 1). The primary reason for the cruise was to investigate the abundance and distribution of the sea scallop, *Placopecten magellanicus* (Gmelin). In addition to a 10-ft (3.05 m) standard offshore dredge used to collect the scallops, a small 30-in (76.2 cm) Digby dredge with a 1/2-in (12.7 mm) liner was towed at all stations to collect a sampling of the biota associated with the scallops. The scallop data were analyzed and reported (Merrill, 1962). The material collected in the lined Digby dredge was slowly sorted, identified, and tabulated as time allowed and the information is being used where appropriate. Several specific studies incorporating faunal data acquired from DELAWARE Cruise 60-7 have been published. Those relating to range extensions and species distribution are briefly summarized below.

Galtsoff and Merrill (1962), studying shell morphology, growth, and distribution of the crested oyster, *Ostrea equestris* Say, extended the range of this oyster northward. Merrill and Webster (1964), surveying oceanic commercial clam distribution, defined the major populations of *Spisula solidissima* (Dillwyn) and *Arctica islandica* (Linné) in the middle Atlantic Bight. Boss and Merrill (1965), monographing the family Pandoridae, clarified distributional patterns of *Pandora* species occurring in the middle Atlantic—the ranges of *P. arenosa* Conrad, *P. trilineata* Say and *P. inflata* Boss and Merrill were extended northward; and *P. gouldiana* Dall, was extended southward. Merrill (1970), working with the family Architectonicidae, found a new species from the offshore waters of Virginia and North Carolina. Merrill, Emery and Rubin (1965), reporting the significance of fossil shells of *Crassostrea virginica* (Gmelin) on the floor of the ocean off the middle Atlantic coast, estimated the time and positions of former sea levels and deduced probable former estuaries after the end of the latest glacial epoch through the distributional pattern of the oyster relics and radiocarbon dating techniques. Merrill (1967), assessing the possible adverse effects of the hydroid eipzoan, *Hydractinia echinata* (Fleming), on sea scallops, defined the offshore distribution of the

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FIG. 1. *Location of stations occupied during a survey of the middle Atlantic shelf (DELAWARE Cruise 60-7). Stations are identified by dots, major transects by dashed lines.*

hydroid in the middle Atlantic. Edwards and Merrill (1977), reconstructing the continental shelf areas of eastern North America for the times 9,500 B.P. and 12,500 B.P., discussed the distribution and age-depth relationship of Holocene fossil-shell deposits of *C. virginica* and *Mesodesma arctatum* (Conrad). These and other studies underway give an indication of the breadth of use of the data to date.

This paper records the range extensions of the mollusks, other than those mentioned above, taken during DELAWARE Cruise 60-7. Table 1 includes the previous range and depth and the new range extension, the number and condition of the specimens and the stations and depths from which the mollusks were taken. Shells from recently dead animals can be distinguished from weathered and fossilized material by the luster and fresh appearance of the shells. Only live or recently dead specimens were used to determine new range and depth extensions. The depth is included in the range extension column only if the known bathymetric range is extended. Range extensions of 32 species are noted in Table 1—22 northward, 9 southward, and one species is recorded in western Atlantic waters for the first time. Depth ranges were also extended for 16 of the 32 species.

Our record of *Cylichna linearis* Jeffreys (fig. 2) from off Wachapreague Inlet, VA, is the first time this European species has been reported from the western Atlantic. This species was introduced as a variety of *C. cylindracea* Pennant, but noted to differ by its smaller shell and the possession of brownish spiral lines at each end of the shell. With regard to other western Atlantic members of the genus, *C. linearis* must be compared with *C. verrillii* Dall. The former species is larger, possesses the numerous spiral brown lines, and the greatest width is toward the anterior end of the shell, not at the middle.

Two Species, *Colus islandicus* (Gmelin) and *Buccinum undatum* Linné, have been reported to range south to South Carolina (Dall, 1903). Later workers have restricted their range well to the north—*C. islandicus* to Labrador and arctic Canada; *B. undatum* to New Jersey in depths to several meters (Johnson, 1934; Abbott, 1974). Bush (1885) failed to find either species in dredgings from six stations north of Cape Hatteras, NC, in depths of 26 to 265 m. Porter (1974) had no record of them south of Cape Hatteras in North Carolina, nor had Merrill and Petit (1965, 1969) from South Carolina. Clarke (1954) found *C. islandicus* south of Georges Bank, MA, to east of Chincoteague Island, VA, in 155-759 m. We now record *C. islandicus* from off Block Island, RI, and off Cape Henry, VA,

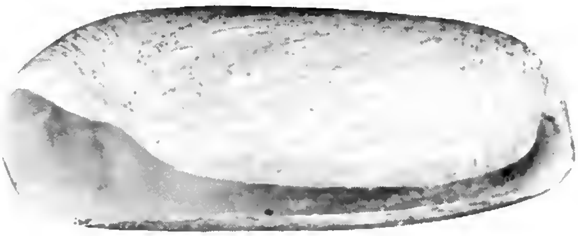

FIG. 2. Cylichna linearis *Jeffreys. R/V DELAWARE Cruise 60-7, Sta. 5-4, off Wachapreague Inlet, VA. 110m. Length, 10 mm.*

in 42-146 m. It is quite possible that Dall's report of *C. islandicus* living at depths of 37-3017 m and ranging to South Carolina is correct but only if the species is living in very deep water, beyond the deepest stations (146 m) made on the DELAWARE Cruise 60-7 transects.

Dall (1903) reported the range of *B. undatum* to Charleston, SC, but with a question mark, in depths of 0 to 1189 m. We found *B. undatum* to be one of the most ubiquitous species in our samples from the middle Atlantic shelf. In all, the species was taken at 42 stations, alive at 28 of them southward to Cape Henry, VA. In addition, egg cases with no adults were collected at three stations. To conserve space only stations with live animals are listed in Table 1. On the basis of the completeness of our data for this species we conclude Dall's southern distributional and depth ranges are invalid. No live specimens were found at the deeper water stations of the eight major transects (fig. 3). The distribution of live specimens and weathered or fragmented shells of *B. undatum* from our cruise were similar latitudinally, but the dead material occupied somewhat deeper waters on the average. Live specimens were recorded to a depth of 73 m; fragments were taken at three stations as deep or slightly deeper, from 73 to 84 m. Dredge tows were made at 32 stations along the coast in waters as deep as 73 m or deeper to 146 m. The species was not found at these deeper waters stations. In contrast, the species was taken at most of the shallow water stations. Below Barnegat, NJ, at 10 stations, the depth averaged 49.5 m for live specimens; at 11 stations 66. 2 m for dead. This suggests that the species is living close to its depth limits. A further analysis of the depth and thermal distribution of this and other species is in preparation.

Our transect off Currituck Beach, VA, is about 70 nautical miles north of Cape Hatteras, NC. In compiling Table 1 we arbitrarily designated Currituck Beach as a starting point to record range extensions above Cape Hatteras. The ratio of new molluscan range extensions to species identified from the cruise is about one to six.

The species listed below were collected at stations 10 to 30 nautical miles above Cape Hatteras and confirm existing ranges reported to and slightly north or south of Cape Hatteras.

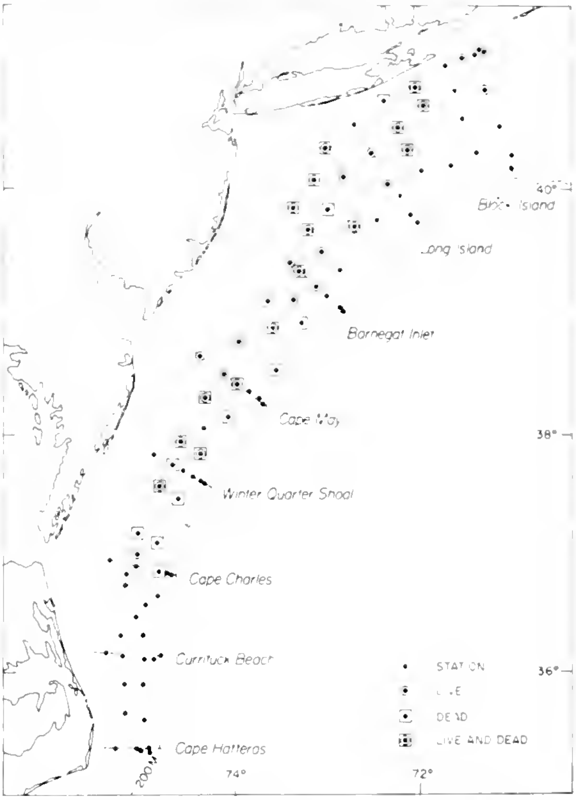

FIG. 3. *Distribution of* Buccinum undatum *Linné along the middle Atlantic shelf (DELAWARE Cruise 60-7) Note the absence of* B. undatum *below the Cape Charles transect and at the deeper water stations on major transects.*

Niso aeglees (Bush, 1885)
**Trivia maltbiana* (Schwengel and McGinty, 1942)
Distorsio clathrata (Lamarck, 1816)
Tonna galea (Linné, 1758)
Nassarius albus (Say, 1826)
Oliva sayana (Ravenel, 1834)
Cylichnella bidentata (Orbigny, 1841)
Dentalium eboreum (Conrad, 1846)
Yoldia limatula (Say, 1831)
Atrina rigida (Lightfoot, 1786)
Aequipecten muscosus (Wood, 1828)
Plicatula gibbosa (Lamarck, 1801)
Lucina nassula (Conrad, 1846)
**Lucina radians* (Conrad, 1841)
**Diplodonta soror* (C. B. Adams, 1852)
Astarte undata (Gould, 1841)
Astarte castanea (Say, 1822)
Eucrassatella speciosa (A. Adams, 1852)
Ervilla concentrica (Holms, 1860)

Tellina squamifera (Deshayes, 1855)
**Tellina aequistriata* (Say, 1824)
Tellina alternata (Say, 1822)
**Tellina sybaritica* (Dall, 1881)
Strigilla mirabilis (Philippi, 1841)
Semele bellastriata (Conrad, 1837)
Chione intapurpurea (Conrad, 1849)
Chione grus (Holmes, 1858)
Pitar fulminatus (Menke, 1828)

* Species not reported north of Cape Lookout, NC.

The species listed below were taken at latitudes 10 to 30 nautical miles south of the latitude of Nantucket Island, MA, and confirm existing ranges reported slightly south of Cape Cod.

Oenopota harpularia (Couthouy, 1838)
Oenopota bicarinata (Couthouy, 1838)
Cyrtodaria siliqua (Spengler, 1793)
Thracia septentrionalis (Jeffreys, 1872)

The mollusks from DELAWARE Cruise 60-7 have been accessioned into the mollusk collection at the Museum of Comparative Zoology.

TABLE 1. List of mollusks with new range extensions collected during R V DELAWARE Cruise 60-7 in the Middle Atlantic Bight. All parenthesized numbers are depths in meters.

Species	*Family*	*Previous Range*	*No. and Condition of Specimens*	*Stations*	*Range Extension*
Alvania areolata (Stimpson, 1851)	Rissoidae	Gulf of St. Lawrence, Canada to off Martha's Vineyard, MA (18-238)	1 Living	3-3(73)	Off Ludlam Beach, NJ
Teinostoma cryptospira (Verrill, 1884)	Vitrinellidae	Off Cape Hatteras, NC to West Indies (18-274)	1 Recently dead	3-3(73)	Off Ludlam Beach, NJ
Phalium granulatum (Born, 1778)	Cassidae	Off Cape Hatteras, NC to Texas; Brazil; Bermuca (low water to 66)	1 Recently dead 2 Weathered or fragmented	7-2(37) A-9(37); 8-1(26)	Off Currituck Beach, NC
Buccinum undatum Linné, 1758	Buccinidae	Arctic Seas to Chincoteague Island, VA (low water to several meters)	250 Living	1-1(37; 1-2(59); 2-2(51); 2-3(73); 3-1(37); 3-2(55); 4-1(37); 1-2(55); A-2(51); A-16(44); A-20(64); A-22(51); A-23(62); A-25(37); A-26(55); A-29(59); A-32(68); A-34(40); A-35(40); A-36(40); A-37(51); A-39(70); A-43(62); A-41(59); A-46(38); A-47(51); A-54(42); A-56(48);	Off Cape Henry, VA (73)
			Recently dead, weathered or fragmented taken at 15 stations with living, and at 22 additional stations.		
Colus islandicus (Gmelin, 1791)	Buccinidae	Labrador; Arctic Canada (37-3017)	2 Recently dead	A-5(146); A-51(42)	Off Cape Henry, VA
Nassarius acutus (Say, 1822)	Nassariidae	Off Beaufort Inlet, NC to Texas	1 Recently dead	5-4(110)	Off Wachapreague Inlet, VA (110)
Olivella floralia (Duclos, 1835)	Olividae	Off Cape Hatteras, NC to both sides of Florida and the West Indies; Brazil; Bermuda (shallow water)	1 Recently dead 1 Weathered and fragmented	7-1(33) 8-1(26)	Off Currituck Beach, NC (33)

Species	*Family*	*Previous Range*	*No. and Condition of Specimens*	*Stations*	*Range Extension*
Olivella mutica (Say, 1822)	Olividae	Off Cape Hatteras, NC to Florida, and Bahamas (low water to 100)	12 Living 7 Recently dead 5 Weathered or fragmented	5-4(110); 6-3(73); 6-4(106); A-5(64); 7-1(33), 7-4(113); A-10(44). 3-5(146); 5-4(110); 6-3(73); A-7(35). 1-5(156); A-1(75); 5-4(110); 8-1(26); A-24(84)	Off Hereford Inlet, NJ (146)
Marginella eburneola (Conrad, 1834)	Marginellidae	Off Cape Hatteras, NC to both sides of Florida and the West Indies (low water to 1,097)	1 Living 7 Recently dead	A-13(33) A-13(33)	Off False Cape, VA
Hyalina veliei (Pilsbry, 1896)	Marginellidae	Off McClellanville, SC to both coasts of Florida (shallow water)	2 Living	6-1(31); A-9(37)	Off Cape Henry, VA (37)
Granulina ovuliformis (Orbigny, 1841)	Marginellidae	Off Cape Hatteras, NC to Florida; West Indies (2-9)	1 Living 2 Recently dead	5-4(110) A-7(35)	Off Wachapreague Inlet, VA (110)
Terebra concava (Say, 1827)	Terebridae	Off Cape Hatteras, NC to Florida and Texas; Brazil (low water to 50)	4 Living Recently dead Weathered or fragmented	8-1(26); A-10(44) 8-1(26); 8-2(37) 7-4(113)	Off Currituck Beach, NC
Pyramidella unifasciata Forbes, 1843	Pyramidellidae	Off Cape Hatteras, NC to Gulf of Mexico (55-2966)	5 Living	A-7(35); A-17(62), A-24(84); A-31(73)	Off Atlantic City, NJ (35)
Odostomia cancellata (Orbigny, 1842)	Pyramidallidae	Off Cape Hatteras, NC; Cuba (26-28)	1 Recently Living	A-13(33)	Off False Cape, VA (33)
Odostomia dealbata (Stimpson, 1851)	Pyramidellidae	Off MA to L.I. Sound, CT (6)	1 Recently dead	3-3(73)	Off Ludlam Beach, NJ (73)
Turbonilla elegantula (Verrill, 1882)	Pyramidellidae	Vineyard Sound to off New Haven, CT	2 Living 1 Recently dead 1 Weathered or fragmented	5-4(110), 8-1(26) 6-4(106) 5-4 (110)	Off Cape Hatteras, NC (110)
Turbonilla polita (Verrill, 1872)	Pyramidellidae	Off Eastport, ME (37)	1 Living	3-3(73)	Off Ludlam Beach, NJ (73)
Turbonilla reticulata (C. B. Adams, 1850)	Pyramidellidae	Off Cape Hatteras, NC to the West Indies	1 Recently dead	A-13(33)	Off False Cape, VA (33)
Cylichna linearis Jeffreys, 1867	Cylichnidae	European waters	1 Recently dead	5-4(110)	Off Wachapreague Inlet VA (110)
Cadulus carolinensis Bush, 1885	Siphondentaliidae	Off Cape Hatteras, NC to Florida; Texas (5-183)	1 Living 1 Recently dead 2 Weathered or fragmented	7-4(113) 5-4(110); 7-4(113), 8-1(26) 5-4(110)	Off Wachapreague Inlet, VA
Crenella fragilis (Verrill, 1885)	Mytilidae	Off Chesapeake Bay, VA to Cape Lookout, NC (128-140)	1 Living 1 Recently dead	5-4(110) 5-4(110)	Off Wachapreague, VA (110)

Species	*Family*	*Previous Range*	*No. and Condition of Specimens*	*Stations*	*Range Extension*
Palliolum subimbrifer (Verrill & Bush, 1897)	Pectinidae	Off Martha's Vineyard, MA (210-667)	10 Living	1-4(110); 2-1(37), 5-4(110), A-3(64), A-5(64); 7-5(146)	NE of Oregon Inlet, NC (37)
			35 Recently dead	1-4(110), 3-5(146); 4-5(146), 5-4(110); A-4(37), 7-5(146)	
			1 Weathered or fragmented	3-4(112)	
Pecten raveneli Dall, 1898	Pectinidae	Off Cape Hatteras, NC to West Indies; Gulf of Mexico (17-75)	3 Recently dead	7-2(37); A-17(62)	Off Cape Charles, VA
Cyclopecten nanus (Verrill & Bush, 1897)	Pectinidae	Off Chesapeake Bay, VA to Texas; Puerto Rico; Brazil (40-538)	740 Recently dead	A-1(75); 5-2(55); 5-4(110), 6-3(73); A-5(64); A-7(35); 7-4(113); A-20(64); A-24(84)	Off Indian River Inlet, DE (35)
			1 Weathered or fragmented	A-24(84)	
Pleuromeris tridentata (Say, 1826)	Carditidae	Off Cape Hatteras, NC to both coasts of Florida; Gulf of Mexico (low water to 227)	1 Living	A-5(64)	Off Chincoteague Inlet, VA
			6 Recently dead	5-1(33); 6-2(37); A-5(64), A-10(44);	
Laevicardium laevigatum (Linné, 1758)	Cardiidae	Off Cape Hatteras, NC to both sides of Florida and the West Indies; Brazil; Bermuda (low water) to 137)	2 Recently dead	7-2(37); 8-2(37)	Off Currituck Beach, NC
Laevicardium pictum (Ravenel, 1861)	Cardiidae	Off Cape Hatteras, NC to Brazil; Bermuda (low water to 155)	18 Recently dead	6-2(37); 7-2(37); A-9(37); 8-1(26); 8-2(37); A-10(44); A-11(33)	Off Cape Henry, VA
			4 Weathered or fragmented	6-3(73); 7-1(33), 8-1(26); 8-2(37)	
Chione cancellata (Linné, 1767)	Veneridae	Off Cape Hatteras, NC to Florida, Texas and the West Indies (low water to 110)	1 Recently dead	7-1(33)	Off Currituck Beach, NC
Chione latilirata (Conrad, 1841)	Veneridae	Off Cape Hatteras, NC to Florida and to Texas; Brazil (18-227)	11 Recently dead	7-2(37), A-9(37) A-10(24)	Off Currituck Beach, NC
Varicorbula operculata (Philippi, 1848)	Corbulidae	Off Cape Hatteras, NC to Florida to Texas; West Indies; Brazil (9-457)	8 Recently dead	6-3(73), 7-2(37); 8-2(37); A-10(44)	Off Cape Henry, VA

Species	*Family*	*Previous Range*	*No. and Condition of Specimens*	*Station*	*Range Extension*
Xylophaga atlantica (Richards, 1942)	Pholadidae	Gulf of St. Lawrence, Canada to Cape Henry, VA (low water to 3718)	1 Living	A-9(35)	Off Oregon Inlet, NC
Periploma papyratium (Say, 1822)	Periplomatidae	Labrador, Canada to Rhode Island (11-2295)	7 Living	A-12(73), A-50(77), A-51(73), A-52(66)	Off Pt. Pleasant, NJ
			7 Recently dead	1-3(73), 2-3(82), A-12(73), A-19(81), A-50(77), A-51(73), A-52(66)	

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A NEW GENUS OF OPERCULATE LAND SNAILS FROM HISPANIOLA WITH COMMENTS ON THE STATUS OF FAMILY ANNULARIIDAE

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Hispaniola is inhabited by many exquisite land animals. It has an especially rich and diverse gastropod fauna. Although much has been written about Hispaniolan mollusks, large geographic areas remain virtually unexplored for land snails and many new forms remain to be described. During the past two years I spent about eight months in the field in the Dominican Republic and made extensive collections of land snails from most areas of the country.

The physiography of Hispaniola is complex. It consists of many mountain ranges, ridges, and isolated hills, all of which combine to form a mosaic of faunal regions. The Cordillera Central consists mostly of igneous and metamorphic rocks, and calciphyllic families of land snails, such as the Urocoptidae and Annulariidae, are conspicuously absent. Elsewhere, to the north, east, and south, calcareous substrates predominate. In these areas some hills and mountain ranges have a high degree of molluscan endemism. One such mountain ridge in Puerto Plata Province is inhabited by a most unusual land snail, whose transparent shell with high fragile ribs cause it to resemble a giant snowflake. It is one of the most striking terrestrial operculates to have been discovered. The transparent, high ribs of the shell is an adaptation for a cryptic existence on an exposed limestone surface. The snail is highly unnoticeable because of the blurred image that is created by its sculpture. This delicate, ornate sculpture is unrivaled by any other known species of "cyclostomid," although similar ornamentation occurs in some members of the pupinid genus *Geothauma* from Borneo.

The snail described herein is a member of the family Annulariidae and the subfamily Annulariinae as defined by Henderson and Bartsch (1920) Controversy exists over the availability of the generic name *Annularia* Schumacher, 1817 as opposed to *Choanopoma* Pfeiffer, 1848 and Annulariidae as opposed to Chondropomidae or Pomatiasidae (see Henderson and Bartsch, 1920; Baker, 1924a: 2-3, Solem, 1960: 419-420; 1961: 192-194). This case is currently before the international Commission on Zoological Nomenclature. For purposes of this paper I tentatively accept Dall's (1905: 298) type species designation of *Turbo lincina* Linnaeus for *Annularia*. Annulariidae Henderson and Bartsch (1920: 54) has page priority over Chondropomi-(dae) Henderson and Bartsch (1920: 59). I arbitrarily follow the subfamily division proposed by Henderson and Bartsch (1920) and Baker (1924a). Later authors, who criticized Henderson and Bartsch's classification, did not provide more useful alternatives. For reasons given below I consider the neotropical Annulariidae and the Old World Pomatiasidae to be separate families.

Licinae Pfeiffer, 1858 was the first family-group taxon name used for the neotropical "cyclostomes." Except for occasional use in the mid-nineteenth century the name went unmentioned in the primary literature until Golikov and Starabogatov (1975) resurrected it as the family name Licinidae. The name Licinidae Pfeiffer is a *nomen oblitum* because of this great time lapse and thus is not available for use (ICZN Article 23, b).

Field work relating to this study was supported by the National Geographic Society, Council for Research, and the Florida State Museum. I am grateful to officials of both organizations for the support they have given me. Dr. Joseph Rosewater (USNM) and Dr. Charlotte Patterson (UMMZ) kindly loaned to me dried specimens of *Cistulops* and *Troschelvindex* from which radulae were extracted

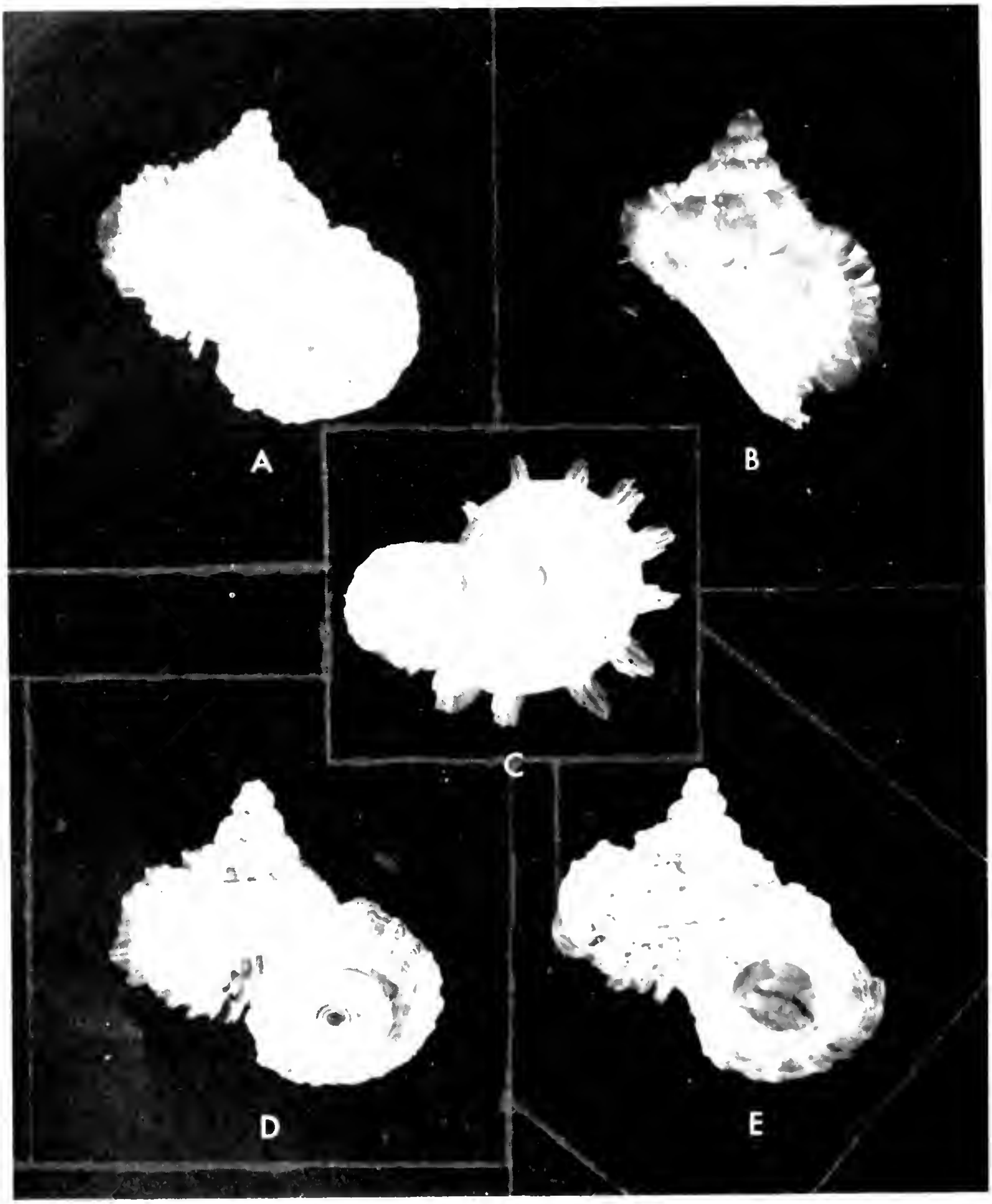

FIG. 1. Megampha rhetta new genus and new species Thompson. A-C, *Holotype (UF [illegible]); D, Paratype (UF 22521)*; *E, Paratype (UF [illegible])*.

for SEM studies. Preserved specimens of *Pomatias elegans* (Müller) used in this study were collected by Dr. S. David Webb (Florida State Museum) while he was a Gugenheim Scholar in France during 1973. I am grateful to the following people who assisted me in field work in the Dominican Republic: Howard W. Campbell, Ronald Crombie, Richard Franz, Roy McDiarmid, Sylvia Scudder, Linda Wiley, and especially Beverly E. Johnson whose energy for hiking up mountains and searching for snails seemed nearly inexhaustible. The photographs comprising fig. 1 were made by Donna B. Drake; SEM micrographs were made by Sylvia Scudder.

Meganipha new genus

Type species: *Meganipha rhecta* new species.[1]

This is a genus of the Family Annulariidae, subfamily Annulariinae. The shell is helicoid with raised nipplelike apical whorls. Spiral sculpture is obsolete. It is indicated only by the undulating bases of the ribs, which occur in spiral sequences. Otherwise the shell is devoid of spiral sculpture even in the umbilicus. The axial sculpture consists of extremely high, widely-spaced fragile ribs that are about half the diameter of the whorl in height. The peristome is double. The outer peristome is very broadly expanded, slightly more so than the ribs, and is recurved posteriorly along its outer edge. The face of the outer peristome is sculptered with numerous close spiral striations.

The operculum bears a raised spiral calcareous lamella that is reflected laterally so that it overlaps, but does not fuse with succeeding turns. The lamella lacks reinforcing ribs or buttresses. The outermost turn of the lamella is reflected beyond the basal chandroid plate so that the operculum is too large to be retracted into the aperture.

The relationship of *Meganipha* to the Annulariinae is clearly indicated by its operculum. In this subfamily it bears a raised spiral calcareous lamella which may be reflected to parallel the basal plate. The lamella may lack reinforcing ribs so than an open cavity is formed between the reflected lamella and the basal plate, or reinforcing ribs may be present, which partially obstruct the cavity.

Meganipha belongs to an assemblage of closely related Hispaniolan genera that includes *Petasipoma*, Bartsch, 1946, *Rolleia*, Crosse, 1891, *Lagopoma*, Bartsch, 1946, and *Abbottella*, Henderson and Bartsch, 1920. This group contains helicoid, depressed-helicoid, or discoidal species that have a double peristome. The genera are separated by sculpture, shell shape, and the development of the opercular lamella. It is beyond the scope of this paper to review the status of these genera. However, each is composed of species that represent natural assemblages, and the use of generic names for these assemblages is warranted. *Petasipoma* has a helicoid shell with both axial and spiral threads. The operculum is unusual in that the lamella is reflected to parallel to the basal plate with successive turns fusing to form a continuous outer plate. The other genera have a gap between the successive turns of the lamella. *Rolleia* is depressed-helicoid and is characterized by having axial ribs only. Spiral sculpture is absent. *Lagopoma* and *Abbottella* have spiral sculpture as well as axial ribs. *Lagopoma* differs from *Abbottella* as well as all other Annulariinae by having a notch in the outer peristome over the parietal wall. *Meganipha* differs from these four genera as well as other annulariids and pomatiasids by its sculpture and its outer peristome. No other genus has axial ribs that approach the fragile lamellar condition characteristic of *Meganipha*, and no other described genus has a peristome that is as broadly expanded and bears the characteristic lacey concentric sculpture on its face. The obsolete spiral sculpture on the shell is also characteristic. The operculum is unusual but not unique within the Annulariidae in that it is too large to be withdrawn into the aperture. In the related genera mentioned above the operculum is retractable internally.

Meganipha rhecta new species

SHELL (fig. 1). - This is an elegant, medium-sized snail that is fragile and delicate in structure. The shell is turbiniform in shape with a slightly concave spire. Usually the shell is wider than high, being about 0.90—1.02 times as high as wide. The last whorl flares laterally conspicuously beyond the

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[1] ETYMOLOGY. *Meganipha* (f.). from the Greek *megas*, giant, and *nipha*, a snowflake; *rhecta*, from the Greek *rhectos*, brittle. The name *Meganipha rhecta* Thompson appears as a nude name in the *Florida State Museum Newsletter*, June 1976, vol. 5, p. 8 (fig.).

curvature of the spire and has a widely reflected fragile peristome. The thin shell is transparent when alive and clearly shows the viscera internally. The color of the shell is a soft frosty white on a translucent background. Occasional specimens have five reddish-brown spiral bands, three on the base, one on the periphery, and one on the shoulder of the whorls (fig. 1, E). The umbilical perforation is broad, being slightly less than the width of the last whorl. There are about 5.0-5.6 whorls with 2.2-2.3 smooth, raised, nipple-shaped embryonic whorls. The suture is deeply impressed. The first and second postembryonic whorls are weakly angular at the shoulder. The body whorl is only weakly in contact with the preceding whorl and is solute and descends near its termination, leaving a triangular gap behind the peristome. The postembryonic whorls are sculptured with elegant, very thin, very fragile evenly spaced vertical ribs that are about half as high as the diameter of the whorl. There are about 10-12 ribs on the last whorl. The ribs are strongly undulated at their base but are flattened near their outer edge. The interspaces are sculptured with vertical rounded threads and striations that parallel the basal undulations of the ribs. The ribs on the earlier postembryonic whorls are usually broken away, leaving only jagged remnants of their bases. The aperture is slightly higher than wide, and is oblique, lying at an angle of about 35° to the axis of the shell. The inner peristome projects forward only slightly. The outer peristome is very broadly reflected and recurved and is about half as wide as the diameter of the aperture. It is thin and fragile and is sculptured on its face with numerous close raised spiral undulating threads that give the peristome a lacey appearance. The threads are densely crowded near the aperture and are more widely spaced toward the periphery.

The operculum (fig. 1,D) bears a strongly reflected calcareous lamella which contacts itself on each succeeding turn so that a calcareous pseudolamellae is formed on the outer surface leaving a tubular spiral space beneath it. The pseudolamellae lacks reinforcing ribs. Usually the lamella on the inner most 3-4 whorls is broken away, exposing the basal chondroid plate. The operculum does not withdraw into the aperture, but lays nearly flush with the peristome.

Measurements of the holotype and four paratypes selected to show ranges of variation (measurements in parentheses include only the caliber of the whorls and not the ribs or outer peristome).

Radula. - The radula is taenioglossate and extends posteriorly into the coelom for about 0.5 whorls behind the buccal mass. Basically it is similar to the radulae of other annulariids in that the central and lateral teeth are unicuspid. The transverse rows of teeth are close-set so that the teeth broadly overlap at their bases, thus reinforcing each subsequent row in its cutting action when feeding (see Solem, 1974, for similar observations on pulmonates). The central tooth has a long lanceolate cusp that projects at about 90° to the base of the tooth. The basal plate is long and relatively slender and bears a strong reinforcing fold along each side between which the distal half of the preceding tooth lies. The lateral teeth are similar to the centrals, but are broader and the cusp is slightly longer (fig. 2, A, D-1). The inner marginal has a single large triangular mesocone that is rather jagged along its outer edge and bears a small ectocone at its base (fig. 2, B-im). The outside margin of the shaft has a short triangular flange below the cusp so that the two marginal teeth interlock at their bases and along their shafts when in use (fig. 2, B). The outer marginal is broadly triangular in outline due to a thin membrane that extends from the shaft of the tooth to the outer end of the cusp margin (fig. 2, B, C-om). The outer marginal bears about 50 slender, sharp, sickle-shaped cusps along the cutting edge. The cusps are largest near the shaft and gradually decrease in size toward the outer edge.

Reproductive system - The male reproductive system is closed throughout its length and terminates in a long slender penis that is triangular in cross-section (fig. 3, E). The penis originates on the right side of the nape deep within the pallial cavity, and in a resting position it is recurved over the center of the nape so that it is U-shaped with its tip pointed anteriorly. The vas deferens is very short and runs transversely along the body wall from the base of the penis to the prostate. The prostate is imbedded in the right wall of the mantle cavity and lies completely anterior to the transverse wall of

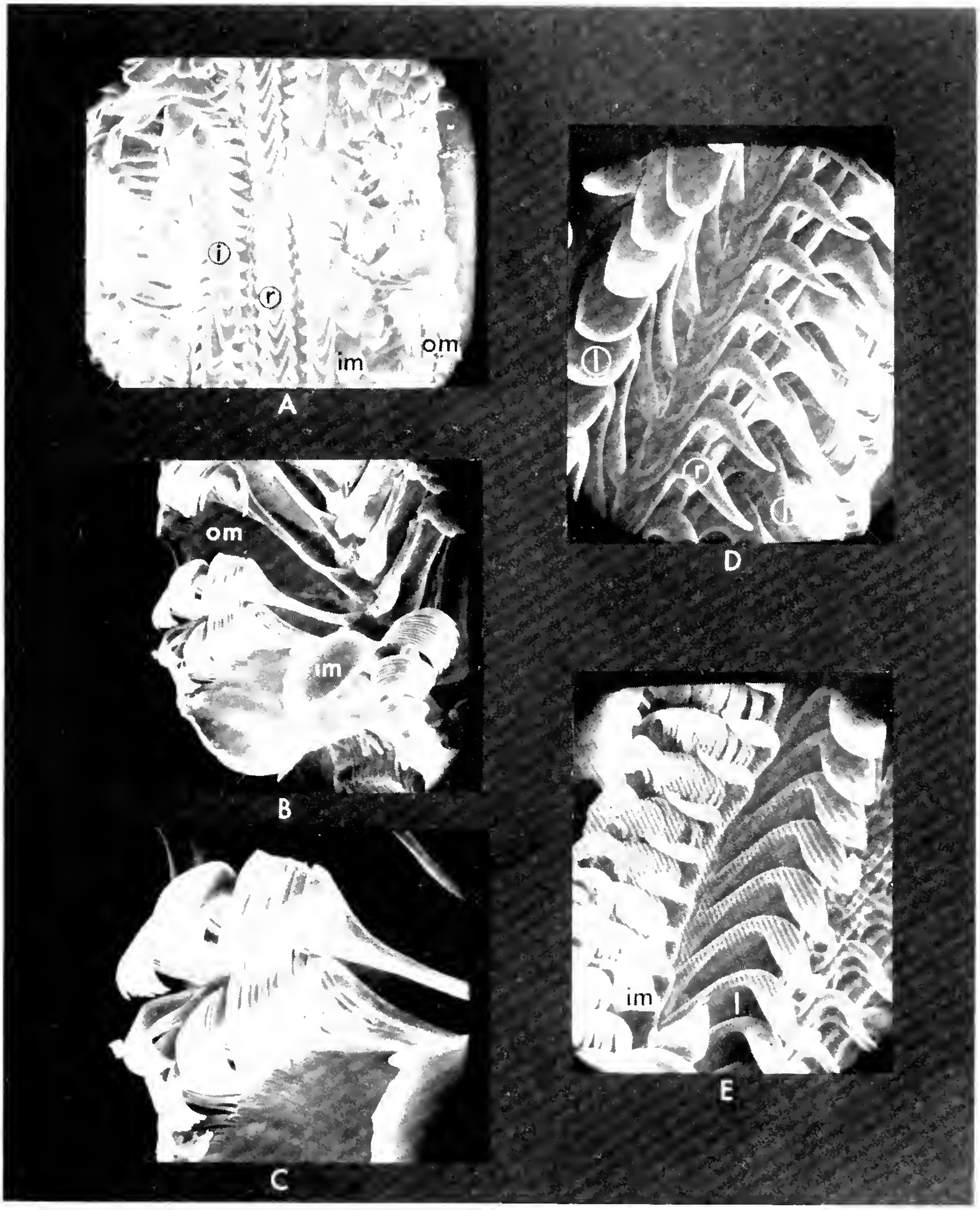

FIG. 2. Meganipha rheeta, *new genus and new species, Thompson. SEM micrographs of radula (UF 22748).* A. *Complete transverse section (× 105).* B. *Marginal teeth (× 260).* C. *Sickle-shaped rasps of outer marginal teeth (× 740).* D. *Oblique view of central and lateral tooth rows (× 250).* E. *Lateral and marginal tooth rows (× 245). Legend:* **r**-*central,* **l**-*lateral,* **im**-*inner marginal,* **om**-*outer marginal.*

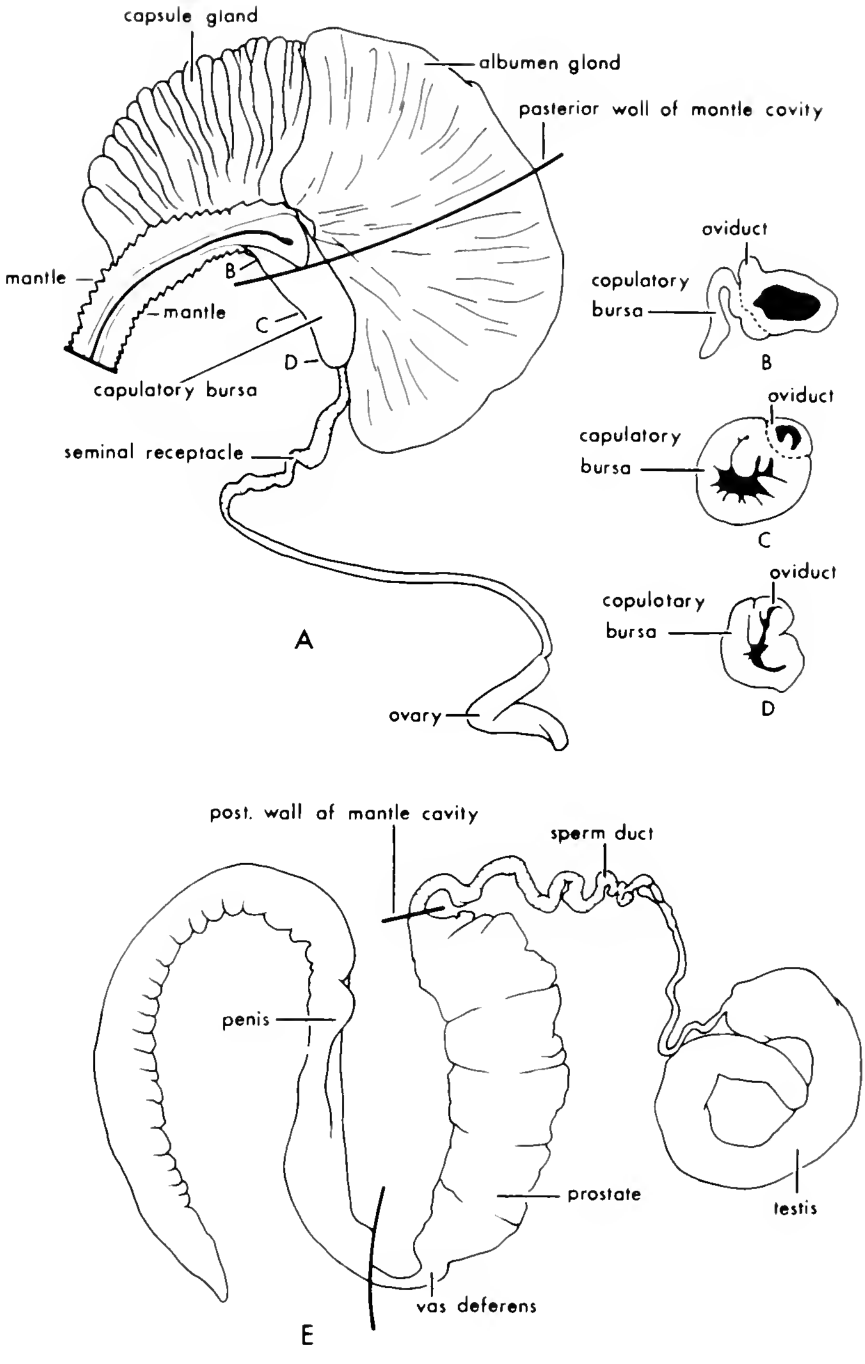

FIG 3. Meganipha rheeta, *new genus and new species*. A. *Female reproductive system*. B-D *Traverse sections through copulatory bursa at corresponding points on A*. E. *Male reproductive system*.

the mantle cavity. The testis is fusiform, relatively stocky, is 1.5 whorls long and lies along the columellar side of the digestive gland. The sperm duct is very narrow and thin walled immediately below the testis. It becomes enlarged along its lower half, forming a seminal vesicle that is rather densely pigmented with melanophores. Numerous small yellow concentration granules of uric acid are scattered throughout the visceral cavity and surround all of the visceral and reproductive organs.

The female reproductive system is tripartite, consisting of an ovary, the primary oviduct and its derivatives, and the pallial oviduct (fig. 3, A). The ovary is elongate-cylindrical and occupies about 1.5 whorls along the basocolumellar side of the digestive gland. The primary oviduct originates from the anterior end of the ovary. It is thin-walled and expands along its lower third to form a densely pigmented seminal receptacle. The oviduct continues in the basal wall of the copulatory bursa (fig. 3, B-D) to the albumen duct, and from there into the capsule gland. The copulatory bursa is thick walled and has about 10-12 longitudinal folds prodtruding into its lumen. An enlarged fold along the columellar side partially divides the lumen longitudinally. The lumen continues into the seminal receptacle by a very narrow perforation at the posterior end of the bursa. The albumen gland is strongly compressed laterally. It overlaps the posterior wall of the mantle cavity so that its posterior half lies along the columellar side of the visceral mass and its anterior half borders the mantle cavity. The capsule gland is a voluminous multifolded chamber that is open throughout its length along the columellar angle of the mantle cavity and beneath the intestine. It contains about 20 vertical undulating folds which presumably expand into a large chamber during ovulation, as occurs in *Pomatias* (see Creek, 1951: 608-609).

Nervous system (fig. 4, A, B). - The brain is an advanced epiathroid type in which the pleural

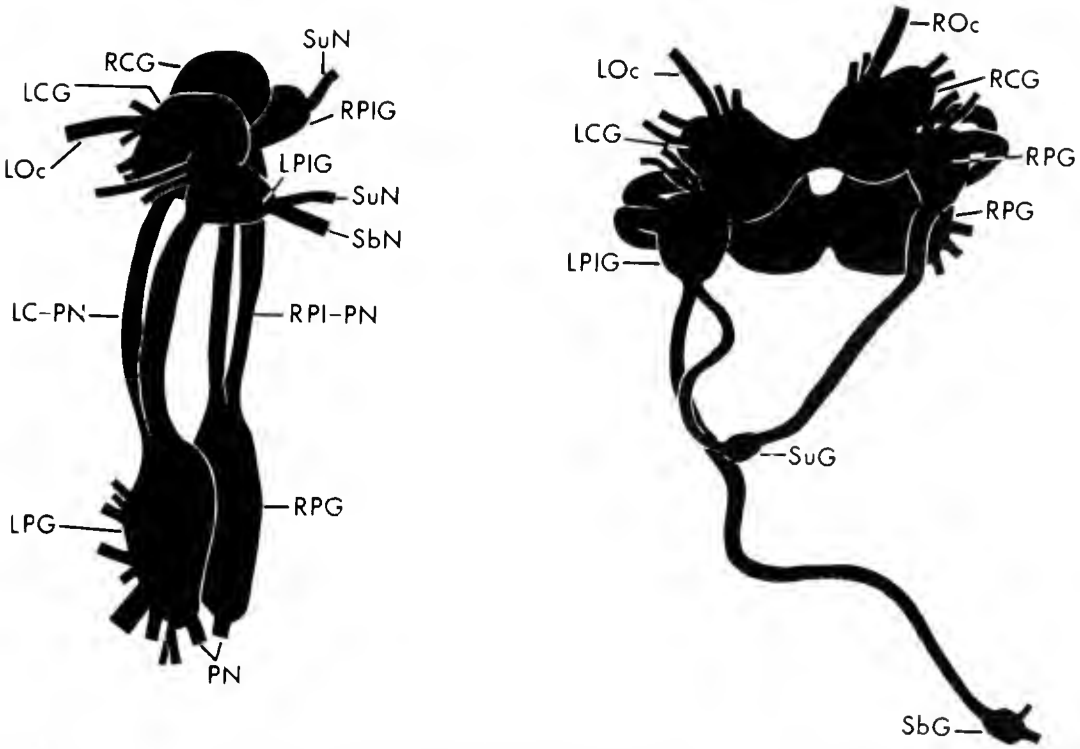

FIG. 4. Meganipha rhecta, *new genus and new species. Central nervous system.* A. *Lateral view* B. *Dorsal view. Legend.* LCG-*left cerebral ganglion.* LC-PN-*left cerebral-pedal nerve;* LO-*left ocular nerve;* LPG-*left pedal ganglion;* LPIG-*left pleural ganglion;* PN-*pedal nerves;* RCG-*right cerebral ganglion;* RPG-*right pedal ganglion;* RPIG-*right pleural ganglion;* RPI-PN-*right pleural-pedal nerve;* SbG-*suboesophageal ganglion;* SbN-*suboesophageal nerve;* SuG-*supraoesophageal ganglion;* SuN-*supraoesophageal nerve.*

ganglia are moved dorsally and are fused with the posterior-lateral corner of the cerebral ganglia. The nerve ring encircles the center of the buccal mass midway between the mouth and the esophagus. The cerebral-pedal connective are independent throughout their lengths. The pedal ganglia are retained within the haemocoel of the foot, a single commissure connects the two pedal nerves. The cerebral ganglia are joined by a short, broad commissure, and each gives rise anteriorly to two labial nerves, the optic nerve and two buccal nerves. Zygoneury occurs between the left pleural ganglion and the supraoesophageal ganglion which lies against the body wall to the left of the esophagus. The connectives between both pleurals and the supraoesopheal ganglia are relatively long for an advanced epiathroid condition. The suboesophageal ganglion lies along the right side of the body wall just below the base of the penis. Zygoneury with the right pleural ganglion does not occur. The penis is innervated by the suboesophageal ganglion, and thus it is pallial in origin and not pedal as in *Pomatias* (Creek, 1951).

Type locality - Dominican Republic, Puerto Plata Province, Loma del Puerto, Yaroa, 700 m elevation. Holotype: UF 22745; collected 11 January, 1976 by Fred G. Thompson and Beverly E. Johnson. Paratypes: UF 22746 (21), UF 22747 (114), USNM 711132 (6); same locality as the holotype.

The type locality is in a mountain fog forest where the prevailing northeasterly winds pass over the crest of the mountain. The crest consists of a rugged karsted limestone outcrop that is shrouded by a dense forest of trees, shrubs, and ferns. A thick carpet of moss covers practically all trees and substrate. Snails were found crawling and aestivating on bare overhanging limestone surfaces. The shells appeared as grayish blurs against the gray calcareous background.

SYSTEMATIC STATUS OF THE ANNULARIIDAE

The status of the neotropical Annulariidae has been a matter of controversy since the group was first separated from the Old World Pomatiasidae (Pfeiffer, 1858 [Licinae]; Dall, 1905; Henderson and Bartsch, 1920; Baker, 1924a, 1924b; Thiele, 1931; Torre and Bartsch, 1928, 1941; Bartsch, 1946; Wenz, 1938; Solem, 1960, 1961; Golikov and Starabogatov, 1975 [Licinidae]. The criterion used by Henderson and Bartsch (1920) to separate the Annulariidae from the Pomatiasidae is the structure of the central tooth of the radula. Arguments against the recognition of two distinct families has to do with the cusp variations that occur in some neotropical species of the subfamily Cistulopsinae.

While determining the phyletic relationships of *Meganipha* it is necessary to reconsider the systematic status of the Annulariidae. Four anatomical systems possess significant characteristics relevant to this problem: (1) the radula, (2) the male reproductive system, (3) the female reproductive system, and (4) the nervous system. Anatomical information on these two families is very limited. Creek (1951) described the reproductive systems of *Pomatias elegans* (Müller). Fretter and Graham (1962: 310) described the nervous system of *P. elegans*. Venmans (1959) described the radula of *P. sulcatus* (Drap.) and *P. militensis*. Other than various accounts of the radula, the soft anatomy of no neotropical species has been described previous to this report. However limited it may be, the data currently available suggests that the annulariids and the pomatiasids are separable as distinct families.

RADULA

Henderson and Bartsch (1920) separated the neotropical Annulariidae from the Old World Pomatiasidae on the basis of the central tooth of the radula. The neotropical species have a narrow unicuspid central tooth in contrast to the broad tricuspid central tooth of the Pomatiasidae. The observations by Henderson and Bartsch were slightly in error. The central tooth of the Pomatiasidae has five cusps, not three, and not all annulariids are unicuspid.

Baker (1924a: 1-4) showed the two neotropical species, *Cistulops raveni* (Cross) and *Troschelvindex illustre* (Poey) [= *T. eandeana* (Orbigny)], have a tricuspid central tooth which bears a long slender mesocone and a minute ecotocone on each side. He proposed the subfamily Cistulopsinae for these genera and suggested that they are primitive in

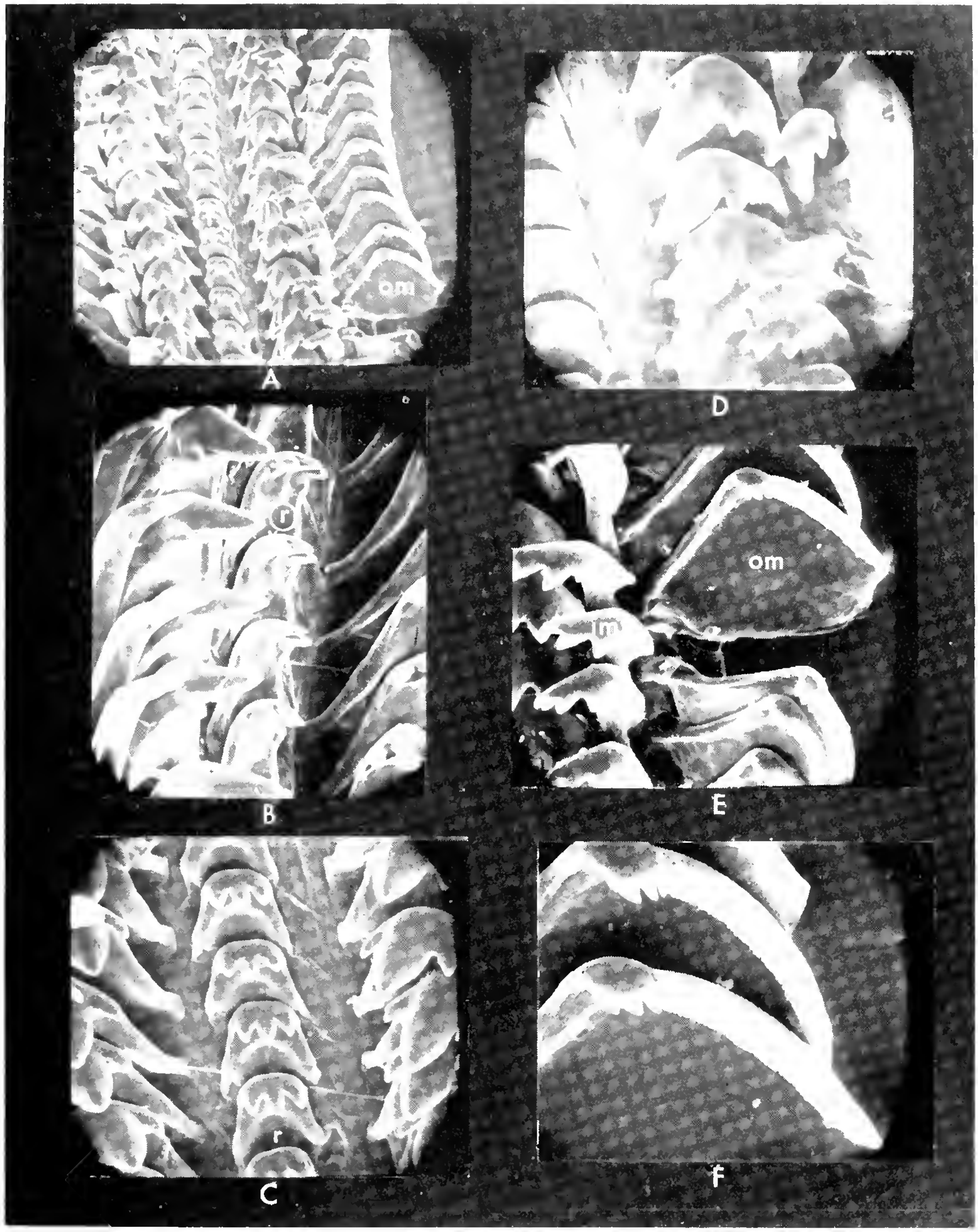

FIG 5. Pomatias elegans *(Muller)*. SEM *micrographs of radula, Montpellier, Dept. L'Herault, France (UF 22749)* A. *Nearly complete transverse section (× 110)* B. *Oblique view of central row* (r) *(× 260)* C. *Vertical view of central row (× 240)* D. *Vertical view of lateral and inner marginal rows (× 260)* E. *Inner marginal and outer marginal teeth (× 270)* F. *Cusps on outer marginal teeth (× 530) Legend* **r**-*central*, **l**-*lateral*, **im**-*inner marginal*, **om**-*outer marginal*

characters of the radula and operculum and are intermediate between the Pomatiasidae and the Annulariidae.

Later authors (Baker, 1924b, 1928; Solem, 1960, 1961; Thompson, 1966) continued to place the neotropical species in the Pomatiasidae because of the intermediate phylectic position that Baker suggested for the Cistulopsinae. SEM examination of the radulae of the genera in question reveals the presence of several characteristics that distinguish the neotropical Annulariidae, including the Cistulopsinae, from the Old World Pomatiasidae. Brief descriptions are given of the radula of relevant genera.

POMATIASIDAE. *Pomatias elegans* (Müller) (fig. 5). Five radulae were removed from the preserved specimens (UF 22749; Montpellier, Dept. L'Herault; France). The transverse rows of teeth overlap only slightly and give weak support to subsequent rows when in use. The central tooth is very broad and has five cusps on the cutting edge. The three foremost cusps are nearly equal sized and are flanked posteriorly by a small tubercular ectocone (fig. 5, B, C-r). The lateral tooth is broadly trapezoidal in shape and bears four heavy cusps: a small entocone, a large lanceolate mesocone, and two ectocones (fig. 5, D-1). The inner marginal has a narrow shaft and base and bears five subequal-sized cusps (fig. 5, D, E-im). The outer marginal is broadly triangular in shape with a wide membrane extending from the base of the shaft to the outer extremity of the rasping margin (fig. 5, E, F-om). The mesad end of the rasping margin overlying the end of the shaft bears three relatively strong, nearly equal sized cusps which are flanked laterally by about 42 small slender blunt filiform cusps. *Pomatias sulcatus* (Drap.) and *P. militensis* (Sow.) differ from *P. elegans* only in the number of cusps on the lateral teeth, not in qualitative differences (see Venmans, 1959).

Tropidophora haemastomum (Anton). Two radulae were extracted from dried specimens (UF 23558; Round Island, Indian Ocean). In most essential features the teeth are like those of *Pomatias elegans*, except that the outer marginal tooth has six enlarged cusps over the end of the shaft (fig. 6, D).

ANNULARIIDAE. The radula of *Meganipha rheeta* n. sp. is described earlier in this paper (fig. 2). Baker (1924a, 1928) examined the radula of about 60 neotropical species. He noted (1924a: 2, 1928: 47-49) the nearly uniform radular structure throughout this group and pointed out two minor variations, one upon which he based the subfamily Cistulopsinae Baker, 1924 (see above) and the other he used (1928: 48) as a basis for a new subgenus of *Licina*, *(Choanopomops)*. All of the Annulariidae for which the radula has been described, have in common: (1) strongly overlapping transverse rows of teeth in contrast to the less overlapping rows in the Pomatiasidae; (2) a narrow unicuspid or weakly tricuspid lateral tooth in contrast to the broad trapezoidal pentacuspid lateral of the Pomatiasidae; (3) the outer marginal tooth has nearly uniform-sized, narrow, sickle-shaped cusps, in contrast to the Pomatiasidae which have several enlarged cusps over the end of the shaft mesad to the smaller filiform cusps; and (4) the central tooth is relatively long and slender and has usually only a narrow beak-like mesocone in contrast to the broad short centrals of the Pomatiasidae, which have a large mesocone flanked on each side by a nearly equal-sized ectocone and a much smaller more posteriorly located ectocone.

CISTULOPSINAE. The radula of the two genera in this subfamily are similar to other Annulariidae in that the transverse rows of teeth strongly overlap, the central and lateral teeth are relatively long and narrow with a long beak-like central cusp, and the outer marginal teeth lack enlarged cusps at the apex of the shaft.

Cistulops r. raveni (Crosse). Five radula were extracted from dried specimens (USNM 393084; Tafelberg, Curacoa). The central and lateral teeth are tricuspid (fig. 6, A, B). Each central tooth bears a large mesocone and a much smaller ectocone on each side. Similarly the lateral tooth is tricuspid with a large mesocone and a minute ectocone and entocone.

Troschelvindex c. candeana (Orbigny). Radulae were recovered from dried specimens (USNM 535559; outside of Havana Cemetery, Havana, Cuba). In most particulars the teeth are similar to *Cistulops r. raveni*. The ectocones on the central tooth are slightly larger in proportion (fig. 6, C).

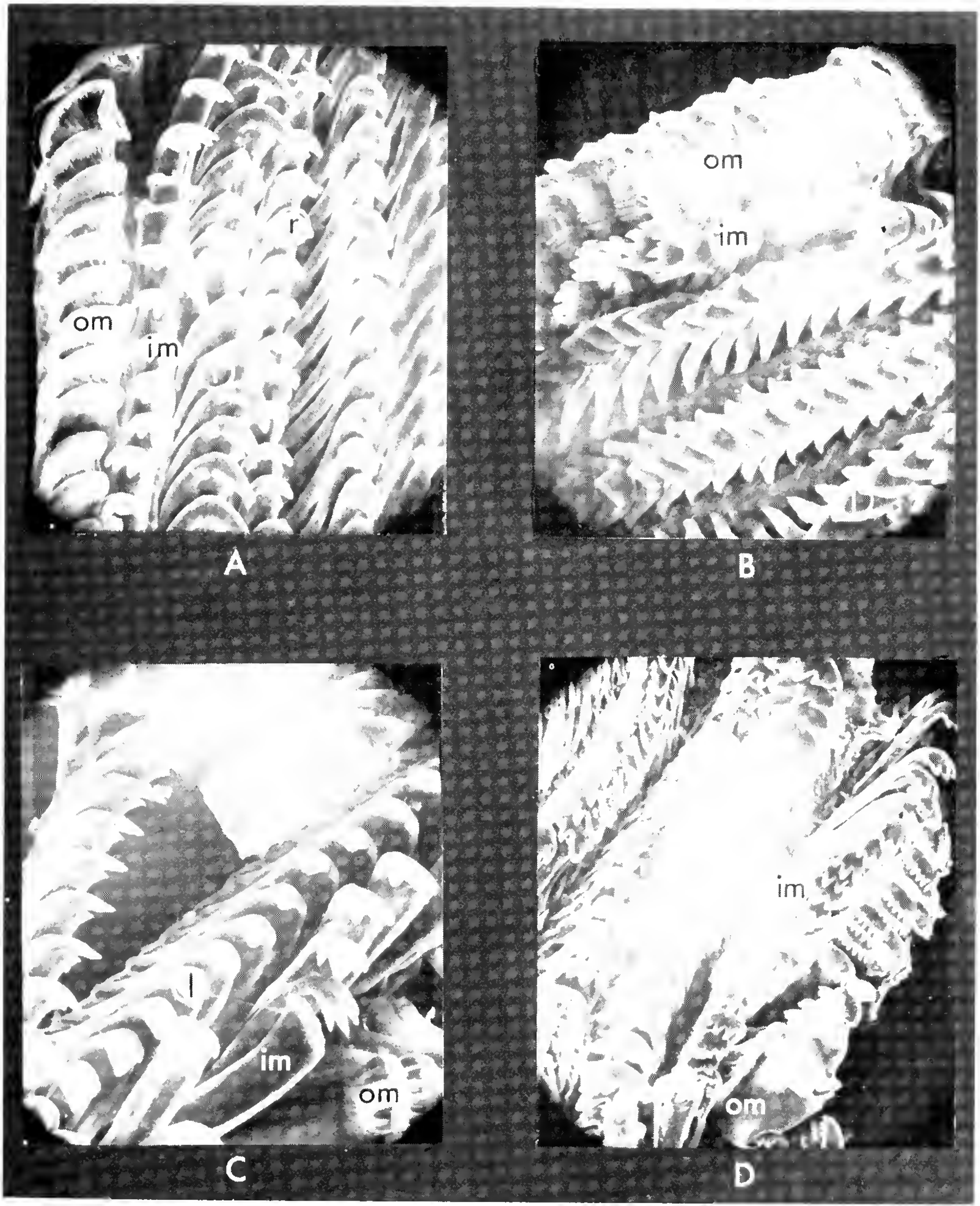

FIG. 6. SEM micrographs of radula. A. Cistulops r. raveni *(Crosse) (USNM 293084) (× 476).* B. *same (× 440).* C. Troschelvindex c. candeana *(Orbigny) USNM 535559) (× 457).* D. Tropidophora haemastomum *(Anton) (UF 23558) (× 481).* *Legend:* **r**-*central,* **l**-*lateral,* **im**-*inner marginal,* **om**-*outer marginal.*

The long slender cusps on the central and lateral teeth and the blade-like cusps on the outer marginal tooth of the Annulariidae contrast strongly with the shorter blunter cusps on the teeth of the Pomatiasidae. In addition the broadly overlapping transverse rows of teeth in the annulariids, which reinforce succeeding rows during feeding, are very unlike the more separated condition that exists in *Pomatias*. These differences indicate different feeding stratgies. The teeth of the annulariids appear to be modified for cutting and gouging deeply into plant tissues, whereas the teeth of the pomatiasids appear to be modified for a scraping action. Correlated with these interpretations is the nature of wear on the cusps. Those in the annulariids that I examined show very little wear on the anterior teeth of the ribbon. Corresponding teeth in *Pomatias* are conspicuously worn and blunted.

The differences in annulariid and pomatiasid radular structure do not in themselves constitute characteristics sufficient for separating the two groups as distinct families. Divergent feeding strategies in land snail families as reflected by radular tooth structure is a common phenomenon (Solem, 1972, 1974). The observed differences between the annulariids and the pomatiasids may represent divergence within a single phyletic group below the family level. However, the radulae of the two groups are dissimilar to the extent that it is difficult to argue a close relationship (intra-familial) on the basis of these organs.

FEMALE REPRODUCTIVE SYSTEM

Scant information is available on the soft anatomy of pomatiasids or annulariids. Creek (1951: 608-609) described the morphology and embryology of the male and female reproductive systems of *Pomatias elegans* (Müller). The reproductive systems of no annulariid have been described prior to the account given above for *Meganipha rhecta*.

Meganipha and *Pomatias* are very similar in general plan. The most striking similarity among the two genera is the elongate cleft along the ventro-lateral margin of the capsule gland forming the terminal opening of the female system. In *Pomatias* this is a modification for ovulation of a very large mucus-coated egg. By inference *Meganipha* ovulates a similar and comparably large egg.

Meganipha differs from *Pomatias* in the structure of the copulatory bursa and the adjacent segment of the oviduct. In *Pomatias* the oviduct enters the distal end of the bursa and continues to the pallial oviduct in an open groove in the floor of the bursal lumen. In *Meganipha* the oviduct and copulatory bursa are interconnected only by a narrow perforation at the end of the bursal lumen, and the oviduct continues anteriorly to the pallial oviduct as a closed tube.

MALE REPRODUCTIVE SYSTEM

Meganipha and *Pomatias* differ in three major aspects. In *Meganipha* the prostate is elongate and lies completely anterior to the transverse wall of the mantle cavity, the vas deferens is very short because of the anteriad location of the prostate, and the penis is pallial in origin. In *Pomatias* the prostate is ovate in shape and only partially overlaps the mantle cavity so that its posterior half lies well within the visceral cavity, the vas deferens is considerably more elongate because of the posteriad position of the prostate, and the penis is pedal in origin.

NERVOUS SYSTEM

Information relating to the brain of *Pomatias elegans* (Müller) is taken from Fretter and Graham (1962: 310). The only annulariid to be described is *Meganipha rhecta* (see above). Three major features distinguish the nervous system of *Meganipha* from *Pomatias:* (1) The brain of *Meganipha* is an advanced epiathroid condition. The pleural ganglia are dorsal-lateral in position and are partially fused with the corresponding cerebral ganglia. The brain of *Pomatias* is not an advanced epiathroid condition. The pleural ganglia are lateral in position and each is attached to the corresponding cerebral ganglion by a slender connective that is about as long as the pleural ganglia. (2) *Meganipha* is zygoneurous between the supraoesophageal and the left pleural ganglia. In *Pomatias* zygoneury does not occur between the supraoesophageal and the left pleural ganglia. (3) The penis of *Meganipha* is innervated by the left pleural ganglion via the suboesophageal nerve. The penis of *Pomatias* is innervated by the right pedal ganglion.

SUMMARY

The data currently available support the separation of the Annulariidae and Pomatiasidae as distinct families. Data relating to the soft anatomy of these two families are very limited, except for the radula. Sufficient numbers of radulae have been examined to characterize the Annulariidae and the Pomatiasidae as distinct and natural categories. The Cistulopsinae is herein considered to be primitive in characteristics of its radula and is a subfamily of the Annulariidae. Other data available on the reproductive systems and nervous system also support the separation of the Annulariidae from the Pomatiasidae. However, far more anatomical information is needed before definitive arguments can be made relating to this question.

The two families are characterized as follows:

POMATIASIDAE

1. Central tooth of radula with 5 cusps—a large mesocone, a subequal ectocone on each side, and a smaller ectocone posteriorly on each side (fig. 5, B, C).
2. Lateral tooth broad, with a large mesocone, a smaller entocone and two subequal ectocones (fig. 5, D).
3. Cusps on outer marginal tooth dimorphic, with 3-6 enlarged cusps over end of shaft, contrasting strongly with more slender filiform cusps that form a comb laterally (fig. 5, E, F).
4. Oviduct entering copulatory bursa and continuing to albumen gland as a groove within the bursal lumen.
5. Prostate compact and partially overlaps the mantle cavity and the visceral coelom.
6. Penis pedal in origin, inervated by the right pedal ganglion.
7. Pleural ganglia lateral in position and attached to corresponding cerebral ganglia by a slender connective.
8. Supraoesophagael ganglion not connected to the left pleural ganglion thru zygoneury.

ANNULARIIDAE

1. Central tooth of radula with a single long mesocone (fig. 2, D). A small rudimentary ectocone also may be present on each side (Cistulopsinae, fig. 6, A, B, C).
2. Lateral tooth similar to central tooth; with a single elongate cusp (fig. 2, D, E), or with an elongate mesocone bordered by a rudimentary ectocone and entocone (Cistulopsinae, fig. 6, A, B, C).
3. Cusps on outer marginal tooth monomorphic, forming a uniform comb along entire length of rasping margin (fig. 2, B, C).
4. Copulatory bursa connected to oviduct through a small terminal perforation. Oviduct continuing to albumen gland independently along side of bursa.
5. Prostate elongate and lying completely anterior to transverse wall of mantle cavity.
6. Penis pallial in origin, inervated by the left pleural ganglion.
7. Pleural ganglia dorsal-lateral in position and partially fused to the corresponding cerebral ganglia.
8. Supraoesophageal ganglion and left pleural ganglion connected by zygoneury.

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TAREBIA (PROSOBRANCHIA: THIARIDAE) IN CUBA

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In *Nautilus* 89(4): 106 (October 1975) I noted the presumably first report of the presence of the Asian thiarid *Tarebia granifera* (Lamarck, 1816) in Oriente Province, Cuba. I did not then know of a previous mimeographed item by Miguel L. Jaume of July 15, 1972 (Circulares Museo y Biblioteca de Zoología de La Habana pp. 1523-1525) in which the presence of this species in extraordinary numbers was reported in the Río Cerrajón, 14 km from Cupeyal, Yateras, Oriente (20°27′48″N, 75°03′4″W). This locality, as well as the others mentioned in my report (loc. cit.) are located generally in the SE tip of Oriente Province, where *Tarebia* seems to be confined at present. This would seem to suggest that the invasion proceeded from Hispianola which lies only 75 km to the east of Cabo Maisí. *Tarebia* was reported from there by Murry in 1971 (The Biologist, **53**(3).

ASIAN CLAM, *CORBICULA*, THREATENS HAWAII

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I found living *Corbicula manilensis* Philippi 1841 being sold as food in Kailua, Oahu Island, Hawaii, on August 18, 1977, in the "Open Market" run by the City and County of Honolulu for the small local farmer and importer. Upon checking with the Department of Agriculture Plant Quarantine Office, it was determined that these clams had entered the state illegally.

The State Health Dept. Office of Food and Drug in the Environmental Section traced their arrival through the seller to the local importer. He had purchased them from his son who was a Los Angeles exporter. All the dealers involved in this transaction were licensed only for other shell fish. In California, *Corbicula* are sold only for fish bait as their pesticide content is believed to be too great for human consumption.

This was part of a second shipment of 100 lbs. of clams. Both shipments were sold completely in the open markets. While the action of the officials cancelled the order of a third shipment of a ton of clams, there is no way yet to see if the *Corbicula* invasion has been stopped entirely in Hawaii at this time.

Living *Corbicula* have been confiscated twice earlier by the Quarantine Office. In those cases the clams had been brought in from the Orient directly.

LOUISIANA CITRUS BEING DAMAGED BY SNAILS

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In the early summer of 1975, the junior author received a request from a citrus grower in Plaquemines Parish, Louisiana, to recommend methods of controlling snails that were damaging fruit. The snail problem persisted through the summer, so again, in November 1975, he visited the citrus grove where the damage was being done. The satsuma fruit were ready for harvest but, due to a depressed market, the grower was delaying the picking. Much of the fruit was overripe and some had begun to decompose. Snails were on almost every fruit including some which were just beginning to turn from green to yellow. The snails, some of which were identified as *Mesodon thyroidus* (Say), had been rasping through the outer peel of the fruit down to the inner peel. The grower pointed out that rot fungi would then attack at the point of damage. The sour odor of the rotting fruit apparently attracts nitidulid beetles which then feed on the infected areas. A hole the size of the rasped area is made in the fruit to a depth of about 12-16 mm by the beetles. As many as six of the beetles have been found in one hole. (fig. 1).

Plaquemines Parish has, for many years, been a commercial citrus growing area. The major crops are navel oranges, grapefruit, and satsumas. Heretofore, there has been no reported damage to citrus from snails, so some doubt about the extent of snail involvement existed (it was thought that the beetles might be the causative agents of the fruit damage and that the snails might be only coincidentally involved). Thus we elected to examine the 1976 crop and run some experiments to determine for certain that the snails and not the beetles were the initial damagers.

In December, 1976, we went to the orchards in St. Martin Parish (near town of Parks, LA.) where similar snail damage had been reported in the summer of 1975. There we found the trees laden with thousands of satsumas. The owner, Mr. Alvin Guidry, said he was once again having the snail problem, showed us bags of damaged fruit, and then took us to the orchard to see for ourselves.

Underneath each tree was a depression (dug out for aiding in watering the plants). Those depressions are covered with grass and weeds which form good cover for snails. The satsuma bottom branches hang down into these areas. A typical tree stands about 2 meters tall with branches from near

FIGS. *(above and below). The snail,* Bradybaena similaris *(Férussac), feeding on the citrus fruit, satsuma.*

ground level up. The depressions contained hundreds of snails: *Mesodon thyroidus* (Say), *Succinea* sp., *Triodopsis fosteri* (F. C. Baker), *Helicina orbiculata* (Say), many *Bradybaena similaris* (Férussac), and *Polygyra texasiana* (Moricand).

The air temperature was in the 5-10°C range after a cold frontal passage, with high wind. The only snails active were *Bradybaena*, although some of the other species were seen in the trees on leaves and fruit. *Bradybaena similaris* was easily available, so a number were collected along with several non-damaged satsumas. Upon return home one undamaged fruit was placed in a container along with six *Bradybaena similaris* and two undamaged satsuma leaves. A few drops of moisture were added and the container left overnight. Next morning the fruit had 24 rasped areas on it (raspings as described above) and each of the leaves had holes in them. No fruit-peel or leaf debris was anywhere in the container, thus indicating that both were consumed. Several additional experiments were done, all with similar results.

It appears evident that the citrus was being damaged by *Bradybaena similaris*. We have no reason to doubt the other grower when he says that *Mesodon thyroidus* is involved also. We do plan to check the Plaquemine Parish orchards also and, next season, run experiments with all of the other species.

It is not known why or how such heavy populations of snails developed in these two orchards located approximately 125 miles apart. The St. Martin Parish orchard is separated from other citrus groves, but the Plaquemines Parish grove is surrounded by others. No report of damage has been received from other growers.

This raises questions such as what caused the snails to become pests and whether or not they will continue causing damage. We plan to follow up on these questions during the next crop-growing season.

PREDATION ON APPLE SNAIL EGGS (*POMACEA*)

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ABSTRACT

Observations confirm Snyder and Snyder's (1971) conclusion that the conspicuous eggs of Pomacea paludosa *are distastful to vertebrates. However certain invertebrates eat* Pomacea *eggs. This complicates the strategies faced by the snail in producing conspicuous eggs that may be aposematic to vertebrate but not to invertebrate predators.*

Many ampullarid snails of the genus *Pomacea* have colored or otherwise noncryptic eggs. The apple snail, *P. paludosa* (Say) lays clusters of conspicuous white eggs on emergent vegetation. Snyder and Snyder (1971) found that the eggs are distasteful in their early stages of development. Although simple palatability tests on a wide variety of animals were inconsistant, Snyder and Snyder found that the eggs were generally distasteful and that some animals may learn to avoid them. They suggested that egg conspicuousness functions as warning coloration. Orians and Janzen (1974) showed that egg palatability is usual among animals. They cited the *Pomacea* findings as one of their few examples of toxicity among animals eggs. The occurrence of natural predation on *Pomacea* eggs bears upon the functional and strategic implications of producing conspicuous, distasteful eggs. This present note discusses instances of natural predation on *Pomacea* eggs.

RESULTS AND DISCUSSION

The apple snail is abundant in the freshwater wetlands of southern Florida (Kushlan 1975) and therby provides many opportunities for observation. Many of my field observations of apple snail eggs parallel those of Snyder and Snyder (1971). Eggs are conspicuous but are apparently ignored by many suitable predators. Snyder and Snyder (1971) found that some captive vertebrates ate proffered eggs, at least at a single offering, including the White Ibis (*Eudocimus albus*). Apple snails comprise over 5% of the ibis' diet in southern Florida, but no snail eggs were found in 199 food samples from wild birds (Kushlan and Kushlan 1975). The attraction of this species to eggs in Snyder and Snyder's study was probably an artifact of confinement, where ibises often eat unusual food items (Kushlan and Kushlan 1975). Other captive vertebrates tested by the Snyders were probably similarly affected. In my experience, wild sunfish, expecially bluegill (*Lepomis macrochirus*), will eat offered eggs initially, but their reaction often wanes with time.

I believe the situation in invertebrate predators may be different than with vertebrate predators. I have seen a coneheaded grasshopper (*Neoconocephalus triops*) eating snail eggs. Coneheaded grasshoppers belong to the family Tettigoniidae in which both predatory behavior and cannabilism occur. I have not seen the grasshopper break open eggs although they have strong jaws and may be capable of doing so. It is possible that the eggs must sustain mechanical damage prior to predation. Regardless, the grasshopper did consume the egg contents that were in the early, and therfore noxious stage of development.

Thus it would appear that *Pomacea* eggs are distasteful to vertebrates and that avoidance-learning occurs which enables conspicuousness to serve an aposematic function. This may not be true for invertebrates. Several types of invertebrates may prey on *Pomacea* eggs. Snyder and Snyder (1971) reported natural predation by a milliped and found that gyrinid beetles (*Dineustes* sp.) and crayfish (*Procambarus* sp.) would eat eggs, although crayfish subsequently rejected them. If a vertebrate-invertebrate dichotomy in the effectiveness of apostasis exists, it would complicate selection pressures for avoiding egg predation. Laying eggs out of water would successfully thwart both vertebrate and invertebrate aquatic predators. Apostasis would reduce losses to terrestrial vertebrates. Protection from terrestrial invertebrates may result from there being relatively few terrestrial predatory invertebrates large enough to eat *Pomacea* eggs in the marsh habitat in which the snails live. Further information on the extent of natural predation on *Pomacea* eggs may shed light on the mechanisms used to reduce such losses.

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________ Vol. 75, no. 2 (Oct. 1961). Review of *Thyasira* (Ockelmann). Marine Shells of Water Island, Virginia (Weber). Eight new land snails, cont'd (Hubricht), etc.

________ Vol. 76, no. 2 (Oct. 1961). New Caribbean Marine Shells (McGinty); Life History of *Haliotis rufescens* (Carlisle). Zinc effects on freshwater mollusks (Wurtz), etc.

________ Vol. 76, no. 3 (Jan. 1963). *Panopea bitruncata* (Robertson). Checklist Illinois Unionidae (Fechtner), etc

________ Vol. 76, no. 4 (April 1963). Mollusks eaten by Puerto Rican bonefish (Warmke). Four new *Olivella* (Burch and Campbell); new land snails (Hubricht)

________ Vol. 77, no. 1 (July 1963). Genus *Olivella* in eastern Pacific (Burch). *Corbicula* in Ohio River (Keup, *et al*), etc

________ Vol. 77, no. 2 (Oct. 1963). Sphaeriid clams (Thomas); western *Goniobasis* (Roscoe); West African Haliotid (Talmadge)

________ Vol. 77, no. 4 (April 1964) *Sinum* and *Agaronia* (Burch). new unionids (Atheam); American Melampidae (Morrison), etc.

________ Vol. 78, no. 1 (July 1964). New *Typhis* (Warmke). biology *Achatina* (Kondo; also Kraus), etc.

________ Vol. 78, no. 3 (Jan. 1965). New Vitrinellidae (Moore); new *Latiaxis* (Emerson and D'Attilio), etc.

________ Vol. 78, no. 4 (April 1965). Ecology of spiny pelecypods (Nicol). Galapagos marines (Emerson and Old). land snails of Bahamas (Jacobson), etc.

________ Vol. 79, no. 1 (July 1965) New *Aspella* (Emerson and D'Attilio); Hosts of *Odostomia* (Scheltema). new records of *Conus* and *Cypraea* (Old), etc

________ Vol. 79, no. 2 (Oct. 1965) New *Cypraea* (Burgess), Mollusks new to South Carolina (Merrill and Petit), *Elliptio spinosa* (Thomas)

________ Vol. 79, no. 4 (April 1966) Size of Recent Pelecypods (Nicol), *Corbicula* in Louisiana (Gunning), larvae of *Lyonsia* (Chanley), etc.

________ Vol. 80, no. 1 (July 1966) Life history of *Achatina* (Kekauoho) (also in no. 2); *Corbicula* in Texas (Metcalf); *Mesodesma* (Davis), etc.

________ Vol. 80, no. 2 (Oct. 1966). Littorinids (Rosewater), new *Sonorella* (Miller), etc.

________ Vol. 81, no. 1 (July 1967) New *Cypraea* (Burgess), new *Sonorella* and *Pachychilus* (Thompson), etc.

________ Vol. 81, no. 2 (Oct. 1967). *Cassis* of North Carolina (Wolfe), *Limopsis* (Nicol), new *Sonorella* (Miller), etc.

________ Vol. 81, no. 3 (Jan. 1968). Bermuda marine mollusks (Abbott); pteropods of Atlantic (Chen); Partulidae (Kondo), etc.

________ Vol. 82, no. 2 (Oct. 1968). Introduced mollusks (Dundee and Hermann); Chromosomes in pelecypods (Menzel); new land species, etc.

________ Vol. 82, no. 4 (April 1969) Mollusks new to South Carolina II (Merrill and Petit); pteropods (Rao), Unionids of Utterback, etc.

________ Vol. 83, no. 1 (July 1969). *Donax fossor* (Chanley), new *Oliva* (Ziegler); Galapagos *Morum* (Emerson); unios, new *Caecum*, etc.

________ Vol. 83, no. 3 (Jan. 1970) New Mitridae (Cernohorsky), new *Cymatium* (Abbott); nudibranch, Doris (Franz); longevity in snails.

________ Vol. 84, no. 2 (Oct. 1970). Memorial number to Hertlein, new scallops (MacNeil). Hertlein's taxa.

________ Vol. 84, no. 3 (Jan. 1971). New *Typhis* (Habe and Koruge); new Hydrobiidae (Hubricht), ecology of *Thyasira* (Kanno), etc.

________ Vol. 85, no. 1 (July 1971). *Hemidonax* affinities (Bors), Fluorescence in snails (Rawls and Yater); Variation in *Mudalia* shells (Branson), etc.

________ Vol. 85, no. 2 (Oct. 1971). Feeding of Florida *Aplysis (Krakauer); Conus patae* (Abbott); Pyramidellids (Corgan); unios, etc.

________ Vol. 85, no. 4 (April 1972). Reef mollusks of South Carolina (Shoemaker), shell growth of *Littorina;* mollusks of Lake Birket Qarun, Egypt (Rose).

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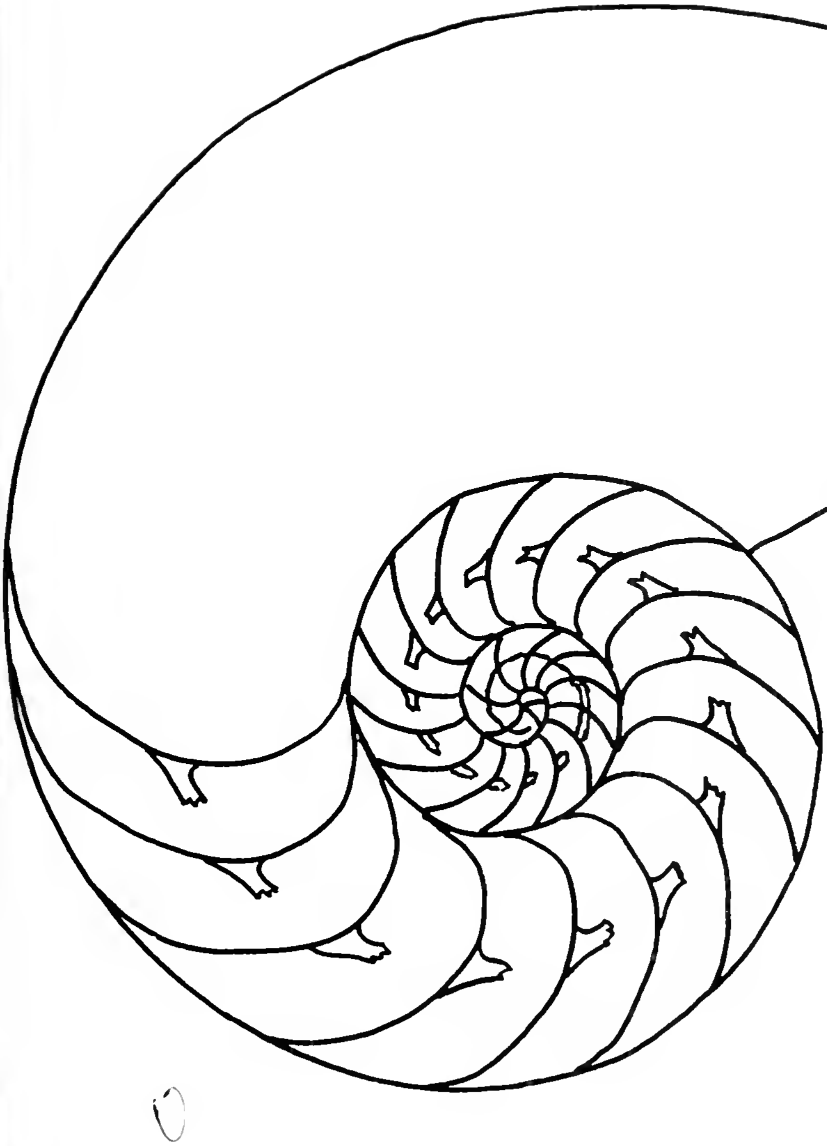

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CONTENTS

Meetings

American Malacological Union, 44th annual meeting will be held July 16-21, 1978, on the campus of the University of North Carolina (UNCW) in Wilmington, North Carolina. For reservations write: AMU, Box 394, Wrightsville Beach, NC 28480.

Western Society of Malacologists, 11th annual meeting will be held June 28-July 1, 1978, at the University of Santa Clara, California. For reservations write: Carol C. Skoglund, 3846 East Highland Avenue, Phoenix, AZ 85018.

In Memoriam

Axel Adolf Olsson

19 April, 1889 — 26 October, 1977

AXEL A. OLSSON — AN OBITUARY

19 April, 1889 — 26 October, 1977

Donald R. Moore
Rosenstiel School of Marine and Atmospheric Science
University of Miami, Miami, Florida 33149

Axel Adolf Olsson became interested in natural history at about the age of twelve, an interest he never lost. Born in Gloversville, New York, he was the son of Swedish immigrant parents, and, as a boy, spent a year with his mother in Sweden. He maintained close contact with relatives in Sweden for the rest of his life.

Axel worked in order to save money to go on for a higher education. He attended the Massachusetts Institute of Technology for one year, then went to Cornell University in 1910. Here, he promptly fell under the influence of Professor Gilbert D. Harris, and a career in geology and invertebrate paleontology was launched. Olsson published two papers in 1912, thus beginning a series of publications over a 61-year period.

Olsson served as laboratory assistant to Professor Harris in his undergraduate years, then was instructor in invertebrate paleontology while a graduate student. During the summers, Harris and his students explored the Atlantic coastal plain in a small cabin cruiser, the "Ecphora." Several papers on the American Tertiary were published by Olsson as a result of this work.

Olsson had received his AB degree in 1913, then began graduate studies under Professor Harris. At this time he was elected to the Society of Sigma Xi while still a student, and also won the Goldwin Smith Fellowship in geology for the years 1913, 1914. In 1916, Olsson and his assistant, Karl Patterson Schmidt, who later became a famous herpetologist, made an expedition to Santo Domingo for Dr. Carlotta J. Maury (1874-1938) who had been financed by the Sarah Berliner Foundation. The purpose of the expedition was zonal division and classification of Miocene beds of the northern part of the island. The work was somewhat hampered by a revolution, but the main objective was achieved. Olsson and Schmidt returned to port by pretending to be Germans, and, speaking this language, they were passed through the front lines by the rebels.

Early in 1917, before finishing his dissertation, Olsson, and several geologists from the U. S. Geological Survey and Johns Hopkins University, went to Central America to work in Panama and Costa Rica. Olsson remained there about a year and a half, working for the Sinclair Oil Company, and made a large collection of fossils which were sent to the U. S. National Museum. He continued with Sinclair Oil, and was sent to Texas. Here he mapped the subsurface geology of the Damon Mounds Salt Dome from well drillings. This was a pioneer work in the use of Foraminifera in oil geology in the United States. This was followed by work in west Texas, Oklahoma, and Louisiana.

Olsson returned to Cornell several times to finish work on his Ph.D. Each time he was pulled away for further petroleum exploration, and was unable to complete his residence requirements. The last time was in 1922 when he was sent to Peru. Olsson never went back to complete his thesis on the Miocene of Virginia, although Harris published his works on Costa Rica and Peru in Bulletins of American Paleontology.

The work in Peru was the beginning of nearly thirty years of work in northern South America. A considerable amount of oil was found, and oil companies were always most generous. Olsson was allowed much freedom of movement and unrestricted publication on his collections of fossils. His Tertiary and Cretaceous Paleontology of northern Peru included 750 pages of text and 128 plates. South America was not his only area of study, however. The quest for petroleum and fossils led to the western United States, the Canadian Rockies, and the maritime provinces of eastern Canada. In 1937 he went to New Zealand for a two year period. In 1939 he considered an offer to work in the near East, but for some reason did not accept the position.

Olsson finally bought a house in Langhorne, near Philadelphia, to house his library and collections. His widowed sister, Freda, and his brother, Oscar, lived with him. He was also a Research Associate of the Academy of Natural Science, and this gave him a base where he could work. He had been associated with H. A. Pilsbry since 1935 and they published a total of 22 papers together. They even made an expedition to Peru during the spring of 1948. Olsson now took an interest in the geology and paleontology of southern Florida, lived for a while in St. Petersburg, then purchased a house in Coral Gables in 1952.

Retirement did not cause any slackening of interest in the natural world. A room off the garage became a laboratory. A spare bathroom was set up as a darkroom. Bookcases proliferated throughout the house. Collections, both fossil and Recent, were stored in rough home made cabinets in the garage, laboratory and Olsson's own bedroom. Work on this material continued up until late in 1976.

Olsson made many field trips in south Florida. These trips were usually with friends or with professional people of various disciplines: geology, paleontology, and biology. Discoveries were brought to him to be met with great enthusiasm, boundless information on fossils, and an offer to accompany people to see for himself the new rockpit or canal bank spoil. Friends brought him so much material that one envious paleontologist referred to them as "Olsson's army of amateurs." But Olsson was interested in more than fossil specimens. To work out the admittedly confusing stratigraphy of the Upper Cenozoic in south Florida, he walked on the bottom of a new canal, kept dry by pumps, for several miles, examined countless rockpits, and collected on spoil banks or outcrops over a wide area. After 1967, F. M. Bayer and Gilbert Voss interested Olsson in the trawled and dredged material collected by various vessels of the School of Marine Science, University of Miami. Three papers were published as a result of this work. A great deal of work, unfortunately was never completed.

Olsson's published works included about 3700 pages, and close to 500 plates, about half of this after his "retirement". He was a Fellow of the Geological Society of America, a charter member of the Paleontological Society, a very early member of the American Association of Petroleum Geologists, and Past President and Life Trustee of the Paleontological Research Institution. He was awarded a Doctor of Science Degree by the University of Miami in 1974. He was also a Research Associate of both the Academy of Natural Sciences of Philadelphia, and of the National Museum of Natural History, Smithsonian Institution.

Axel married Elsie Carleton Lawton on September 11, 1971, thus ending over eighty years of bachelorhood. The Olssons traveled extensively in Europe and in Latin America until late in 1976. After an operation early in 1977, Axel went into a decline, and died 26 October, the same day and month as had his old friend, Henry Pilsbry, some twenty years before.

Axel Olsson never lost his interest in natural history and the life of the past. His service to mankind includes his work in the petroleum industry, his help and advice to one and all, and his voluminous literature on Cenozoic Mollusca.

MAJOR WORKS PUBLISHED BY A. A. OLSSON

1922 The Miocene of Northern Costa Rica with notes on its general stratigraphic relations. *Bull. Amer. Paleo.* **9**(39): 1-309, pls. 1-32.

1928 Contributions to the Tertiary Paleontology of Northern Peru: Part 1. Eocene Mollusca and Brachiopoda. *Bull. Amer. Paleo.* **14**(52): 1-154, pls. 1-26.

1929 Contributions to the Tertiary Paleontology of Northern Peru: Part 2. Upper Eocene Mollusca and Brachiopoda. *Bull. Amer. Paleo.* **15**(57): 67-116, pls. 9-16.

1930 Contributions to the Tertiary Paleontology of Northern Peru. Part 3. Eocene Mollusca. *Bull. Amer. Paleo.* **17**(62): 1-96, pls. 1-12.

1931 Contributions to the Tertiary Paleontology of Northern Peru: Part 4. The Peruvian Oligocene. *Bull. Amer. Paleo.* **17**(63): 97-264, pls. 13-33.

1932 Contributions to the Tertiary Paleontology of Northern Peru: Part 5. The Peruvian Miocene. *Bull. Amer. Paleo.* **19**(68): 1-272, pls. 1-24.

1934 Contributions to the Paleontology of Northern Peru Part 6. The Cretaceous of the Amotape Region. *Bull. Amer. Paleo.* **20(69):** 1-104, pls. 1-11.

1941 (with H. A. Pilsbry). A Pliocene fauna from western Ecuador. *Proc. Acad. Nat. Sci. Philad* **93:** 1-79, pls. 1-19.

1942 Tertiary and Quaternary fossils from the Burica Peninsula of Panama and Costa Rica. *Bull. Amer Paleo* **27(106):** 157-234, pls. 14-25.

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1945 (with H. A. Pilsbry). Vitrinellidae and similar gastropods of the Panamic Province. Part 1. *Proc. Acad. Nat. Sci. Philad.* **97:** 249-278, pls. 22-30.

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1956 Studies on the genus *Olivella Proc. Acad. Nat. Sci. Philad.* **108:** 155-225, pls. 8-16.

1958 (with T. L. McGinty). Recent marine mollusks from the Caribbean coast of Panama with the description of some new genera and species. *Bull. Amer Paleo* **39**(177): 5-58, pls. 1-5

1961 Panamic—Pacific Pelecypoda. Paleontological Research Institution, Ithaca, New York: 1-574, pls. 1-86.

1964 Neogene mollusks from northwestern Ecuador. Paleontological Research Institution, Ithaca, New York: 1-256, 38 pls.

1964 (with R. E. Petit). Some Neogene Mollusca from Florida and the Carolinas. *Bull. Amer Paleo* **47**(217): 509-574, pls. 77-83.

1967 Some Tertiary mollusks from south Florida and the Caribbean. Paleontological Research Institution, Ithaca, New York: 1-66, pls. 1-9.

1971 Mollusks from the Gulf of Panama collected by R. V. PILLSBURY, 1967. *Bull. Mar. Sci.* **21**(1): 35-92, 103 figs.

NEW SPECIES OF MITRIDAE, COSTELLARIIDAE AND TURRIDAE FROM THE HAWAIIAN ISLANDS WITH NOTES ON *MITRA SPHONI* IN THE GALAPAGOS ISLANDS

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ABSTRACT

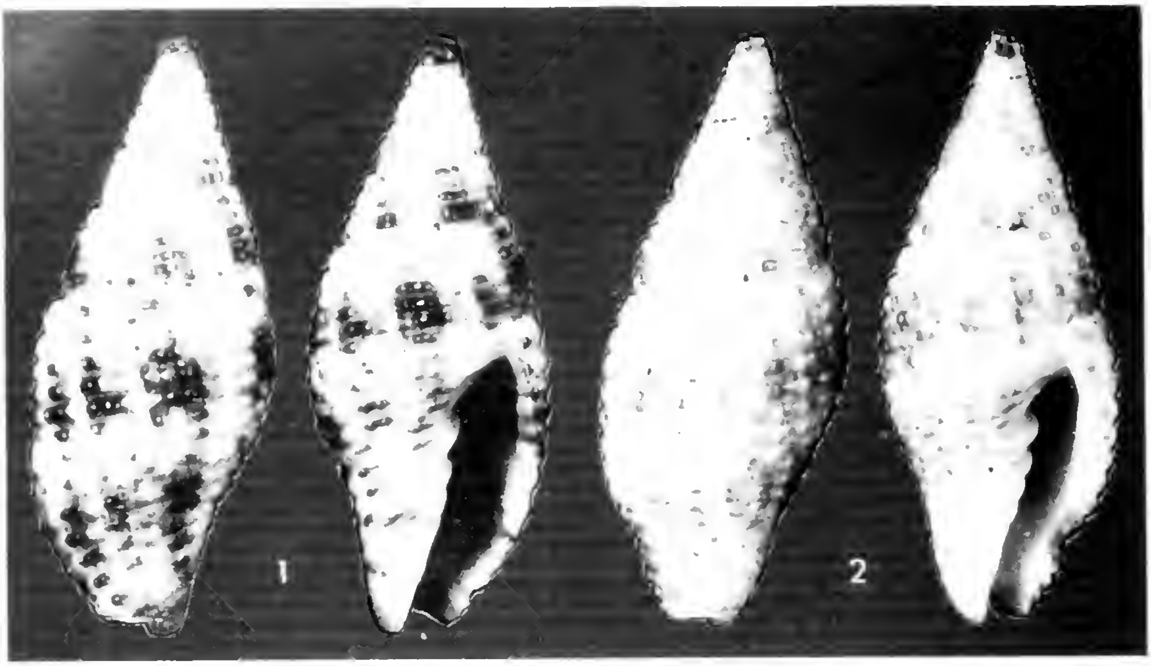
Two new species of Costellariidae, i.e. Vexillum (Costellaria) wolfei *sp. nov., and* V. (C.) adamsianum *sp. nov., a new mitrid* Neocancilla kayae *sp. nov., and a new turrid* Mitrolumna salisburyi *sp. nov., are described from deeper water in the Hawaiian Islands. The previously reported occurrence of* Mitra sphoni *Shasky & Campbell, in the Galapagos Islands is here confirmed and documented by an illustrated specimen; the species is re-assigned to* Mitra (Nebularia).

Family Mitridae

Neocancilla kayae *new species*

(Figs. 1, 2)

Description—Shell moderately small, 8.0 - 14.0 mm in length, elongate-ovate and stumpier than other species of the genus, width about 40-43% of length, protoconch incomplete but multispiral and consisting of 3+ smooth, glassy embryonic whorls, teleoconch consisting of 5-6 almost flat-sided, mature whorls, sutures deeply incised. First 1-3 post-embryonic whorls sculptured with deep vertical and horizontal grooves which produce 3 spiral rows of laterally or vertically elongated nodules, fourth whorl with 4 rows of nodules, penultimate whorl with 5 rows and body whorl with 11-14 rows of nodules and 8-9 smoother and oblique cords basally; on the last two whorls the nodules are regular, elevated and round, close-set and sometimes touching each other and connected to each other both laterally and vertically; the



FIGS. 1, 2. Neocancilla kayae *new species.* **1.** *Holotype, length 8.7 mm.* **2.** *Paratype, length 13.5 mm.*

interspaces are deep and the nodules are regularly aligned in both directions. Aperture slightly longer than the spire, narrow and smooth within, outer lip convex, columella with 4 strong, oblique folds which decrease in size anteriorly; siphonal canal straight, siphonal notch deep. White in colour, ornamented with reddish brown streaks which are saturated in blotches, occasional nodule coloured reddish brown, aperture creamy-white and with an indication of 2 orange-brown zones.

Measurements (mm)

	length	width
Holotype (AIM/TM-1355)	8.7	3.5
Paratypes:		
No. 1 (Auck. Ins. Mus.)	13.5	5.8
No. 2 (coll. Salisbury)	12.0	5.0

Material—HOLOTYPE and type locality: Pokai Bay, Oahu, Hawaiian Ids., 60-70 fathoms; AIM/TM-1355. PARATYPES: No. 1—Pokai Bay, Oahu, H.I., 100 fathoms; AIM. No.'s 2-3—same locality as No. 1; coll. R. Salisbury.

Range—Apparently endemic to the Hawaiian Islands, 60-100 fathoms, in mud and sand or sand and coralline algae.

Remarks—This species differs from all other *Neocancilla* species in the deeply incised sutures and regular rows of round, close-set nodules. *N. papilio* (Link), has a complicated sculpture of alternating larger and smaller, low fillets which appear stepped in profile and numerous, shallow longitudinal grooves and filleted narrow spiral cords. The sculpture in *N. clathrus* (Gmelin) and *N. arenacea* (Dunker) is of similar style to *N. papilio* and also consists of alternating low, quadrate fillets with laterally elongate fillets in between, and numerous longitudinal grooves.

The new species is only tentatively assigned to *Neocancilla* until the radula is examined. The species is named for Dr. Alison Kay, University of Hawaii, for her valuable research contributions to Hawaiian and Polynesian malacology.

Mitra (Nebularia) sphoni *Shasky & Campbell, 1964*

(Fig. 3)

1964 *Mitra (Strigatella) sphoni* Shasky & Campbell. The Veliger, vol. 7, no. 2, p. 118, pl. 22, figs. 13, 14

1971 *Mitra (?Strigatella) sphoni* Shasky & Campbell, Keen, Sea Shells Tropical west America, ed. 2, p. 642, fig. 1428.

1976 *Subcancilla sphoni* (Shasky & Campbell), Sphon, The Nautilus, vol. 90, no. 2, p. 63.

1976 *Mitra (Nebularia) sphoni* Shasky & Campbell, Cernohorsky, Indo-Pacific Moll. vol. 3, no. 17, p. 452, pl. 401.

Sphon (1976) reported a range-extension for this species, (which originally has been described from Guaymas, Mexico) to the Galapagos Islands. This range extension is confirmed by another specimen dredged in 40 metres by the "Foxtrot" Expedition between Isla Barbara and Isla Santa Cruz, Galapagos, in May 1974. This Galapagan specimen has somewhat deeper longitudinal troughs which give rise to weak axial folds on the body whorl, and the interspaces of the spiral cords are obsoletely lirate.

We agree with Sphon (*op. cit.*) that the original placement of the species in the mitrid subgenus *Strigatella* Swainson, was inappropriate, since *Strigatella* species show a consistent feature of a posteriorly thickened outer lip, which frequently takes the form of a blunt denticle. However, Sphon's placement of *sphoni* in the genus *Subcancilla* Olsson & Harbison, is equally inappropriate since *sphoni* lacks the characteristic features of that genus. *Mitra sphoni* is closely related to the west American *M. crenata* Broderip, and is conchologically extremely similar to such Indo-Pacific *Nebularia* species as *M. proscissa* Reeve, *M. fraga* Quoy & Gaimard, *M. rubritincta* Reeve, and several others whose radulae are known to be of the *Mitra* type. It is my opinion that once the radulae of *M. crenata* and *M. sphoni* are examined, they will prove to be of the mitrine type.

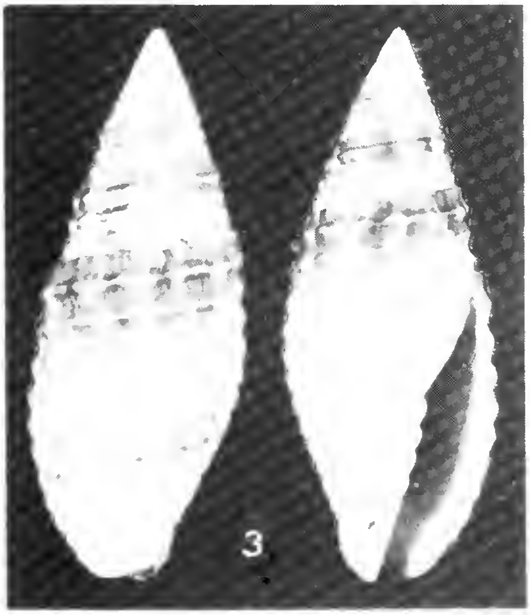


FIG 3. Mitra (Nebularia) sphoni *Shasky & Campbell, specimen from the Galapagos, Ids., length 25.6 mm*

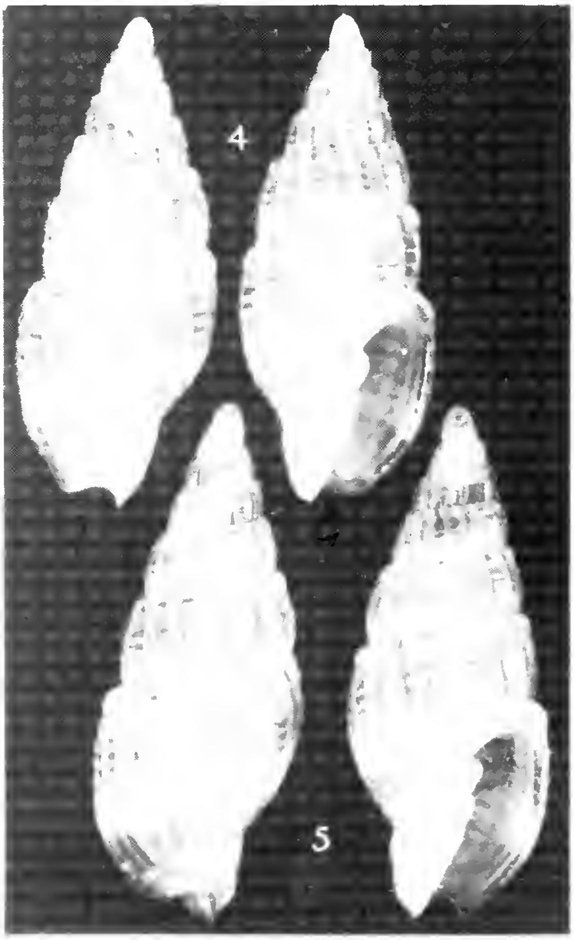
Family Costellariidae Macdonald, 1860

The chronologically prior family-group name Costellariidae Macdonald, 1860, will have to replace Vexillidae Thiele, 1929. For further discussion on this subject see Cernohorsky (1976).

Vexillum (Costellaria) wolfei *new species*

(Figs. 4, 5)

Description—Shell very small, 5.0-10.0 mm in length, elongate-ovate, width 38-42% of length, shining, protoconch conical-multispiral, consisting



FIGS 4, 5. Vexillum (Costellaria) wolfei *new species.* **4.** *Holotype, length 6.3 mm.* **5** *Paratype, length 6.6 mm* of 3¼-3¾ glassy, embryonic whorls which are either straight or tilted, teleoconch consisting of 5-6 convex, mature whorls. Sculptured with slender and thin axial ribs which produce a row of sutural nodules and number from 12-17 on the penultimate and 14-17 on the body whorls; spiral sculpture consists of narrow, flattish spiral cords which only ascend the wall of the ribs rendering these imperceptibly nodulose; spiral threads number from 5-7 on the penultimate and from 10-12 on the body whorl, base of shell with 3 or 4 nodulose cords followed by 3 or 4 smoother cords. Aperture slightly shorter than the spire, height 42-47% of length, lirate within, outer lip convex, columella only weakly calloused and with 3 or 4 prominent, oblique folds which decrease in size anteriorly. Base colour white, frequently with a translucent golden sheen, 4 spiral cords anteriorly to the sutures and 4 cords at the base of the body whorl lined with reddish brown and giving the impression of a broad central band, interspaces of sutural nodules usually spotted with reddish brown in mature individuals; aperture white and lined with reddish brown; columella white.

Measurements (mm)

	length	width
Holotype (AIM/TM-1348)	6.3	2.5
Paratypes:		
No. 1 (DMNH 112103)	6.0	2.2
No. 2 (BPBM)	7.0	2.7

Material—HOLOTYPE: Pokai Bay, Oahu, Hawaiian Ids., 60-70 fathoms; AIM/TM-1348. PARATYPES: No. 1—same data as the holotype: DMNH 112103. No. 2.—same data as the holotype: BPBM. No. 3—Keehi Lagoon, Oahu, H.I.; 100 fathoms; Salisbury coll. Nos. 4-24—same data as the holotype; AIM and other institutions and collections.

Range—Apparently endemic to the Hawaiian Islands, 60-100 fathoms.

Remarks—*V. (C.) wolfei* can be compared with the moderately common intertidal and subtidal Indo-Pacific species, *V. (C.) amanda* (Reeve, 1845), but the latter species is somewhat larger, considerably more solid with a duller surface and more slender sutural nodules which are usually the same width as the ribs, and more numerous, finer and thinner spiral threads. *V. (C.) amanda* has a continuous dark-brown sutural band on the spire whorls and 2 or 3 dark-brown bands on the body whorl, and lacks the reddish brown-lined cords, as well as the translucent sheen of *V. (C.) wolfei*.

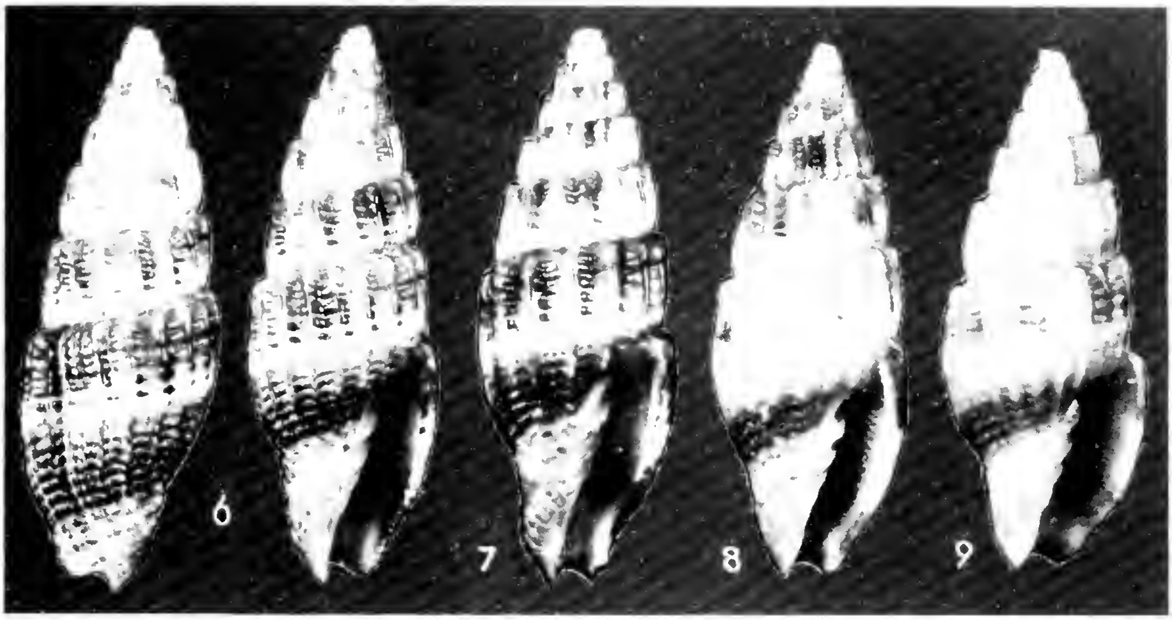
This new species is named for Mr. C. S. Wolfe, Honolulu, in appreciation for his services to the Hawaiian Malacological Society, Junior Shell Club, and other Hawaiian malacological projects

Vexillum (Costellaria) adamsianum *new species*

(Figs. 6-9)

1963 "*Mitra agria* Dall MS", J. Cate, The Veliger, vol. 6, no. 1, p. 36, pl. 7, fig. 32 (*nomen nudum*) - placed in synonymy of *Vexillum xenium* Pilsbry, 1921.

Description—Shell moderately small, 8.0-17.0 mm in length, elongate to elongate-ovate, some individuals broader than others, width 34-42% of length, protoconch conical-multispiral, consisting of 3½ glassy, white embryonic whorls, teleoconch consisting of 5½-7¼ slightly convex mature whorls which are distinctly angulate at the sutures. Sculptured with angulate and usually straight axial ribs which number from 13-17 on the penultimate and from 13-21 on the body whorl; spiral sculpture consists of distinct, low spiral cords which ascend the walls of the axial ribs and usually notch their summits, cords number from 5-7 on the penultimate and from 8-12 on the body whorl, siphonal fasciole with 2 or 3 nodulose, oblique cords. Aperture slightly shorter or longer than the spire, 44-55% of length, lirate within, outer lip weakly convex, columella not calloused and with 4 or 5 (usually 4) oblique folds which decrease in size anteriorly. Variable in colour but usually white and sparsely or densely ornamented with dark reddish brown or purple-brown areas of varying intensity and usually appearing as quadrate or rectangular blotches arranged in two broad bands on the body whorl and a single band on the spire whorls; the white central band is with or without an interrupted reddish brown sprial line, aperture rose-purple to violet-purple.



FIGS. 6-9. Vexillum (Costellaria) adamsianum *new species. Keehi Lagoon, Oahu, Hawaiian Ids.* **6.** *Holotype, length 13.7 mm.* **7.** *Paratype, length 11.3 mm.* **8.** *Paratype, length 16.8 mm.* **9.** *Paratype—subadult, length 9.0 mm.*

Measurements (mm)

	length	*width*
Holotype (AIM TM-1354)	13.7	4.7
Paratypes:		
No. 1 (col. A. Adams)	16.8	6.1
No. 2 (USNM 173197)	10.2	4.3
No. 3 (USNM 338182)	10.0	3.8
No. 4 (DMNH)	9.0	3.7

Material—HOLOTYPE: Keehi Lagoon, Oahu, Hawaiian Islands, 50 fathoms; AIM/TM-1354. PARATYPES: No. 1—same data as the holotype; coll. A. Adams. No. 2—St. 3846, south coast of Molokai Id., H.I., 60-64 fathoms at 71.5° F; USNM 173197. No. 3—reef near Honolulu, Oahu, H.I.; USNM 338182. No. 4—same data as the holotype: DMNH. Paratypes No. 5-14 from Keehi Lagoon, Oahu, H.I., 125 fathoms, from Makaha Beach, Oahu, H.I., 40 fathoms, and from Pokai Bay, Oahu, H.I., 40-100 fathoms, are in the B. P. Bishop Museum, Honolulu, AIM, coll. A. Adams and coll. R. Salisbury. Specimens from Hitiaa, Tahiti, French Polynesia, are in coll. J. Trondle and AIM.

Range—Various stations in the Hawaiian Islands, 40-125 fathoms, in *Pinna* beds or sand and coral-rubble. Also occurs at Hitiaa, Tahiti, 10-12 m.

Remarks—The first three specimens of the new species were taken many years ago by the U. S. Fish Commission in the Hawaiian Islands and a single specimen was found by D. Thaanum on a reef near Honolulu. The late W. H. Dall marked these specimens "*Mitra agria* Dall" on labels in the National Museum of Natural History, Washington, clearly recognizing the taxon as new to science. The name has never been published and remained a manuscript name. J. Cate (1963) in a revision of Dall's Hawaiian Mitridae, published the name "*Mitra agria*" as a *nomen nudum*, and considered the species to be a juvenile stage of *Vexillum (Costellaria) xenium* Pilsbry, 1921. Dall's specimens, however, are conspecific with *V. (C.) adamsianum* and have been included in the type-series of this species.

V. (C.) adamsianum is superficially similar to *V. (C.) wolfei* but differs in its larger size, distinctly angulate whorls, coarser sculpture, colour, and absence of a sutural row or nodules and the translucent golden sheen. In some younger specimens of *V. (C.) adamsianum* the axial ribs protrude slightly above the suture and giving them a hooked appearance.

The species is named for Mr. Andrew C. Adams, Aiea, Hawaii, in recognition of his subtidal dredging efforts in the Hawaiian Islands which brought to light specimens of the new species.

After the manuscript and plates were completed, we have received 2 specimens of *V. (C.) adamsianum* from Hitiaa, Tahiti, which were collected by Mr. J. Trondle from Papeete. Although collected in only 10-12 metres, the specimens are undoubtedly *V. (C.) adamsianum*.

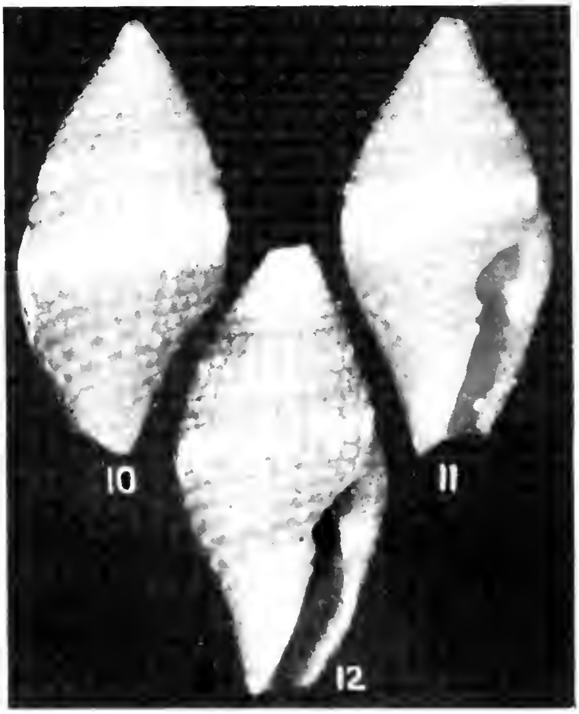
Family Turridae

Subfamily Mitromorphinae Casey, 1904

Mitrolumna salisburyi *new species*

(Figs. 10-12)

Description—Shell minute 3.0-4.0 mm in length, ovate-biconic, width 47-50% of length, shining, sutures barely distinguishable and only indicated by a slightly deeper sutural trough on which are superimposed short axial riblets connecting the two sutural rows of nodules: protoconch conical-multispiral, consisting of 3½ smooth, glossy , golden-brown embryonic whorls, teleoconch consisting of 4¼-4½ mature convex whorls. Sculpture on first one-half of the post-embryonic whorls consists of 3 or 4 spiral rows of small, regular nodules, subsequent whorls with 3 rows of nodules, penultimate whorl with 4 rows of nodules, the two central rows partly fused together and forming short axial ribs which number from 24-26, body whorl with 7 or 8 spiral rows of moderately large nodules, followed by 6 or 7 oblique cords which commence in line with the first columellar fold, first 3 or 4 posterior cords nodulose, last 3 cords fairly smooth. Aperture about the same height as the spire, narrow, shortly lirate within, constricted posteriorly by a prominent callosity which sometimes consists of two fused denticles, turrid sinus moderately distinct but not deep, columella centrally with a "V"-shaped fissure which produces 2 prominently swollen cords, posterior cord slightly larger than anterior one, siphonal canal spout-shaped. Base colour orange-brown, both posterior and anterior row of sutural nodules rosy-mauve, nodules anteriorly to the body whorl suture white, followed by a rosy-mauve peripheral band extending over 2 rows of nodules and another rosy-mauve basal band extending over the first 3 oblique cords on the siphonal fasciole; aperture rosy-mauve, callus on outer lip pale rose or whitish.



FIGS. 10-12. Mitrolumna salisburyi *new species.* **10., 11** *Holotype, length 4.0 mm.* **12.** *Paratype, length 4.2 mm.*

Measurements (mm)

	length	width
Holotype (AIM/TM-1349)	4.0	2.0
Paratypes:		
No. 1 (AIM)	4.2	2.0
No. 2 (DMNH 112101)	3.9	1.9

Material—HOLOTYPE and type locality: Maile Point, Oahu, Hawaiian Ids., at base of cliff, 32 fathoms (*leg.* R. Salisbury, 22-V-1976); AIM/TM-1349. PARATYPES: No. 1-same data as the holotype; AIM. No. 2—same data as the holotype; DMNH 112101. No.'s 3-5—in coll. R. Salisbury, Honolulu, from the type-locality.

Range—Known only from Maile Point, Oahu, Hawaiian Ids., in 32 fathoms.

Remarks—This is the second known species of *Mitrolumna* from the tropical Indo-West Pacific, the other being *M. stepheni* (Melvill & Standen, 1897). The Indo-Pacific *Mitromorpha lachryma* (Reeve, 1845) and *M. (Lovellona) atramentosa* (Reeve, 1849), and the Hawaiian *M. peaseana* Finlay, 1927 (= *Conus fusiformis* Pease, 1861 =

C. parvus Pease, 1868, both homonyms), also belong to the subfamily Mitromorphinae, but should be assigned to *Mitromorpha* Carpenter, since all 3 species lack the biplicate columella which is a characteristic feature of *Mitrolumna.*

Mitrolumna stepheni (M. & St.), is similar to *M. salisburyi*, but is more elongate, the axial ribs are more angulate, wider-spaced and better developed, and the axial sculpture terminates on the body whorl at the periphery where it is replaced by flattish, smooth spiral cords which commence in line with the sinus. In *M. salisburyi* the whole body whorl is nodulose with the exception of the last 3 anterior cords, and the oblique spiral cords commence in line with the first columellar fold. There are only 15-16 axial riblets on the penultimate whorl in *M. stepheni* but 24-26 in *M. salisburyi*. *M. stepheni* is coloured quite differently, being white to yellowish-fawn, ornamented with a single row of wide-spaced, dark brown spots on the penultimate whorl suture, and the dorsal side of the body whorl has a large, dilacerated, dark orange-brown blotch which intrudes partly between the interspaces of the axial ribs. *M. stepheni* also has 3½-4 conical embryonic whorls, but they are milky-white in colour and not glassy golden-brown.

Although other species of *Mitrolumna* have 1½-2½ dome-shaped embryonic whorls, *M. stepheni* and *M. salisburyi* have a protoconch of 3½-4 conical embryonic whorls, and the Galapagan *M. keenae* Emerson & Radwin, 1969, a protoconch of 3¼ whorls. The same diversity of protoconch features exists in other genera of Turridae, and a further subdivision of *Mitrolumna* on this basis alone is not warranted.

The new species is named for Mr. R. Salisbury, Honolulu, in recognition for his extensive fieldwork in the Pacific, resulting in the discovery of several new species.

ACKNOWLEDGMENTS

I would like to express my thanks to Dr. H. A. Rehder, National Museum of Natural History, Washington, for the loan of Dall's mitrid specimens, and to Mr. R. Salisbury, Honolulu, Mr. B. Parkinson, Rabaul, and Mr. J. Trondle, Papeete, Tahiti, for the loan of specimens.

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MEASUREMENTS OF VELOCITY FROM EXCURRENT SIPHONS OF FRESHWATER CLAMS[1]

Richard E. Price and **Frank R. Schiebe**[2]

ABSTRACT

In the study of trace metal accumulation and food web relationships of plankton and clams, it is important to know the volume of water passing through a clam. Water velocities from the excurrent siphon of Anodonta *sp. were measured using a hot-film anemometer and hydraulic procedures. Clam siphons were measured and volumes of water pumped were calculated. Pumping velocities for individuals, regardless of size, were nearly constant. The volume of water passing through clams was correlated with their sizes.*

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[2] Graduate Student, University of Mississippi, and Research Hydraulic Engineer, U. S. Sedimentation Laboratory, respectively.

In studying the feeding habits of freshwater clams (*Anodonta* sp.), the quantity of water passing over the gills should be known. Water is pumped in by ciliary action and passed across the gill filaments. Plankton suspended in the water is trapped on the gills to be used as food (Hart and Fuller, 1974). Allen (1914 and 1921) stated that "food particles are carried into the mantle chamber by water currents induced by cilia on the gills and are intercepted on the surface of the gills by cilia there," and that "lake mussel continues feeding at nearly all times." This would suggest that a constant stream of water is being siphoned by the clam and passed over the gills. Little is known about the velocity or the quantity of water involved in the feeding processes. Knowledge of the quantity of water being filtered and the concentration of food particles would give information relative to food delivery to the organism. To obtain this knowledge, a method was developed for measuring the velocity of water from the excurrent siphons of clams.

MATERIALS AND METHODS

The required instrumentation should meet several criteria: the measurement should be taken as near as possible to the siphon, if not inside it; the device should be sensitive and accurate enough to detect the very low currents produced by the clams; and it should not disturb the clam's natural functions. A hot-film anemometer meets these criteria.

The basic principles of the hot-film anemometers were explained by King (1914). He described the manner by which heat energy is transferred away from a heated cylinder positioned normal to a flow. The amount of heat lost from the cylinder is related to flow velocity. These principles have been applied in commercial developments in recent years, and practical instruments capable of measuring very low velocities with small sensors are available (La Barbera and Vogel, 1976).

Hot-film probes can be obtained to fit inside the excurrent siphon with little or no adverse effect on the clam and yet are accurate enough to monitor the velocity of water being ejected. The probe used in these experiments was a Thermo-Systems 1210 cylinder[3], 1 mm long and 0.05 mm in diameter. The probe was positioned with the axis of the cylinder normal to the flow, and was used in conjunction with a Disa No. 55D00 anemometer system.

The hot-film anemometer was calibrated using a small orifice facility wherein the water velocity through the orifice is related to the head difference across the orifice. A curve for velocity vs. voltage was obtained.

Four clams were obtained from Lake Washington near Greenville, Mississippi, and placed in a 38-liter aquarium containing sand. Distilled water spiked with lake water was used to simulate natural chemical conditions. Clams were allowed time to adjust and to position themselves for feeding. Water temperature during the experiment was held constant at 21° C.

Measurements of the flow into the incurrent siphon were attempted, but due to difficulties associated with the flow field into an opening, they were discontinued in favor of measuring the more uniform jet-like flow of the excurrent siphon. The probe was positioned 2 mm or less from the excurrent siphon of the clams.

The siphon length and width and shell dimensions of each clam was measured with a caliper. The cross-sectional area of each siphon was approximated by assuming the opening was elliptical. The volume of the shell was approximated by assuming an ellipsoid with axis lengths equivalent to the shell dimensions and calculating its volume.

RESULTS AND DISCUSSION

Pumping velocities for all the specimens were nearly constant, regardless of shell size (see Table 1). That no change in the velocity was detectable when the probe was repositioned within the siphon further attested to the uniformity of the flow. Thus, the mechanism by which water is moved appears to be independent of physical size.

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[3] Names of products are given for information purposes only and do not constitute an endorsement or preferential use by the U. S. Department of Agriculture or the University of Mississippi.

TABLE 1 *Physical Dimensions, Excurrent Velocity and Discharge of Clams.*

Shell size			Siphon size Excurrent			
Length cm	*Width* cm	*Height* cm	*Length* cm	*Width* cm	*Velocity* cm/sec	*Discharge* cm³/sec
5.63	2.15	2.79	0.20	0.20	11.278-11.326	0.351-0.450
7.38	3.30	1.72	0.46	0.18	10.668	0.693
10.45	4.89	6.10	0.82	0.28	12.497-13.106	2.253-2.363
11.52	5.15	7.21	0.87	0.27	12.497-13.106	2.306-2.418

Differences in the volumes of water circulated by individuals are thus related to siphon size and gill area.

Tolstikova and Orlov (1972) have shown by statistical methods that a fixed relationship exists between shell length, height, and convexity. This relationship differs in different genera and species. If the product of shell length, height, and width is proportional to the clam volume, then it also may be proportional to the gill area. This index figure could be used to determine discharge among individuals of a species. A curve showing the relationship of clam volume to discharge is presented in Fig. 1. Although there were only 4 measurements, they do indicate a definite trend.

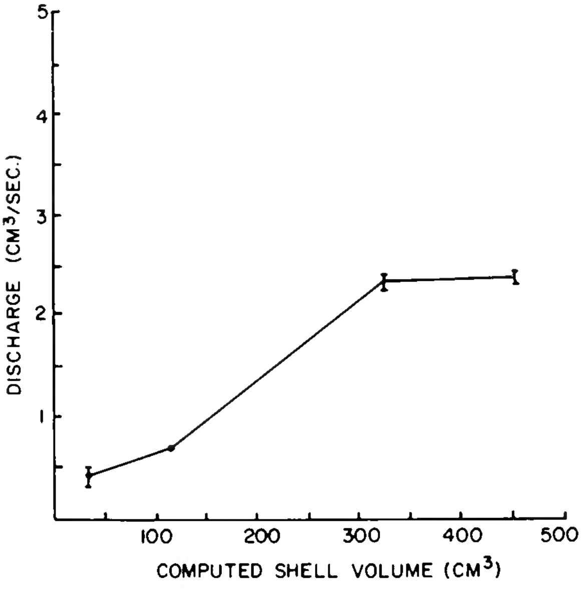

FIG. 1. *Relationship between volume of* Anodonta *clam shell and excurrent discharge.*

CONCLUSIONS

1. The hot-film anemometer is a useful and accurate means of measuring the velocity of water pumped from excurrent siphons of clams.
2. Pumping velocities for individual clams was nearly constant, regardless of their size.
3. The volume of water pumped by clams is related to their shell size.

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SIZE TRENDS IN LIVING PELECYPODS AND GASTROPODS WITH CALCAREOUS SHELLS

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ABSTRACT

I recorded the shell size of each living molluscan species having a calcareous shell in at least 10 faunas of each of the following groups: marine, freshwater, and land gastropods and marine and fresh-water pelecypods. In marine pelecypods there is a higher percentage of large-sized species in warm water than in cold water; and in the Arctic, east Greenland, Antarctic, and deep-sea faunas, no species of pelecypod attains a size of more than 100 mm. There is a larger number, but not percentage, of large-sized marine gastropods in warm water, and the range of size is greater in warm water than it is in cold water. The much more diverse marine gastropods do not have nearly so marked a trend toward larger size in warm water as do the marine pelecypods. Both the marine pelecypods and gastropods have an uncommonly high percentage of small-sized species (10 mm or less) in the Antarctic region. The freshwater pelecypods have a strong trend toward a higher percentage of large-sized species in warm water, and only the pisidiids, which are of small size, are found in regions of coldest water, as for example, Iceland and Patagonia. The freshwater gastropods also have a strong trend toward a higher percentage of large-sized species in warm water. One regional anomaly is that New Zealand has an exceptionally high percentage of small-sized species of both freshwater and land gastropods. The land gastropods show a trend toward a higher percentage of large-sized species in the lower latitudes, but it is not so pronounced as it is in the freshwater pelecypods and gastropods. The largest species of land gastropods are commonly confined to warm and moist regions.

INTRODUCTION

I recorded the size of each species of living pelecypod and gastropod having a calcareous shell in 10 or more regional faunas in each of the following groups: marine and freshwater pelecypods and marine, freshwater, and land gastropods. Little analysis of this kind has been done on invertebrates, although Bé (1968, p. 881) noted that tropical and subtropical species of planktonic Foraminiferida were generally larger than those species living in cold water, and Nicol and Martin (1976) showed that the largest calcareous benthic Foraminiferida live in warm water and the largest agglutinated Foraminiferida live in cold water. Nicol (1966) observed that a higher percentage of large-sized species of marine pelecypods live in warm water.

This type of size analysis was performed by Lindsey on poikilotherm vertebrates (1966). He recorded the size of each species from regional monographs and arranged them into size classes. Lindsey found a clear trend toward a higher percentage of large-sized species of freshwater fish in the higher latitudes or colder water. He found the same trend occurring, to a somewhat less extent, in shallow-water marine fish. Lindsey noted a geographic anomaly: in the Sea of Okhotsk the species of fish were of uncommonly small size, considering the coldness of the water in that region. Surprisingly enough, the trend toward a higher percentage of large-sized species in higher latitudes was even more marked in deep-sea fish than it was in shallow-water marine fish, but Lindsey did not specify what he meant by deep sea. The trend toward a higher percentage of large-sized species in colder climates is also well marked in all amphibians—frogs, toads, and salamanders. With the exception of the Boidae, which are largely restricted to the tropics, the snakes show a slight trend toward larger size in the higher latitudes. There is no correlation between size and latitude in either the lizards or non-marine turtles. It is interesting to note the latitudinal differences in size trends in these poikilotherm vertebrate groups from very marked, through slight, to none at all, because these differences also occur in some living invertebrate groups with calcareous shells or tests. It will also be noted that regional anomalies in size distributions occur in calcareous-shelled mollusks.

SIZE ANALYSIS

In marine pelecypods there is a higher percentage of large-sized species in warm water than in cold water, the reverse of what Lindsey found in fish and amphibians (Fig. 1). In the deep-sea pelecypod fauna (2,000 m or more in depth), and also in the east Greenland and Antarctic pelecypod faunas, no species attains a size greater than 100 mm.

The largest living species of pelecypod is the well known *Tridacna gigas* (Linné), which attains a length of 1,370 mm. The giant clam is confined to the warmest water of the western Pacific and eastern Indian Oceans (Rosewater, 1965). This distribution coincides with the region of maximum diversity of living hermatypic corals (Stehli and Wells, 1971; Newell, 1971). The Tridacnidae are all large; the smallest species reaches a size of 200 mm, and one other species of *Tridacna* attains a size of 513 mm. All species of living Tridacnidae live in the lower latitudes of the Indian and western Pacific Oceans.

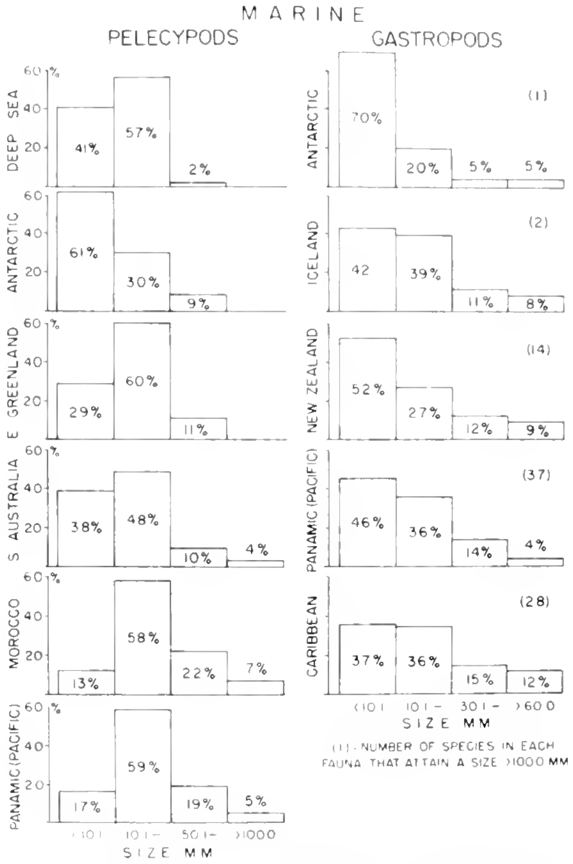

FIG. 1. *Frequency histograms showing the percentages of species in four size classes in cold- and warm-water marine pelecypod and gastropod faunas.*

The smallest pelecypods are about 1.0 mm in size, and these tiny bivalves may live in either cold or warm water. The Antarctic region has an uncommonly high percentage (61%) of species that are no larger than 10 mm. The east Greenland fauna, in contrast, has only 29% of its species no larger than 10 mm. The Antarctic pelecypod fauna has many species of the families Philobryidae and Cyamiidae (Nicol, 1967b). Species of these two families rarely attain a maximum size of more than 10 mm. These two families have many species in the Southern Hemisphere, and this partially explains why the South Australian and New Zealand pelecypod faunas have a surprisingly high percentage of species that never attain a size of more than 10 mm. Philobryids and cyamiids are absent from the

Arctic and east Greenland faunas. Many of the families which show the greatest diversity of species in deep or shallow cold water (5° C or less) never attain a large size, even where their representatives are found in warmer water. The deep-sea pelecypod fauna is dominated by protobranchs (Knudsen, 1970), which rarely attain a size of more than 75 mm.

The largest species of a genus or a family may be found in the coldest water. For example, *Limopsis marionensis* Smith is the largest living species of limopsid and occurs in the Antarctic region. The largest species of *Limatula* lives in Arctic and boreal waters.

It is interesting to compare the sizes and distributions of two superficially similar marine pelecypod families, the Limopsidae and the Glycymerididae. The latter family is commonly found in warm shallow water, but a few species live in temperate or cool-temperate water. Glycymeridids are absent from the Antarctic, the Arctic, and the deep sea. The maximum size of the largest living glycymeridid is about 125 mm, and several other species nearly attain that size. The largest limopsid is about 80 mm and almost all species attain only half that size or less. The limopsids are found mainly in the Antarctic and in deep water but are absent from the Arctic region. One method of distinguishing many species of glycymeridids from limopsids is the larger size of the species of the former family (Nicol, 1967a).

The calcareous-shelled marine gastropods have a much less pronounced trend toward having more large-sized species living in warm water (fig. 1). Furthermore, a few species of cold-water gastropods do attain a size of more than 100 mm in the Antarctic and Arctic. One species of Antarctic gastropod has been recorded attaining a size of at least 107 mm, and four species of Arctic gastropods attain a size of more than 100 mm, with a maximum size of 142 mm recorded. These larger maximum sizes for cold-water gastropods are even more surprising because the average size for marine gastropod species is considerably less than for marine pelecypod species. For every species of marine pelecypod, there are probably three species of marine gastropods, and the major increase in gastropod diversity is among the small ones of 10 mm or less in size. Table 1 is a summary of the number of species of gastropods and pelecypods in 14 marine faunas broken down into six size classes. Table 1 clearly shows that the percentage of gastropods declines as the shell sizes increase, and the reverse is true for the pelecypods. Above 50 mm there are actually more pelecypod than gastropod species, even though gastropods comprise 70% of the overall total of the six size groups. All size classes of 20.1 mm and above have less than 70% gastropod species. Among the very smallest species (5.0 mm or less), the gastropods comprise 88% in all 14 marine faunas.

There is a high percentage of small-sized species of gastropods, as compared to small-sized species of pelecypods, in both cold and warm water faunas. Of the small species in the eastern Pacific faunas at Puget Sound, southern California, and the warm-water Panamic fauna, more than 85% are gastropods. The other faunas having a higher than average percentage of small-sized gastropod species are the Arctic and the French Mediterranean faunas. Both of the coldest water faunas, the Arctic and Antarctic, have an uncommonly large percentage of gastropods of more than 50 mm as compared to pelecypod species of that size. Among species of more than 50 mm in size, the ratio of

TABLE 1 *Marine gastropod and pelecypod species placed in six size classes and the number and percentage of gastropod and pelecypod species in each size class.*

Size	Number of species	%
10.0 mm or less		
Gastropods	2,838	85
Pelecypods	512	15
10.1 - 20.0 mm		
Gastropods	1,418	75
Pelecypods	470	25
20.1 - 30.0 mm		
Gastropods	710	65
Pelecypods	390	35
30.1 - 40.0 mm		
Gastropods	406	57
Pelecypods	310	43
40.1 - 50.0 mm		
Gastropods	241	52
Pelecypods	233	48
50.1 mm or greater		
Gastropods	589	46
Pelecypods	703	54
Total of all species		
Gastropods	6,202	70
Pelecypods	2,608	30

gastropods to pelecypods is 74:26 in the Arctic and 73:27 in the Antarctic. In New Zealand and Victoria, Australia, the ratio in this large size class is 55% gastropods and 45% pelecypods. In no other regional fauna do large-sized gastropod species outnumber large-sized pelecypod species. From these data we see some regional similarities in adjacent faunas in these percentages—the uncommonly high percentage of small-sized gastropod species in the eastern Pacific faunas and the rather high percentage of large-sized gastropod species, as compared to large-sized pelecypod species, in the New Zealand and Victoria, Australia, faunas.

There is a smaller number (not percentage) of large gastropod species in cold water than in warm water, as the numbers in fig. 1 attest: one in the Antarctic, two in Iceland, 14 in New Zealand, 37 in the tropical eastern Pacific, and 28 in the Caribbean. However, the percentage of species of gastropods that attain a size of more than 100 mm in warm- and cold-water marine faunas remains nearly the same at all latitudes because of the much greater number of small-sized gastropods in the tropical faunas. Unfortunately, size data on small-sized gastropods in almost all of the diverse tropical gastropod faunas are definitely inadequate. The size ranges of warm-water gastropods are much greater than in cold-water gastropods.

The largest living marine gastropod is *Syrinx aruanus* (Linné), which reaches a length of 610 mm (Rippingale and McMichael, 1961). This maximum size is still much less than that of *Tridacna gigas*. *Syrinx aruanus* lives along the shores of Queensland and northern Australia.

Seventy per cent of all gastropod species in the Antarctic attain a size of no more than 10 mm. The New Zealand gastropod fauna also has a surprisingly high percentage of small-sized species (52%). These regional anomalies of a high percentage of small-sized species of gastropods in cold and temperate water of the Southern Hemisphere are like those found in the marine pelecypods.

The size trend toward a higher percentage of large-sized species in warm water is much more pronounced in marine pelecypods than it is in marine gastropods, perhaps because the pelecypods are a much simpler and less diverse group, and their size is affected by fewer biological factors. Almost all marine pelecypods can be considered either suspension or deposit feeders. The suspension feeders are by far the more common, and all of the truly large pelecypods are suspension feeders. The protobranchs are all deposit feeders, and the largest living species attains a length of only 107 mm. Among the deposit-feeding tellinaceans (the Semelidae and the Tellinidae), one species of tellinid attains a size of about 116 mm. All other species belonging to the semelids and tellinids are small (Nicol, 1964). On the other hand, the much more diverse gastropods have a wide variety of feeding habits. Besides deposit and suspension feeders, some gastropods are carnivores, others are herbivores, and still others are parasites. These three other modes of feeding would certainly have some effect on the size the animal would need to attain in order to be successful in its particular niche or feeding habit. Thus, while the size of marine pelecypods is affected chiefly by temperature, the size of marine gastropods is affected by other factors as well, with the result that a greater range of gastropod sizes is found in cold water.

By far the two most common groups of fresh-water pelecypods are the naiades and the pisidiids. The naiades are seldom less than 25 mm, are commonly more than 100 mm, and may attain a size of 280 mm. The pisidiids are small, but a few species reach medium size (25 mm). The naiades attain almost as large a size in temperate fresh-water as they do in warm fresh-water. Naiades are not found in the regions where the water is coldest. For example, only pisidiids occur in Patagonia or south of the Rio Negro in Argentina. As one goes northward from the Rio Negro to the La Plata River, the number of species of naiades increases (Pilsbry, 1911, pp. 513-514). The only fresh-water pelecypods in Iceland are four species of pisidiids (Mandahl-Barth, 1938). As further proof of the distribution of these two groups of pelecypods, one has only to look at the distribution maps of the fresh-water pelecypods of the Canadian interior basin (Clarke, 1973). Almost no species of naiades are found as far north as 60° north latitude, but many species of pisidiids occur north of that latitude, and some range as far north as 70° north latitude. There is a clear trend of a higher percentage of large-sized

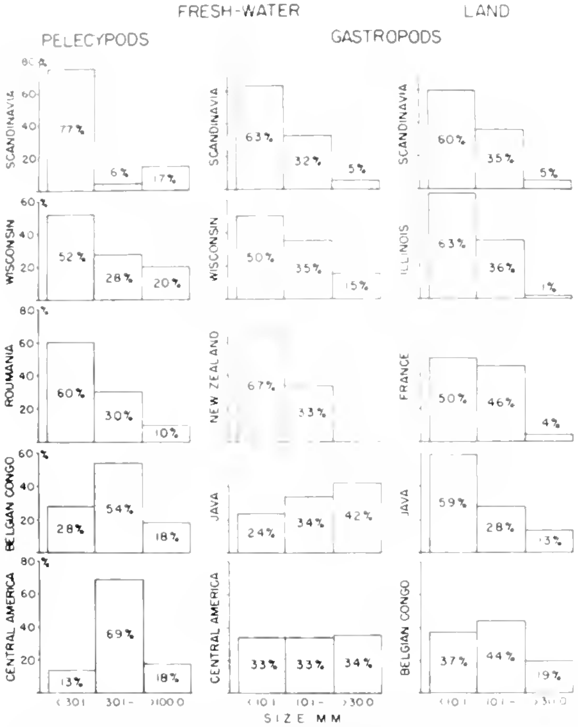

FIG. 2 *Frequency histograms showing percentages of species in three size classes in freshwater pelecypod and gastropod faunas and land gastropod faunas.*

freshwater pelecypods living in warm water as shown in Fig. 2.

There is at least one regional anomaly. It is the uncommonly high percentage of naiades, which attain a large size, found in Wisconsin as compared to Scandinavia. The central and eastern United States is noted for its diverse naiad fauna.

A major problem in getting adequate faunal data is that some large islands have surprisingly few species of freshwater pelecypods: New Caledonia has only one species, New Zealand has only eight, and Java has sixteen.

Freshwater gastropods are generally smaller than freshwater pelecypods. The maximum size of any freshwater gastropod is about 200 mm. The following table (Table 2) is a summary of 12 freshwater molluscan faunas comparing the percentage of gastropods and pelecypods in six size classes. Although the ratio of total numbers of gastropod species to pelecypod species is approximately the same in freshwater as it is in the seas, the ratio in some size classes is quite different. From Table 2 one can see that there is little change from the smallest size class up to 30 mm. Above this size, the percentage of pelecypods increases rapidly, and above 50 mm the pelecypods comprise 81% of the molluscan species in all of the faunas. The rather steady increase in pelecypod percentages in all size classes in the marine faunas is not seen in the freshwater pelecypods. In the coldest freshwater molluscan faunas analyzed, there is a low percentage of small-sized species (10 mm or less) of gastropods as compared to small-sized pelcypod species. Wisconsin has only 53% small-sized gastropod species, Scandinavia 65%, and Czechoslovakia 69%. All other regions analyzed had 76% or more small-sized species of freshwater gastropods. No other size trends were seen in the ratios of gastropods to pelecypods in freshwater.

The largest freshwater gastropods are found in the tropics, and, unlike the marine gastropods, the freshwater representatives show a clear trend toward larger size in warm water. One regional anomaly is the high percentage of small freshwater gastropods in the New Zealand fauna, as seen in Fig. 2.

TABLE 2. *Freshwater gastropod and pelecypod species placed in six size classes and the number and percentage of gastropod and pelecypod species in each class.*

Size	Number of species	%
10.0 mm or less		
Gastropods	662	80
Pelecypods	169	20
10.1 - 20.0 mm		
Gastropods	288	82
Pelecypods	63	18
20.1 - 30.0		
Gastropods	155	82
Pelecypods	33	18
30.1 - 40.0 mm		
Gastropods	109	73
Pelecypods	40	27
40.1 - 50.0 mm		
Gastropods	50	52
Pelecypods	47	48
50.1 mm or greater		
Gastropods	69	19
Pelecypods	295	81
Total of all species		
Gastropods	1,694	69
Pelecypods	755	31

Calcareous-shelled land gastropods tend toward large size in the tropics, but the trend is not as pronounced as in the freshwater gastropods and pelecypods. The giants among land snails are the Achatinidae, and they are endemic to Africa south of the Sahara. Maximum size of a species of achatinid is about 200 mm. The Achatinidae thrive in warm and moist regions, and such areas as the Belgian Congo have a high percentage of large-sized species of land gastropods because this family has many species living there. Small- to medium-sized land gastropods predominate in arid regions, such as Algeria and Western Australia, and, surprisingly, they also predominate in New Zealand, which is not arid. Perhaps the large number of small- to medium-sized land gastropods in the fauna of New Zealand can be accounted for by aerial dispersal by wind and birds. Vagvolgyi (1976) points out that on Pacific islands the land snails are commonly less than 10 mm in size and that the dispersal of these gastropods is by aerial means to these remote islands. This may also be a factor in the distribution of small-sized freshwater gastropods and pelecypods.

In each of the 13 faunas studied, the land gastropods have about the same size range and maximum size as the freshwater gastropods in the same region. The average ratio of land snails to freshwater snails is 79:21 in the three smaller size groups (30 mm or less) and 67:33 in the larger size groups.

The range in size within a group of animals is considered by ecologists to be a factor in diversity because two species that differ considerably in size are not in direct competition with one another. The ratio of the largest species to the smallest species, or absolute size ranges, is shown in Table 3 for the marine pelecypods and gastropods, the freshwater pelecypods and gastropods, and the land gastropods. The marine pelecypods have a somewhat greater size range than the marine gastropods but are actually a much less diverse group. The main cause for the greater size range in the marine pelecypods is the exceedingly large size of one species, *Tridacna gigas*, which is more than twice as large as any other living marine pelecypod. Although the size of the largest species of freshwater pelecypod is greater than the largest species of freshwater gastropod or land gastropod, the ratio of largest to smallest species of freshwater pelecypod is less than it is in the freshwater gastropods and land gastropods. This may be one of the reasons why the freshwater and land gastropods are more diverse than the freshwater pelecypods.

TABLE 3. *The size range of each of the groups of living species studied and the ratio of these ranges.*

Groups	Largest species	Smallest species	Ratio
Marine pelecypods	1,370 mm	1.0 mm	1,370:1
Marine gastropods	610 mm	0.5 mm	1,220:1
Freshwater pelecypods	280 mm	1.6 mm	175:1
Freshwater gastropods	200 mm	1.0 mm	200:1
Land gastropods	200 mm	1.0 mm	200:1

SPECIES DIVERSITY

As a by-product of the study on size trends, some data on diversity were gleaned from an enumeration of all of the species in each fauna. In Table 1 it can be seen that gastropods comprise 70% of all calcareous-shelled species of gastropods and pelecypods in the 14 marine faunas. This would be a ratio of seven gastropod species to three pelecypod species. No regional trends could be discerned within the 14 marine faunas, but it is obvious from the data that most of the small species of warm-water gastropods were inadequately covered.

The total in Table 2 of all species of freshwater gastropods and pelecypods shows that freshwater gastropod species outnumber freshwater pelecypod species approximately seven to three, the same as in the marine faunas. Of the 12 freshwater molluscan faunas analyzed, only the Wisconsin fauna had a greater number of pelecypods than gastropods because of the large number of naiad species in this fauna. The areas of low annual rainfall seem to have a lower average percentage of pelecypods, as for example, Algeria with only 21% pelecypod species. Besides many large islands, some of the continental regions have a surprisingly low number of freshwater pelecypod species—Algeria 17, South Africa 16.

In the 13 land and freshwater gastropod faunas analyzed, there is a ratio of 39 land-gastropod species to 11 freshwater gastropod species. This, of course, excludes the land slugs, which would make this ratio slightly higher in favor of the land gastropods. New Zealand has an impoverished freshwater molluscan fauna. The freshwater species of pelecypods were mentioned earlier, but there are also only 27 living species of freshwater gastropods, which comprise only 8% of the non-marine gastropod species of New Zealand. In the non-marine gastropods of British India, 84% are land species and only 16% are freshwater species. These are the two most exceptional deviations from the normal percentages of land and freshwater gastropod species in the 13 faunas analyzed.

After comparing the number of species of marine, freshwater, and land gastropods and marine and freshwater pelecypods in more than 30 well documented faunas, I now believe that my estimate of 107,000 living species of mollusks is too high (Nicol,1969). The estimate given by Boss (1971) of 46,810 living species is probably nearer the truth. My main reason for believing this is based on the surprisingly small number of freshwater pelecypods on some large islands and even on some large continental areas. To a lesser extent, this is also true of the freshwater gastropods. Several years ago Dr. J. P. E. Morrison told me of his estimate that there are no more than 2,000 living species of freshwater pelecypods. I am inclined to believe that even this figure is too high and that perhaps 1,500 living species of freshwater pelecypods is a more accurate estimate. Taking 1,500 living species as a base, there would then be about 3,500 living species of freshwater gastropods, using the seven to three ratio shown in Table 2. In this way one could estimate the number of living land gastropods from the freshwater gastropod estimate. Also, one could estimate the number of marine gastropods from an accurate count of the marine pelecypod species.

CONCLUSIONS

It has been noted that broken sea urchin spines are regenerated or calcified more rapidly when these animals are placed in warm water (Davies *et al.*, 1972). Calcium carbonate is more readily obtainable in warm water by animals needing it for skeletal material, and the metabolism of these animals increases at higher temperatures, thus utilizing calcium carbonate more rapidly. This at least partially explains the trend toward larger size at warm temperature in most animal groups that use calcium carbonate.

Besides the physical factors affecting size trends in the groups analyzed herein, there are biological factors that alter a particular trend locally and bring about regional anomalies. One of these biological factors is genetics. It seems obvious that the naiades have genes for large size whereas the pisidiids have genes for small size. Geographic distribution and regional diversity are also important factors. As an example: the central and eastern United States has an uncommonly high diversity of naiades, giving these faunas in temperate freshwater an unusually high percentage of large-sized species of pelecypods. In northwestern Europe the naiad fauna is not nearly so diverse even though the freshwater in this region is no colder than it is in parts of the United States. Ecological factors are also important. Many suspension feeders attain a large size, whereas parasites and many commensals are small. Amongst the pelecypods, there are relatively few species of commensals and apparently no parasites. The erycinacean pelecypods are generally commensals and are among the smallest-sized marine species. The marine gastropods, on the other hand, have a large number of parasitic species and commensal species. This is undoubtedly an important reason why there are so many more small-sized marine gastropods than pelecypods. These biological factors that we see occurring today were likewise operating throughout at least the Phanerozoic to a considerable degree. This explains why we see some fossil marine faunas that have an uncommonly high percentage of small-sized or large-sized species.

Besides sorting by wave and current action and other physical factors, we must bear in mind the biological factors as well. Therefore, we must know something of the life habits, the size range of the genus or family, and the geographic distribution of each group represented in the fossil fauna, because in certain regions biological factors may be more important than physical factors in determining the sizes of species in a particular fauna.

RELIABILITY OF THE DATA

In analyzing a fauna, it is most important to know the group well in order to evaluate the reliability of the data taken from each faunal monograph and also to avoid the pitfall of incomplete coverage of the group in a specific region. All too commonly the title of a paper fails to indicate that the coverage is not complete. For example: I found a monograph on freshwater pelecypods of Australia that seemed to suit my purposes perfectly; but after recording the size of all the species, I found that the monograph covered only the naiades, all of which are of medium to large size. If I had relied on this paper, I would have come to the erroneous conclusion that there are no small-sized species of fresh-water pelecypods in Australia. I found that older faunal monographs should generally be avoided, if there is a more recent treatment of the same group in the same region. The older faunal monographs frequently have two drawbacks: (1) the coverage of the group is not exhaustive, particularly the small-sized species; (2) the large-sized species, at least of the naiades, are commonly split too much.

Some monographers do not adequately cover the small-sized species. However, I feel that the marine pelecypod data are reliable because most marine pelecypods are not small. I also feel confident that the freshwater pelecypod data are reasonably ac curate. The marine gastropod data are less accurate. Small-sized gastropods in warm-water marine faunas are poorly covered and frequently the descriptions include no accurate information on size. In some of these instances, the size group of the species can only be estimated. I am less certain of the absolute accuracy of the size data of the freshwater and land gastropods because of my lack of knowledge of these groups.

In some instances I had to take size data that were not in the metric system and convert them. Fractions of inches are not so accurate as measurements in millimeters, and there is also the possibility of error in the process of conversion from inches to millimeters.

Some of the references that were first analyzed were later discarded as untrustworthy or repetitious. Only those publications used in the final analysis of the data are listed in the references at the end of this paper.

It is imperative that a taxonomist do this kind of analysis because the taxonomist has the kind of experience and knowledge that is necessary to evaluate the reliability and completeness of the basic data.

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STATUS OF *EULIMA SUBCARINATA* ORBIGNY, 1842 AND *E. CAROLII* DALL, 1889 (GASTROPODA: MELANELLIDAE)[1]

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ABSTRACT

Eulima subcarinata *Orbigny, 1842, is redescribed and transferred to the genus* Eulimostraca *Bartsch, 1917. The species occurs from the Caribbean and Yucatan to intermediate-depth shelf waters off Florida and North Carolina. Confusion regarding the species' identity is discussed.* Eulima carolii *Dall, 1889 (formerly* affinis *C. B. Adams, 1850, non Philippi, 1844) is considered a* nomen dubium.

Orbigny (1842) introduced the name *Eulima subcarinata* for a small melanellid from Guadeloupe, West Indies. Among the characters included in his Latin description (1845) were "*anfractibus octonis. . . linea fulva ornatis, ultimo subcarinato*", expanded in French (1853) as "*le dernier [tour] un peu caréne en avant. . . Couleur. Blanc uniforme avec une légère bande jaunâtre ou fauve sur la partie carénéé antérieure.*" His illustrations (1842, pl. XVI, Figs. 4-6) were somewhat schematic, depicting a shell of typical, unornamented melanellid form but with a peripheral line suggesting a low carina on the last whorl.

Mörch (1875) reported the species from St. Thomas [Virgin Islands]; and Dall (1889a) extended the range to the southeastern United States. No subsequent records have appeared, although the name has been continuously used in compilation lists of western Atlantic marine mollusks.

I recently examined the holotype of *Eulima subcarinata*, presently in the British Museum of Natural History [BM(NH)]. The shell (Fig. 1a),

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[1] Contribution no. 316, Florida Department of Natural Resources, Marine Research Laboratory.

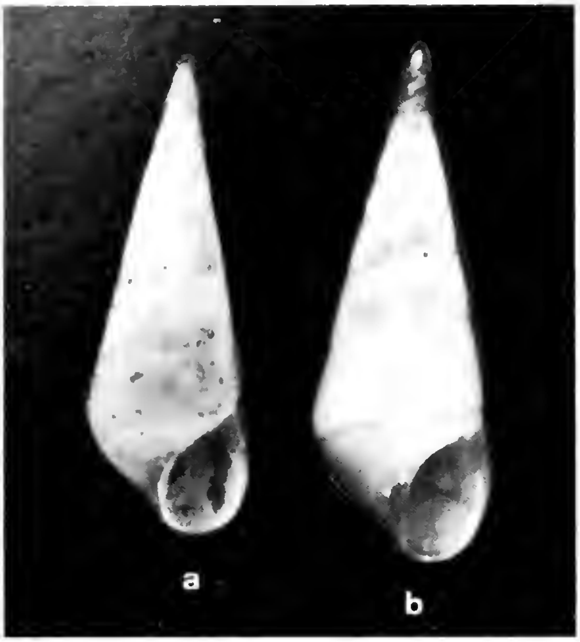

FIG 1. Eulimostraca subcarinata *(Orbigny, 1842)* **a.** *holotype, 3.1 mm, Guadeloupe;* **b.** *adult shell, 3.4 mm, off Egmont Key, Florida, FSBC I 10886 (both ×20).*

although faded, badly worn, and possessing a large hole drilled by another gastropod on the back side of the penultimate whorl, agrees in all other respects with Orbigny's description. It is conspecific with others from U. S. Fish Commission (USFC) collections in the National Museum of Natural History (USNM), Washington, D.C., and additional shells in the Delaware Museum of Natural History (DMNH), Greenville, Delaware, and the Florida Department of Natural Resources Marine Research Laboratory (FSBC I), St. Petersburg, Florida. These specimens have allowed a more complete description of the species and better understanding of its phylogenetic position and its geographic and bathymetric range. In addition, some of the specimens create doubt regarding the accuracy of Dall's (1889a) treatment of several melanellids from the southeastern United States.

Eulimostraca subcarinata (Orbigny, 1842)

new combination

(Figs. 1a, b)

Description: Shell small, length to about 3.6 mm, straight, glossy, with evenly tapering, slightly convex whorls. Protoconch extremely sharp, slender, of about 3½ whorls, merging almost imperceptibly with spire. Teleoconch with about 6½ smooth, slightly convex whorls; central portion of each whorl light golden brown, with a thin, brown spiral line at each suture; periphery of body whorl rounded, with a distinct brown spiral line. Aperture about ¼ shell length, broadly ovate, rounded but not extended anteriorly, slightly attenuated behind; posterior half of outer lip brown, color diminishing anteriorly at termination of peripheral line; inner lip dark brown, curved, thickened, forming a shallow, narrow umbilical depression.

Material examined: HOLOTYPE: BM(NH) Reg. no. 1854. 10.4.141, cat. no. 129; 1 dead, length 3.1 mm, Guadeloupe. NORTH CAROLINA: 1 dead, USFC sta. 2597, south southwest of Cape Hatteras, 27 m (USNM 97516); 2 dead, USFC sta. 2598, south southwest of Cape Hatteras, 40 m (USNM 94570); 1 dead, 3.2 mm, USFC sta. 2608, off Cape Lookout, 40 m (USNM 83274); 1 dead, USFC sta. 2608 (same) (USNM 94803); 5 dead + 1 fragment, 2.0-2.5 mm, USFC sta. 2608 (same) (USNM 97530); 1 dead, 3.3 mm, USFC sta. 2610, southeast of Cape Lookout, 40 m (USNM 92810); 1 dead, USFC sta. 2610 (same) (USNM 97515); 3 dead, USFC sta. 2611, southeast of Cape Lookout, 57 m (USNM 92809). FLORIDA: 1 dead, RSP sta. 003, 28° 37′ N, 80° 11.2′ W, off Cape Canaveral, 40 m, January 16, 1973 (FSBC I 11177); 2 dead, RSP sta. 003 (same), November 2, 1973 (FSBC I 11178); 6 dead, RSP sta. 003 (same), November 5, 1974 (FSBC I 11179); 1 dead, south of Dry Tortugas, 192 m (DMNH 114557); 4 dead, 2.6-3.1 mm, west of Naples, 55 m (FSBC I 15030); 1 dead, Hourglass sta. K, 26° 24′ N, 82° 58′ W, off Sanibel Island, 37 m, November 14, 1967 (FSBC I 10885); 1 dead + 5 fragments, Hourglass sta. L, 26° 24′ N, 83° 22′ W, off Sanibel Island, 55 m, September 5, 1966 (FSBC I 10884); 1 dead, 60 mi (97 km) west southwest of Johns Pass, 68 m (DMNH 114556); 4 dead, south southwest of Johns Pass, 62 m (DMNH 114553); 1 dead, 3.6 mm, west southwest of Johns Pass, 46 m (DMNH 114552); 2 dead, 3.3-3.4 mm, Hourglass sta. B, 27° 37′ N, 83° 07′ W, 18 m, November 2, 1967 (FSBC I 10886); 2 dead, Clearwater Beach (DMNH 114555). MEXICO: 1 dead, northeast of Contoy Light, Yucatan, 119 m (DMNH 114554).

Range: Off North Carolina, both coasts of Florida, and Yucatan, 18-192 m; St. Thomas (?) and Guadeloupe, West Indies.

Remarks: Orbigny's species belongs to the genus *Eulimostraca* Bartsch, 1917, a group of small melanellids with slender, acute apices, flattened to slightly rounded whorls, broadly ovate apertures, and brown markings on the shell. Keen (1971) listed two eastern Pacific species, including *E. galapagensis* Bartsch, 1917, the type species of *Eulimostraca*. This species is quite similar to *E. subcarinata*, but apparently has more slender anterior whorls and lacks brown marking on the columella or inner lip. *Eulimostraca bartschi* Strong and Hertlein, 1937, from Mazatlan, west Mexico, lacks a brown spiral line and is considerably smaller, having nine whorls in a total length of only 1.8 mm. No western Atlantic species have been previously assigned to *Eulimostraca*, but several evidently belong here, including *Eulima hemphillii* Dall, 1884 (subsequently placed in *Leiostraca*, *Melanella*, and *Strombiformis* by various authors), and several other species, presently undescribed, which occur in the Bahamas and off both Florida coasts.

Shell color and peripheral markings of *E. subcarinata* (Fig. 1b) are strikingly like those of *Niso aeglees* Bush, 1885. The two species occur together throughout at least the continental range of *E. subcarinata*, but can hardly be confused. The shell of *Niso aeglees* is larger, broader, and strongly umbilicate.

The holotype of *Eulima subcarinata* is a nearly mature shell still bearing suggestions of the angled periphery common on juveniles of many melanellid species. This feature is probably the source of Orbigny's description of peripheral carination, for fully mature adults lack such angulation. Tryon (1886) reported the last whorl to be "obtusely carinated", but his illustration (pl. 69, Fig. 44) depicted a shell with both a peripheral carina and numerous well defined axial striae nearly the size of riblets, the latter character unknown on any western Atlantic melanellid. It is quite dissimilar from Orbigny's illustration and from the holotype.

Dall (1889a) briefly reviewed the West Indian Eulimidae (=Melanellidae). He did not mention Tryon's figure of *E. subcarinata*, but assigned another on the same plate (pl. 69, Fig. 36) to that species. Tryon had assigned that figure to *E. oleacea* Kurtz and Stimpson, 1851, but Dall stated it was not appropriate for that species. The figure is too small and imprecise to be assigned with certainty to either species. Dall also extended the range of *E. subcarinata* from the Antilles to Florida and [Cape] Hatteras, but his concept of this "carinate" species may have been influenced incorrectly by Orbigny's description and Tryon's later error. All USNM specimens designated *E. subcarinata* by Dall have proved, upon inspection, to be worn shells of various other melanellids, usually with the lip broken back to produce a "carina" on the penultimate whorl.

C. B. Adams (1845) described *Eulima jamaicensis*, and soon thereafter (1850) described five additional melanellid species *(E. affinis, E. arcuata, E. conica, E. fulvocincta,* and *E. gracilis)* from Jamaica. Dall (1889a) recognized *arcuata*, *gracilis*, and *jamaicensis* as valid species, synonymized *fulvocincta*, and proposed a new name for *affinis*, pointing out that Adams' name was preoccupied by *Eulima affinis* Philippi, 1844. He renamed Adams' species *Eulima carolii*. Dall suggested that he had examined the types of *arcuata* and *jamaicensis*, and evidently had access to Adams' specimens of *conica* and *fulvocincta* as well (Lyons, 1977), but there is no evidence to indicate he had seen Adams' type of *affinis*.

Dall's concept of Adams' *affinis* was apparently incorrect. He (1889a) applied most Adams' names to other specimens of western Atlantic Melanellidae, identifying eight lots as *E. carolii* and redefining its range to include "Florida to North Carolina, in 8-63 fms" (15-105 m). Dall's *carolii* material actually contains several species, with most specimens in very poor condition. Five of the lots, all USFC collections from off North Carolina, contain *Eulimostraca subcarinata*. However, neither his 15-meter nor his 105-meter lot, from which he established the bathymetric range of *carolii*, contain *subcarinata*. The type of *affinis* Adams is missing (Clench and Turner, 1950), but its description fits none of Dall's material especially well. Adams' description of *affinis* was brief, being a comparison of several characters separating it from *Eulima conica* which he described on the same page. He noted *E. conica* to be white; by inference, this must apply to *affinis* as well, demonstrating that the brown-marked *subcarinata* specimens are not *carolii*. Apparently, none of Dall's material is actually *carolii*, and his records should be rejected. Until Adams' type is located, the name should be considered a *nomen dubium*. To my knowledge, no subsequent specimens of *E. carolii* have been reported, although the name has appeared on several faunal lists (Dall, 1889b; Johnson, 1934; Abbott, 1974) repeating Dall's information.

Identity of specimens Dall (1889a: p. 329) mentioned "with brown varices and a brown peripheral line, which I have only fragments insufficient fully to characterize" is uncertain. He was probably referring to three additional unidentified lots of USFC material also containing *E. subcarinata*, but none of these shells have brown varices (areas of arrested shell growth where color markings sometimes occur on melanellids). *Eulimostraca subcarinata* lacks such markings. It is possible that Dall's remark referred to the brown marking on the posterior portion of the outer lip of *E. subcarinata*, but there is only one such marking per shell on that species, whereas Dall implied more than one brown varix. At least one of the undescribed south Florida *Eulimostraca* has brown varices, but it lacks a peripheral line. Moreover, I found no specimens of that species in collections available to Dall.

Mörch's (1875) record of *E. subcarinata* from St. Thomas must remain in question until the specimens are examined. It could have been *Eulima auricincta* Abbott, 1958, a shell of similar size, with a slightly angled periphery on the penultimate whorl and bearing a brown or golden band on each whorl. The latter is common in beach drift throughout the northern Caribbean.

Beached specimens of *Eulimostraca subcarinata* are rare; I have seen only the lot from Clearwater Beach, Florida (DMNH 114555), although Orbigny's type and Morch's record, if correct, may have been similarly obtained. In the southeastern United States, the species is evidently most common along the intermediate portion of the continental shelf in depths of about 18 to 62 m. Such occurrence often indicates northern submergence of shallow-water Caribbean species, but I have not seen *E. subcarinata* among many melanellids from shallow collections in the Florida Keys and Bahamas. I have examined only single juveniles (1.6, 1.8 mm), from off Dry Tortugas and Yucatan respectively, taken from depths greater than 62 m, suggesting that adult populations may not occur at greater depths.

ACKNOWLEDGMENTS

Ms. Kathie Way, British Museum (Natural History), London, kindly loaned the holotype of Orbigny's species. Dr. Joseph Rosewater, Curator of Mollusks, National Museum of Natural History, Washington, D.C., provided access to those collections and later loaned material; he and fellow staff members provided many courtesies during my visit there. Mrs. Barbara Steger, Tampa, Florida, and later Dr. R. Tucker Abbott, both provided material from the Steger collection, now at the Delaware Museum of Natural History. Mrs. Sally D. Kaicher, St. Petersburg, photographed the figured specimens. Dr. Anders Waren, University of Göteborg, Sweden, is thanked for discussions regarding identities of Florida and Caribbean Melanellidae. Dr. Donna D. Turgeon and Mr. David K. Camp kindly read the manuscript. All are gratefully acknowledged.

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HEBETANCYLUS EXCENTRICUS (MORELET) (PULMONATA: ANCYLIDAE) IN LOUISIANA AND A REPORT OF SEPTUM FORMATION

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ABSTRACT

Hebetancylus excentricus *is first reported from Louisiana where it is widely distributed in shallow ponds and streams in the southeastern part of the state. An 18-month survey of one population revealed polymorphism with certain individuals forming a septum, which partially closed the shell aperture. Septum formation, not previously reported for the species, was of seasonal occurrence.*

The freshwater limpet *Hebetancylus excentricus* has a Caribbean distribution, but has been reported in North America from southern Florida and coastal Georgia (Basch, 1963), south-central Texas (Pilsbry, 1889; Walker, 1903), north central Texas (McMahon and Aldridge, 1976), and southern Oklahoma (McMahon *et al.*, 1976).

H. excentricus is here reported to be widely distributed on emergent vegetation in shallow streams and ponds in southeastern Louisiana, where it often occurs sympatrically with the other ancylids, *Laevapex fuscus* and *Ferrissia fragilis*. *H. excentricus* probably has an interrupted Gulf Coast distribution occurring in enclaves where suitable ecological conditions exist.

Louisiana habitats differ from those reported for other North American populations. Basch (1963) reported their occurrence on floating and deep submerged debris in canals and ditches, while McMahon and Aldridge (1976) collected them on the surfaces of rocks in fast flowing streams.

Richardot *et al* (1972) reported that under certain undetermined environmental conditions, and among certain individuals in populations of the European ancylid, *Ferrissia wautieri*, peripheral shell growth ceased and a septum or thin horizontal calcareous shelf was formed. This septum, which was deposited by the posterior margin of the mantle and was of the same composition and crystalline structure as the shell, partially closed the aperture. Later, when

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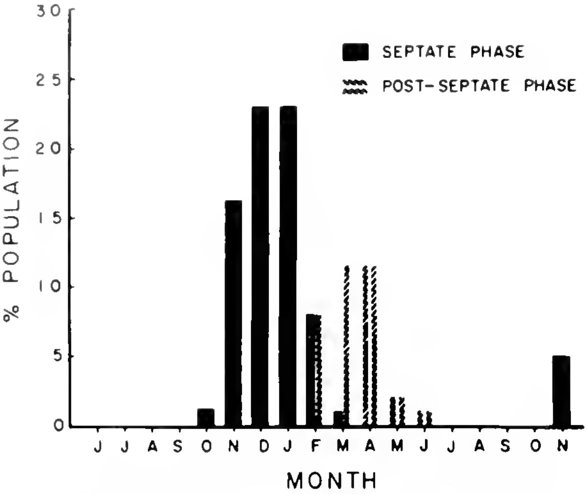

FIG. 1. *Percent* Hebetancylus excentricus *population in either septate or post-septate phases.*

peripheral shell deposition resumed, growth was from the margin of the constricted aperture and resulted in what Parodiz (1957) called the "post-septate" stage.

North American septate ancylids were assigned to the genus *Gundlachia;* however, Basch (1963) concluded that they were referable to the genus *Ferrissia.* He also noted that habitats for septate *F. fragilis* were temporary roadside ditches and woods pools, both of which dried up during part of the year. Septum formation has not been reported for *H. excentricus.*

FIG. 2. Septate Hebetancylus excentricus *exhibiting various degrees of septum formation. Scale in mm.*

FIG. 3. *Post-septate* Hebetancylus excentricus. *Scale in mm*

From June 1975 through November 1976, a survey of an *H. excentricus* population was conducted at a small stream on the Louisiana State University Sheep Farm, East Baton Rouge Parish, southeastern Loiusiana (30° 22′ 11″ N, 91° 11′ 39″ W). Collections were made twice monthly, once during the first week and again during the third week of each month. Data from both collections were pooled. A total of 3,700 *H. excentricus* were removed from leaves and stems of alligator weed, *Alternathera* sp., and taken to the laboratory for study.

In October 1975 septate *H. excentricus,* which were anatomically identical in "soft-parts" to the non-septate forms, appeared in the population. By December and January they comprised 23% of the population (Fig. 1). In February there occurred a decline in septate forms accompanied by a transition from septate to post-septate phase (Figs. 2 and 3). This phase persisted in the population until July and was replaced by non-septate forms. During November 1976, the last month of the study, septate forms reappeared with 5% of the population involved.

The septum may serve as a functional epiphragm permitting limpets to aestivate and survive desiccation (Boss, 1974). However, it should be noted that at no time during the study did the water level in the stream approach drought conditions, thus suggesting another unknown reason for septum development.

Voucher specimens of septate *H. excentricus* have been deposited in the Delaware Musuem of Natural History (DMNH 108368).

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FUSINUS STEGERI (GASTROPODA: FASCIOLARIDAE), A NEW SPECIES FROM THE EASTERN GULF OF MEXICO[1]

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ABSTRACT

Fusinus stegeri *n. sp. from 100-205 fms (183-375 m) depths off western Florida differs from* F. eucosmius *(Dall, 1889) by its greater length (to 102 mm), white color, and diminishing strength of axial ribs on anterior whorls.* Fusinus eucosmius *is known only to depths of 89 fms (162 m). Twenty-six other names applied to western Atlantic* Fusinus *are listed.*

Commercial shell dredging during the past several years has resulted in increased availability of many deep water west Florida mollusks. A species of *Fusinus* common among private shell collections is here described. Specimens of the new species are deposited in collections of the Academy of Natural Sciences of Philadelphia (ANSP), Pennsylvania, the American Museum of Natural History (AMNH), New York, New York, the British Museum (Natural History) (BMNH), London, the Museum of Comparative Zoology (MCZ), Cambridge, Massachusetts, the National Museum of Natural History, Smithsonian Institution (USNM), Washington, D.C., and the Florida Department of Natural Resources Marine Research Laboratory (FSBC I), St. Petersburg.

Fusinus stegeri, *new species*

(Figures 1-5)

Description: Shell large, to at least 102 mm total length, slender, fusiform, with about 13 whorls. Embryonic whorls about 2½, small, elongate, flattened apically, with only slightly convex lateral margins; last half whorl with strong axial riblets. Nearly 11 postembryonic whorls bearing prominent, swollen axial ribs, increasing numerically but decreasing in strength anteriorly; first five spiral whorls with 6 or 7 ribs, sixth whorl nearly always with 7 ribs, seventh with 8-10, eighth with 9-13, ninth with 10-14, and tenth with 13-16 ribs. Spiral whorls rounded, with strongly convex sides and constricted sutures; each whorl crossed by 6-8, usually 7, prominent spiral cords. About 10 or 11 strong cords on body whorl, 9-12 on base, sometimes with weaker cords between. Aperture ovate, slightly constricted anteriorly and posteriorly; parietal callous extended, forming sharp, thin lamina (inner lip) along columellar border of aperture; lamina sometimes present but reduced along columellar zone of anterior

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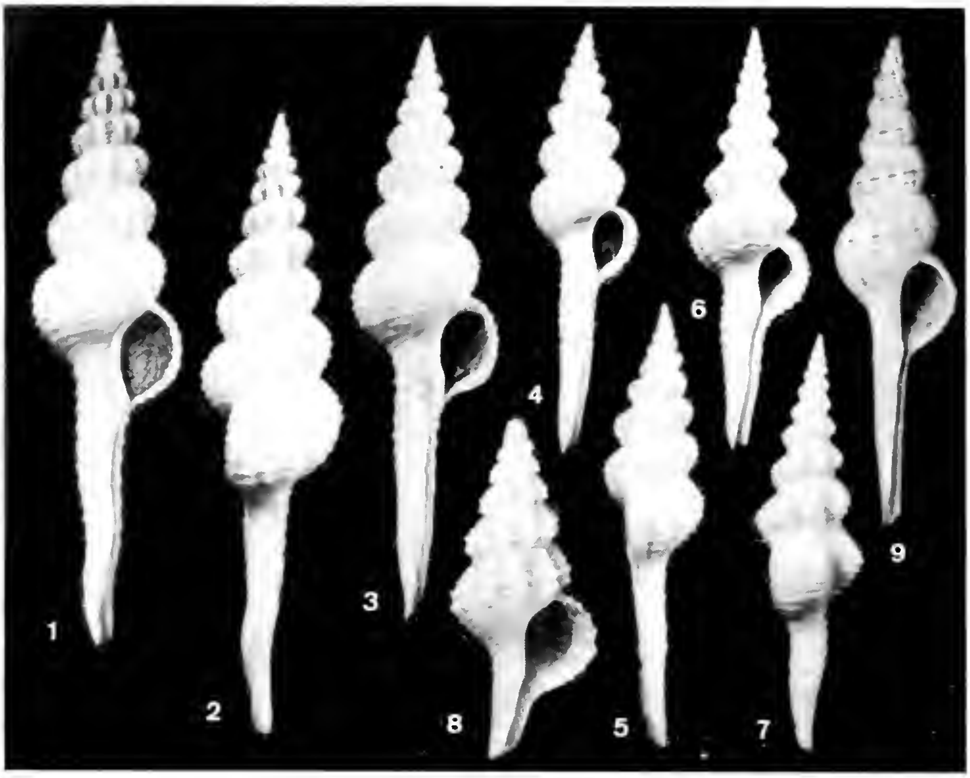

FIGS. 1-9. *Western Atlantic* Fusinus: **1.** F. stegeri, *n. sp., holotype, 102 mm, USNM 749082;* **2.** *same, lateral view;* **3.** F. stegeri, *paratype, 97 mm, BMNH 197810;* **4.** F. stegeri, *paratype, 70.4 mm, ANSP 345472;* **5.** *same, lateral view;* **6.** F. eucosmius, *73.8 mm, Hourglass Sta. C, 27° 37′ N, 83° 28′ W, depth 37 m, FSBC I 2284;* **7.** *same, lateral view;* **8.** F. amphiurgus, *holotype, 14 mm, USNM 508725;* **9.** F. halistreptus, *holotype, 80 mm, USNM 93333.*

siphonal canal; one or two small teeth at inner, posterior portion of parietal callus, obsolete in largest shells; inner surface of outer lip with 14-18 simple, usually paired lirae or teeth. Base and anterior siphonal canal slender, about half total length of shell. Operculum thick, rough, corneous, of same size and shape as aperture. Shell white, commonly stained gray posteriorly.

Holotype: Length 102.0 mm, Gulf of Mexico off Sarasota, Florida, 183 m (USNM 749082).

Other material: 3 paratypes, 42.9-84.9 mm, west of Dry Tortugas, 183 m (FSBC I 15028); 1 paratype, 97.0 mm, same data (BMNH 197810); 1 paratype, 80.0 mm, same data (MCZ 288494); 1, 65.5 mm, west of Sarasota, 183 m, Withrow colln.; 4, 57.9-92.4 mm, south of Dry Tortugas, 375 m, Withrow colln.; 1 paratype, 70.4 mm, southwest of Egmont Key, 76 m [?; depth probably actually about 200 m] (ANSP 345472); 1 paratype, 97.9 mm, same data (AMNH 183874); 87.0 mm, same data, Hepler colln.

Etymology: The species is named in memory of the late Daniel D. Steger, Tampa, Florida, whose early dredging and study of Gulf of Mexico mollusks stimulated much of the present interest in this fauna.

Discussion: Fusinus stegeri is distinguished from the similar *F. eucosmius* (Dall, 1889) (Fig. 6) by its larger size, possession of more numerous ribs on anterior whorls, and white color. Color of living or freshly dead *F. eucosmius* shells is orange or apricot, with strongest pigmentation in intercoastal areas. *Fusinus eucosmius* attains a maximum length of approximately 86 mm, but specimens larger than 80 mm are uncommon. At maximum size, *F. eucosmius* has eight or nine strong axial ribs on the terminal (usually eleventh) whorl. Axial ribs increase with shell size throughout the development of *F.*

eucosmius, the final rib on the terminal whorl being far larger than any other rib on the shell (Fig. 7). Conversely, axial ribs on later whorls of *F. stegeri* are markedly smaller than those on some intermediate whorls (Figs. 2, 5). The inner lip, an extension of the parietal shield and columella, is usually very well developed on large *F. stegeri,* and may be present on specimens as small as 70.4 mm (ANSP 345472), but I have seen shells as large as 84.9 and 87.0 mm (FSBC I 15028; Hepler colln.) with no inner lip development. On shells of similar length, apertures are placed more posteriorly on *F. stegeri* than on *F. eucosmius.*

Bathymetric ranges of *F. eucosmius* and *F. stegeri* are apparently separate. Dall (1889) reported *F. eucosmius* at eight stations, seven of which ranged in depth from 27 to 73 fms (49-134 m) and actually contained the reported species. I have since seen *F. eucosmius* dredged in 89 fms (162 m) off Key West by Henderson (USNM 414794). However, Dall's other station, from 111 fms (203 m) off west Florida, contained two small specimens of *F. stegeri,* which Dall labeled *F. eucosmius* var. (USNM 93650). I have seen additional specimens labeled as being captured from depths of approximately 100-205 fms (183-375 m), all from off the Florida west coast between Cape San Blas and Dry Tortugas, and even one lot labeled "250 ft" (76 m); all specimens were originally dredged by Mr. Riley Black, Ft. Myers, Florida, who told me the species was most common in depths of 100-110 fms (183-201 m) and was never collected in 250-ft. depths.

Specimens of *Fusinus stegeri* are common in the cabinets of many shell collectors who have obtained unsorted deep water dredgings from the eastern Gulf of Mexico. The shells are usually erroneously identified as *F. eucosmius, F. amphiurgus* (Fig. 8) (Dall, 1889), or *F. halistreptus* (Dall, 1889). Differences between the new species and *F. eucosmius* have been discussed. *Fusinus amphiurgus* (Fig. 8) is a small species possessing eight whorls in a length of 14 mm and colored yellowish, with sprial touches of reddish brown; it is clearly not the new species. *Fusinus halistreptus* (Fig. 9) is similar to *F. stegeri,* but possesses only very low, rudimentary ribs and occurs at greater depth; I have seen only the holotype (USNM 93333) from 338 fms (609 m) near the Little Bahama Bank.

Other names validly or otherwise applied to living western Atlantic *Fusinus* species include: *aepynotus, alcimus alcimus, alcimus rushii, amiantus,* and *benthalis,* all Dall, 1889, *brasiliensis* Grabau, 1903, *bullatus* Dall, 1927, *ceramidus* Dall, 1889, *closter* Philippi, 1850, *couei* Petit, 1853, *dowianus* Olsson, 1954, *caboblanquensis* Weisbord, 1962, *frenguellii* Carcelles, 1953, *gradatus* Reeve, 1848, *hartvigii* Shuttleworth, 1859, *helenae* Bartsch, 1939, *marensis* Weisbord, 1962, *marmoratus* Philippi, 1846, *schrammii* Crosse, 1865, *sinistralis* Lamarck, 1816, *spectrum* Adams and Reeve, 1848, *strigatus* Philippi, 1851, *timessus* Dall, 1889, and *vitreus* Dall, 1927. Some of these have since been shown to belong to faunas of other oceans, others are not species of *Fusinus,* and some may be synonyms of still others on the list. All were eliminated as possible names of the new species.

Early whorls of *F. stegeri* are usually somewhat eroded and stained gray, as often occurs on gastropods living at the outer continental shelf edge or upper slope. However, several specimens are sufficiently intact to reveal that axial sculpture occurs only on approximately the last half whorl of the protoconch, indicating the species should be assigned to *Fusinus s.s.* Abbott (1974) included *F. eucosmius, F. couei,* and *F. helenae* with *F. timessus* and *F. dowianus* in the subgenus *Heilprinia* Grabau, 1904, but embryonic sculpture of the first three species clearly dictates their placement in *Fusinus s.s.;* the last two species, with strong axial riblets on all embryonic whorls, are properly *Heilprinia.* Abbott's speculation that *F. dowianus* might represent only a southern subspecies of *F. eucosmius* is therefore incorrect.

ACKNOWLEDGMENTS

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A NEW FOSSIL *ASHMUNELLA* (PULMONATA:POLYGYRIDAE) FROM THE SIERRA DIABLO AND HUECO MOUNTAINS, TEXAS

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ABSTRACT

A new species of fossil polygyrid land snail, Ashmunella watleyi, *is described. The species has been found in deposits of probable late Pleistocene age in the Sierra Diablo and Hueco Mountains of western Texas. An associated molluscan fauna is reported and paleoecological implications discussed.*

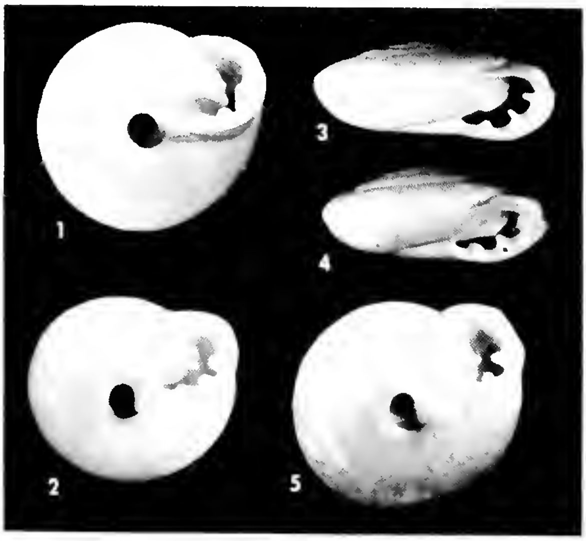
Extreme western Texas is located in the Basin and Range Physiographic Province. Some "ranges" may be no more than uplifted plateaus between lower-lying basins. Such is the Diablo Plateau, located mainly in Hudspeth County, Texas. It is bordered by the Salt Basin on the east and Hueco Bolson on the west. Fenneman (1931: 395) characterized the area thus: "Near the Texas boundary there rises. . . the Diablo Plateau. . . bounded by faults and sloping eastward. . . The dissected fault scarps on both sides appear as mountains when viewed from the basins. That on the west, 2,000 ft. high, is known as the Hueco Mountains and farther south as the Finlay Mountains. The somewhat lower scarp on the east is the Diablo Range." The fossils treated herein are from the Sierra Diablo (Fenneman's "Diablo Range") and the Hueco Mountains. The bedrock of both ranges is predominantly limestone of Permian age.

The fossiliferous deposits at the type locality (Loc. 1, described at end of paper) occur on an east-facing slope in the upper end of the main, south arm of Victoria Canyon, which debouches eastward into Salt Basin. The deposits are of sharply angular limestone rock rubble, derived from the Permian bedrock of the area, with interstices filled with silts of rock color "Moderate yellowish-brown, 10YR 5/4." The rubbly deposit forms a mantle on the lower part of the slope. Eleven species of gastropods have been taken from this deposit, including an *Ashmunella* judged to be new. From the Hueco Mountains only one specimen of *Ashmunella* has been taken at each of two localities (Locs. 2 and 3). These shells also were obtained from deposits of hillslope colluvial mantle.

Ashmunella watleyi *new species*

(Figs. 1-4)

Description of Holotype: Shell moderately thick, 12.5 mm in diameter and 5.35 mm high; moderately depressed with spire forming angle of 145°; angular peripherally with angulation at $^{2}/_{3}$ height of body whorl; body whorl not descending; umbilicus narrow, 2.1 mm wide and contained 5.95 times in diameter of shell; aperture obliquely oriented at angle of 60° to vertical, 3.5 mm high and 3.8 mm wide. Peristome thickened, lamellar and distinctly raised above subtending body whorl surface on parietal wall and forming callus in outer lip. Parietal peristome bearing two denticles: (1) a single, much larger, obliquely oriented lower tooth, 2.3 mm long and 0.6 mm high, bearing a short ventroposteriorly inclined "tail" below; (2) an upper tooth oriented horizontally, scarcely more than an elongate swelling, *ca.* 0.6 mm long and not joining the lower tooth posteriorly. Callus of outer lip subtending three denticles: (1) uppermost (palatal) denticle subrectangular with straight outer margin, 1.4 mm long and rising 0.45 mm above lip callus, separated by 0.7 mm from middle tooth; (2) middle tooth peglike, 0.7 mm wide, rising 0.6 mm above callus and separated by 0.75 mm from lowermost (basal) tooth; (3) basal tooth rounded and oriented obliquely on callus, 1.4 mm long and rising 0.6 mm above callus. Outermost one mm of lip reflected back over body whorl. Number of whorls, 5. Nuclear 1.5 whorls smooth; upper surface of succeeding whorls bearing weak growth lines, these becoming stronger on body whorl. Upper surface of whorls two and three bearing many short, slightly raised papillae, parallel to growth lines (see below). Lower shell surface generally smooth with some weak growth lines, these stronger near lip.



FIGS. 1-4. Ashmunella watleyi *new species:* **1, 4.** *Holotype (12.5 mm, diameter);* **2, 3.** *Paratype (13.5 mm, diameter) from Loc. 3, Hueco Mts.* **5.** Ashmunella carlsbadensis *Pilsbry (14.75 mm, diameter) from northern Sierra Diablo (mentioned in text).*

The papillae noted above seem to give evidence of the presence of cuticular scales on at least part of the dorsal surface of the shell in life. They greatly resemble those described by Clench and Miller (1966: 2) for *Ashmunella bequaerti:* "In older specimens where the scales have worn off, there remain raised hyphen-shaped papillae, parallel to the growth striae, giving a granular appearance to the surface."

This species is named in honor of Mr. Ray Watley, Texas Parks and Wildlife Department, who hospitably escorted us to and on the Sierra Diablo Wildlife Management Area, which contains the type locality (Locality 1, described hereafter).

Holotype, Delaware Museum of Natural History 118338. Paratypes: Dallas Museum of Natural History 5359; University of Texas at El Paso 3638, 4375 and 4978.

Variation: Only eight measurable paratypes were recovered from Loc. 1. For these the following measurements (in mm) and proportions were obtained (mean outside parenthesis; range inside parenthesis): Diameter: 12.94 (11.2-14.2); Height: 5.2 (4.75-5.6); Width of Umbilicus: 2.53(2.1-2.9); Length of Lower Parietal Tooth: 2.26 (1.8-2.6); Length of Palatal Tooth: 1.64 (1.5-2.0); Number of Whorls: 4.99 (4.85-5.2); Diameter/Height: 2.44 (2.36-2.54); Diameter/Width of Umbilicus: 5.14 (4.48-6.14).

Among specimens from Loc. 1 there is little variation in shells. The sculpture of raised papillae is not observable on most of these shells probably because of exfoliation. The upper parietal denticle is barely discernible in some specimens. One specimen (11.2 mm in diameter), although seemingly mature, is notably smaller than the others and also exhibits stronger growth lines.

Specimens from the Hueco Mountains (Locs. 2 and 3) have the size, shape and shell texture of *A. watleyi*. Minute papillae are barely discernible on the upper surface of the shell on whorls two and three. They differ slightly from specimens from Loc. 1 in denticulation, having a longer and higher upper parietal tooth and a more slender middle tooth in the outer lip (Figs. 2, 3). Similarities seem great enough to provisionally assign the few specimens from the Hueco Mountains to *A. watleyi*. Possibly *A. watleyi* is a species that occupied, at least during late Wisconsinan time, much of the escarpment that bounds the Diablo Plateau on the east, south and west. Few collections of Quaternary fossil gastropods have been made in this area, however.

COMPARISONS

Fullington has collected living *Ashmunella* in the northern part of the Sierra Diablo *ca.* 22 km north of Loc. 1, immediately south of Apache Canyon on the Puett Ranch. This species seems to be *A. carlsbadensis* Pilsbry, known otherwise from the Guadalupe and Delaware Mountains on the east side of Salt Basin. Shells of this species (Fig. 5) differ from those of *A. watleyi* in being thinner and relatively flatter. They are carinate rather than angular and the outer lip teeth are all relatively smaller, the palatal tooth being markedly narrow. *Ashmunella carlsbadensis* lacks cuticular scales, which seem likely to have been present in *A. watleyi*. *Humboldtiana ultima* Pilsbry, a land snail otherwise known only from the Guadalupe Mountains, also occurs with *A. carlsbadensis* in the northern Sierra Diablo.

Ashmunella watleyi is larger, more depressed and less ribbed than the fossil species, *Ashmunella nana* Metcalf and Fullington, from the Guadalupe Mountains. On the other hand, *A. watleyi* is smaller than the subspecies that have been ascribed to *A. kochii* Clapp from the Guadalupe and Cornudas Mountains. These latter species also have a broader umbilicus and lack the cuticular scales that were probably possessed by *A. watleyi*.

Cuticular scales are found in *A. pasonis pasonis* (Drake) of the Franklin Mountains, west of the Hueco Bolson and in *A. bequaerti* Clench and Miller of the Davis Mountains, southeast of the Sierra Diablo. However, both these latter species are more depressed, more strongly keeled and have larger denticles thatn those of *A. watleyi*.

It is probable that *A. watleyi* and the other species mentioned above all belong to a group of Ashmunellas of the mountains of southern New Mexico and far western Texas that was referred to as the *Ashmunella mearnsi* group by Pilsbry (1940: 972) and Metcalf (1973: 39). However, affinities of *A. watleyi* within this group are not clear.

ASSOCIATED FAUNA AND PALEOECOLOGICAL IMPLICATIONS

In addition to *A. watleyi*, the following ten species of gastropods were found in the colluvium at Loc. 1: *Gastrocopta pellucida* (Pfeiffer), *G. pilsbryana* (Sterki), *Pupilla blandii* Morse, *P. sonorana* (Sterki), *Vallonia perspectiva* Sterki, *Succinea* sp., *Vitrina pellucida alaskana* Dall, *Hawaiia minuscula* (Binney), *Retinella (Glyphyalinia) indentata paucilirata* (Morelet) and *Euconulus fulvus* (Müller).

We searched for living gastropods on the steep east-facing scarp of the Sierra Diablo at two places on the Wildlife Management Area and found only *Gastrocopta pellucida* and *Retinella i. paucilirata*. It is likely, however, that *Hawaiia minuscula* and the succineid also occur in the area. However, the remaining species found in the colluvium probably no longer occur in the range, although they do occur at higher, more mesic elevations in the Guadalupe Mountains, across Salt Basin to the northeast. Thus, a life zone depression is inferred, such as often has been discerned in regard to glacial-age faunas of the southwestern United States. It is deemed extremely likely, then, that the sediments were deposited during a glacial-equivalent time with colder temperatures and more effective moisture than at present. This is borne out by the nature of the sediments, containing, as they do, rock rubble of the kind produced by frost action and not being produced at these elevations today. As there has been relatively little subsequent deposition and as sediments are not indurated, it seems likely that they were deposited no longer ago than during the late Wisconsinan (Woodfordian) Glaciation.

LOCALITIES OF COLLECTIONS

1. Texas, Culberson Co., 31° 17′ 25″ N; 104° 54′ 47″ W. Sierra Diablo Wildlife Management Area, Texas Parks and Wildlife Department. Upper end of main, south branch of Victoria Canyon on west wall of canyon, *ca.* 300 m east of Hudspeth-Culberson counties boundary along trail leading northward from Area headquarters buildings and 2.09 km north of these, 1660 m elevation. 12 September 1976.

2. Texas, Hudspeth Co., 31° 52′ 21″ N; 105° 59″ W. Hueco Mts., on west slope of Alacran Mt., 3.5 km north of Hueco Inn. 1585 m. elev. Collected by Ronald Simpson, 7 March 1975.

3. Texas, El Paso Co., 31° 56′ 30″ N; 106° 00′ 7″ W. Hueco Mts., on east-facing hillslope, 4.2 km ENE of Hueco Tanks State Park Headquarters. 1478 m elev. 15 February 1973.

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MOLLUSKS WITH INDO-PACIFIC FAUNAL AFFINITIES IN THE EASTERN PACIFIC OCEAN

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ABSTRACT

Forty-one species of prosobranch gastropods and seven species of bivalves that have Indo-Pacific faunal affinities are recorded from the eastern Pacific Ocean. The vast majority of these taxa (79%) are known in eastern Pacific waters only from the offshore islands, namely: Clipperton (38 taxa), Revillagigedo (6 taxa), Cocos (4 taxa), Galapagos (9 taxa), and Guadalupe (1 taxon). Only 10 of these taxa are known to occur on the continental shelf of the west American Borderland, including the Tres Marias Islands. The fossil record provides little direct evidence to document the biogeography of this faunal element in the New World tropics.

A considerable amount of new zoogeographic and geologic data has become available since I presented a lecture on this subject to the Eleventh Pacific Science Congress at Tokyo, Japan, in 1966 (Emerson, 1967). The purpose of this paper is to update the list of the Indo-Pacific molluscan species occurring in the tropical eastern Pacific and to review briefly the temporal significance of this faunal element in the New World tropics.

The presence of a minor element of the modern Indo-Pacific Faunal Province has been long recognized in shallow water benthonic faunas of tropical western America, the Panamic Faunal Province (*cf.* Ekman, 1953 and Briggs, 1974). Separated from the nearest Central Pacific islands by some 3100 miles of open ocean, the Panamic Province extends from near the head of the Gulf of California, Mexico, southward to northern Peru. Nearly 3400 species of mollusks, representing all the extant molluscan classes, are known from these waters (Keen, 1971).

Within the large Panamic fauna, only 48 species of the prosobranch gastropods and the bivalves are recognized as having Indo-Pacific faunal affinities. Constituents of this small Indo-Pacific element are restricted to the offshore islands, except for the rare occurrences of 10 species on the continental shelf from Mexico to Ecuador (Table 1). The presence of an Indo-Pacific element in the Panamic Faunal Province is in sharp contrast to the apparent absence of Panamic faunal elements in the Indo-Pacific Faunal Province (Emerson, 1967).

THE INDO-PACIFIC FAUNAL ELEMENT

The present tabulation of the Indo-Pacific element is limited to the prosobranch gastropods and the bivalves (Table 1). The gastropods (41 species) greatly outnumber the bivalves (7 species). All inhabit shallow water and are epifaunal species, with the exception of one species of bivalve.

Many of the gastropods represent groups with larval forms that can remain in the plankton for long periods of time, as much as ten months (Robertson, 1964; Scheltema, 1966, 1968, 1972; Thorson, 1961). Of the bivalves, seven are attaching or boring forms; one, *Codakia thaanumi*, is the sole infaunal species. Nearly all of these mollusks potentially are capable of being transported over vast distances of open water in the form of drifting larvae, or by the attachment of eggs, larval or adult forms to floating debris. These dispersal mechanisms have been postulated as the primary vehicle to account for the presence of the Indo-Pacific element in the modern Panamic fauna.

In the more than 40 years since Hertlein (1937) critically reviewed the composition of this Indo-Pacific element, the known species representing this faunal element have quadrupled in number, and the verified records of these species living on the continental shelf has increased from one to ten. Despite recent advances in the knowledge of the paleogeography of the New World tropics, the fossil record still provides limited data on the origins of this faunal element.

PALEOGEOGRAPHY

The small Indo-Pacific faunal element in the Panamic Province (Table 1) is generally believed to have been the result of rather recent introductions, whereas the minor element of essentially circumtropical species (Table 2) in the west American tropical waters is thought to represent relict elements dating from late Tethyan faunas (*cf.* Keen, 1971, p. 2; Olsson, 1972). Unfortunately, there is little direct evidence to substantiate these biogeographical conclusions. The only Recent Indo-Pacific species recognized as fossils in West American deposits are *Cypraea cernica* Sowerby in Pleistocene terrace deposits on Guadalupe Island (Kellogg, 1976) and possibly *Conus tessulatus* Born (described as *C. bramkampi* Hanna and Strong, and compared by Hanna (1963) to *C. tessulatus)* from the late Pliocene of Imperial County, California.

The oldest of the offshore islands based on fossil evidence are in the Galapagos archipelago, where Pliocene (Hertlein, 1972) and late Miocene (Durham & McBirney, 1975) mollusks are known. The meager geological evidence suggests that the other offshore islands are young, probably Pleistocene in age (Emerson, 1967). As all of the offshore islands, except the Tres Marias, are on submerged ridges or on fracture zones, one cannot ignore the possible existence of formerly emergent islands on these topographic structures that may have served as temporary dispersal bridges. The modern Galapagos Islands, for example, are interpreted by Holden and Dietz (1972) as the most westerly emergent remnants of a volcanic chain of which the most easterly components have subsided. They postulate that a series of ancestral "Galapagos Islands" may have existed over a span of 40 million years and thus

TABLE 1 *Molluscs with Indo-Pacific faunal affinities (exclusive of Opisthobranchs) occurring on the west coast of the New World and the offshore islands, based on numbered references in Literature Cited, and on* **25:** *Coll. A.M.N.H. (Panama),* **26:** *Coll. Darwin Research Station, Galapagos*

West American Mainland

Gastropoda

Conus ebraeus Linnaeus - 1, 6, 11, 18, 19, 21, 28
Conus tessulatus Born - 19, 21, 25
Cypraea teres Gmelin - 1, 9, 19, 21, 27, 29
Heliacus trochoides (Deshayes) - 21
Microdaphne trichodes (Dall) - 19, 21
Mitra mitra (Linnaeus) - 21, 27
Quoyula madreporarum (Sowerby) - 5, 13, 18, 19, 21, 27
Terebra affinis Gray - 2, 19, 21
Terebra laevigata Gray - 19, 21
Titiscania limacina (Bergh) - 19, 21

Galapagos Islands

Gastropoda

Conus chaldeus (Röding) - 1, 11, 12, 13, 19
Conus ebraeus Linnaeus - 1, 6, 11, 12, 13, 19
Coralliophila neritoides (Lamarck) - 8, 19
=*C. violacea* (Kiener)
Cypraea moneta Linnaeus - 4, 8, 13, 19
Cypraea teres Gmelin - 4, 8, 9, 19
Drupa ricinus (Linnaeus) - 10, 13
Microdaphne trichodes (Dall) - 19
Mitra mitra (Linnaeus) - 24, 26
Pseudocypraea adamsoni (Sowerby) - 8, 19

Clipperton Island

Gastropoda

Bursa granularis (Röding) - 16, 18, 19, 23
Conus chaldeus (Röding) - 1, 11, 12, 13, 18, 19, 23
Conus ebraeus Linnaeus - 1, 6, 11, 12, 13, 18, 19, 23
Conus tessulatus Born - 15
Coralliophila neritoides (Lamarck) - 8, 16, 19, 23
=*C. violacea* (Kiener)
Cypraea depressa Gray - 4, 13, 15, 18, 19
Cypraea maculifera (Schilder) - 4, 15, 19
Cypraea scurra indica Gmelin - 4, 13, 15, 18, 19
Cypraea caputserpentis Linnaeus - 4, 15, 19
Cypraea moneta Linnaeus - 4, 15, 19
Cypraea helvola hawaiiensis Melvill - 4, 15, 19
Cypraea rashleighana Melvill - 4
Cypraea arenosa Gray
=*C. schilderorum* (Iredale) - 4, 15, 19
Cypraea teres Gmelin - 4, 8, 9, 13, 15, 18, 19, 23
Cypraea vitellus Linnaeus - 4, 15, 19
Diodora granifera (Pease) - 17, 19
Drupa morum Röding - 10, 16, 23
Drupa ricinus (Linnaeus) - 10, 13, 16, 18, 19, 23
Harpa gracilis Broderip & Sowerby - 16, 20 23
Littorina pintado schmitti Bartsch & Rehder - 16, 18, 19, 22, 23 (an endemic subspecies)
Magilus robillardi Liénard - 16, 18, 23
Mitra edentula Swainson - 16, 23
Mitra ferruginea Lamarck - 16, 23
Mitra papalis (Linnaeus) - 13, 16, 18, 19, 23
Morula uva (Röding) - 13, 16, 18, 19
=*M. aspera* (Lamarck)
Nassa francolinus (Bruguière) - 16, 23
Nerita plicata Linnaeus - 16, 18, 23
Quoyula madreporarum (Sowerby) - 16
Strigatella litterata Lamarck - 23
Terebra crenulata interlineata Deshayes - 16
Peristernia thaanumi Pilsbry & Bryan - 17
Cerithium nesioticum Pilsbry & Vanatta - 17, 19

Bivalvia

Acar c. f. laysana Dall, Bartsch & Rehder - 17
Spondylus hawaiensis Dall, Bartsch & Rehder - 23
Spondylus gloriosus Dall, Bartsch & Rehder - 17, 19, 23
Hyotissa hyotis (Linnaeus) - 17, 19, 23
Codakia thaanumi Pilsbry - 17, 23
Martesia striata (Linnaeus) - 17

Revillagigedo Group

Gastropoda

Conus tessulatus Born - 11, 12, 18
Coralliophila neritoides (Lamarck) - 8, 19
Hastula albula (Menke) - 2, 3, 19
Quoyula madreporarum (Sowerby) - 13, 18
Terebra crenulata (Linnaeus) - 2, 3, 19
Terebra maculata roosevelti Bartsch & Rehder - 2, 3, 19 (an endemic subspecies)

Cocos Island

Gastropoda

Cypraea moneta Linnaeus - 4, 7, 8, 13, 14, 19
Cypraea rashleighana Melvill - 4, 8, 14, 19
Terebra maculata maculata (Linnaeus) - 2, 3, 7, 19

Bivalvia

Isognomon quadrangularis (Reeve) - 7, 14

Guadalupe Island

Gastropoda

Morula uva (Röding) - 19

Tres Marias Islands

Gastropoda

Quoyula madreporarum (Sowerby) - 19

TABLE 2. *Tropicopolitan gastropods (exclusive of Opisthobranchs) known to occur in the western Atlantic and western Pacific as well as on the west coast of North and Central America and the offshore islands, based on:* **1**-*Emerson and Old, 1963;* **2**-*Emerson and Old, 1965;* **3**-*Hertlein, 1937;* **4**-*Hertlein and Allison, 1960b;* **5**-*Keen, 1971;* **6**-*Radwin, 1969;* **7**-*Strong and Hertlein, 1939. Excluded are tropical superspecies with allopatric populations in the western and eastern Pacific and the westen Atlantic that are presently recognized as distinct species; e.g.:* Casmaria erinaceus *(Linnaeus),* C. vibexmexicana *(Stearns), and* C. atlantica *(Clench).*

Mainland of Central America

Cheilea equestris (Linnaeus) - 3, 5 (as *C. cepacea* Broderip)
Crepidula aculeata (Gmelin) - 3, 5, 7
Cymatium parthenopeum (von Salis) - 1, 5 (as *C. p. keenae* Beu)
Cymatium pileare (Linnaeus) - 1, 5
Hipponix antiquatus (Linnaeus) - 3, 5 (as *H. panamensis* C. B. Adams)

Galapagos Islands

Cheilea equestris (Linnaeus) - 3
Crepidula aculeata (Gmelin) - 3
Cymatium parthenopeum (von Salis) - 1, 5 (as *C. p. keenae* Beu)
Cymatium muricinum (Röding) - 6
Hipponyx antiquatus (Linnaeus) - 3

Clipperton Island

Cymatium nicobaricum (Röding) - 4
Cymatium pileare (Linnaeus) - 1
Hipponyx antiquatus (Linnaeus) - 4

Revillagigedo Group

Crepidula aculeata (Gmelin) - 3
Cymatium pileare (Linnaeus) - 1

Cocos Island

Cymatium pileare (Linnaeus) - 2

provided for the isolation necessary to evolve the many endemic terrestrial organisms found on the present Galapagos (*cf.* Shields, 1976: 51). By their model, animals would have negotiated a short span of water to a new volcanic island as an older extinct volcanic island drifted eastward and became submerged and attached to the end of the Cocos and Carnegie ridges. They concede that no guyots are known from either the Carnegie or Cocos chains, but stress there is no evidence to preclude that these ridges were not subaerial at some time in their history.[1] As Rosen (1975) points out, this view is in sharp contrast to the Darwinian concept of the Galapagos as oceanic islands, which could not have been historically connected to the mainland. Moreover Holden and Dietz conceive the Galapagos as emergent outposts of an ancient Cocos-Carnegie ridge system, the eastern part of which is subsiding, and is being consumed by the Cordilleran Trench system of the South American plate. Indeed, the lack of preservation of fossilferous marine Tertiary deposits in much of the middle west American Borderland largely limits paleogeographic interpretations of the faunistic history of the modern Panamic Province to the regional Pleistocene record and to comparisons with the Tertiary record of the adjoining faunistic regions.

The Tertiary Caribbean Province, as defined by Woodring (1966; 1972) based largely on Mio-Pliocene molluscan faunas, included parts of the modern Caribbean and Panamic provinces. It extended from the règion of Tampico, Mexico, to northern Brazil in the western Atlantic, and from southern Nicaragua to northern Peru in the eastern Pacific. The northwest limits of the Tertiary province in the eastern Pacific cannot be determined because no marine deposits of Tertiary age are recorded from southern Nicaragua to Baja California, Mexico, a stretch of 3,000 kilometers. Presumably most of these sediments have been lost by subduction into the Middle American Trench system. The deficiency of the Tertiary record from this part of west America has invited faunal comparisons with the better preserved Tertiary faunas of the Caribbean region in attempting to determine the faunal affinities of the modern Panamic Province. As a result, taxa that survive in the western Pacific, but are not known to be living or as fossils in the eastern Pacific and also occur in the modern or Tertiary faunas of the Caribbean region, are considered to represent largely Tethyan relicts that reached the Caribbean Province by migration across the Atlantic Ocean. On the other hand, larval dispersal into eastern Pacific waters from the Caribbean region before the closure of the trans-American seaways in the Pliocene is suggested by the apparently earlier occurrence in the western Atlantic than in the eastern Pacific for most of

---

[1] An assemblage of invertebrates of probable Miocene age was dredged from a guyot at a depth of 227 meters on the Nasca Ridge, located to the south and fronting the peru Trench. Hermatypic corals in the sample suggest a tropical, shallow-water habitat (Allison, *et al.*, 1967).

the taxa comprising the Caribbean Tertiary Province, and by the presence of numerous closely related "twin species" separated by the Panama Land Bridge in the modern Panamic and Caribbean provinces. There is a small element in the Caribbean Tertiary Province for which the earliest fossil record is in the eastern Pacific and an even larger element which has essentially a contemporaneous appearance in both the eastern Pacific and the Caribbean regions of the Tertiary Province (Woodring, 1965, 1966; Vokes. 1976). Owing to the incompleteness of the fossil record of the west American Borderland and to gaps in the fossil record in the western Atlantic, the origin of these elements can not be determined on the basis of paleontological evidence. They may well have been represented earlier in the eastern Pacific than in the western Atlantic. These tropical elements, however, have not been recognized in the fossil record of western North America, with the exception of a few warm-water taxa in the Miocene of central California and the tropical taxa persisting in the Pliocene of southeastern California and the Gulf of California (Keen, 1976). The presence of these faunal elements in the "Pacific Outposts of the Tertiary Caribbean Province," to use Keen's appellation, requires a paleogeographic reexamination of these faunas. Futhermore, as Rosen (1975) has stressed in proposing a vicariance model of Caribbean biogeography, ". . . fossils give a minimum age rather than a maximum age for the groups of which they are members." Because of the limitations of the fossil record and the failure to appreciate fully the influence sea-floor spreading, plate tectonics and continental drift has had on the alteration of shorelines and oceanic current systems, a seemingly overly simplistic paleogeographic model has been inferred for the tropical faunas of the New World Tertiary.

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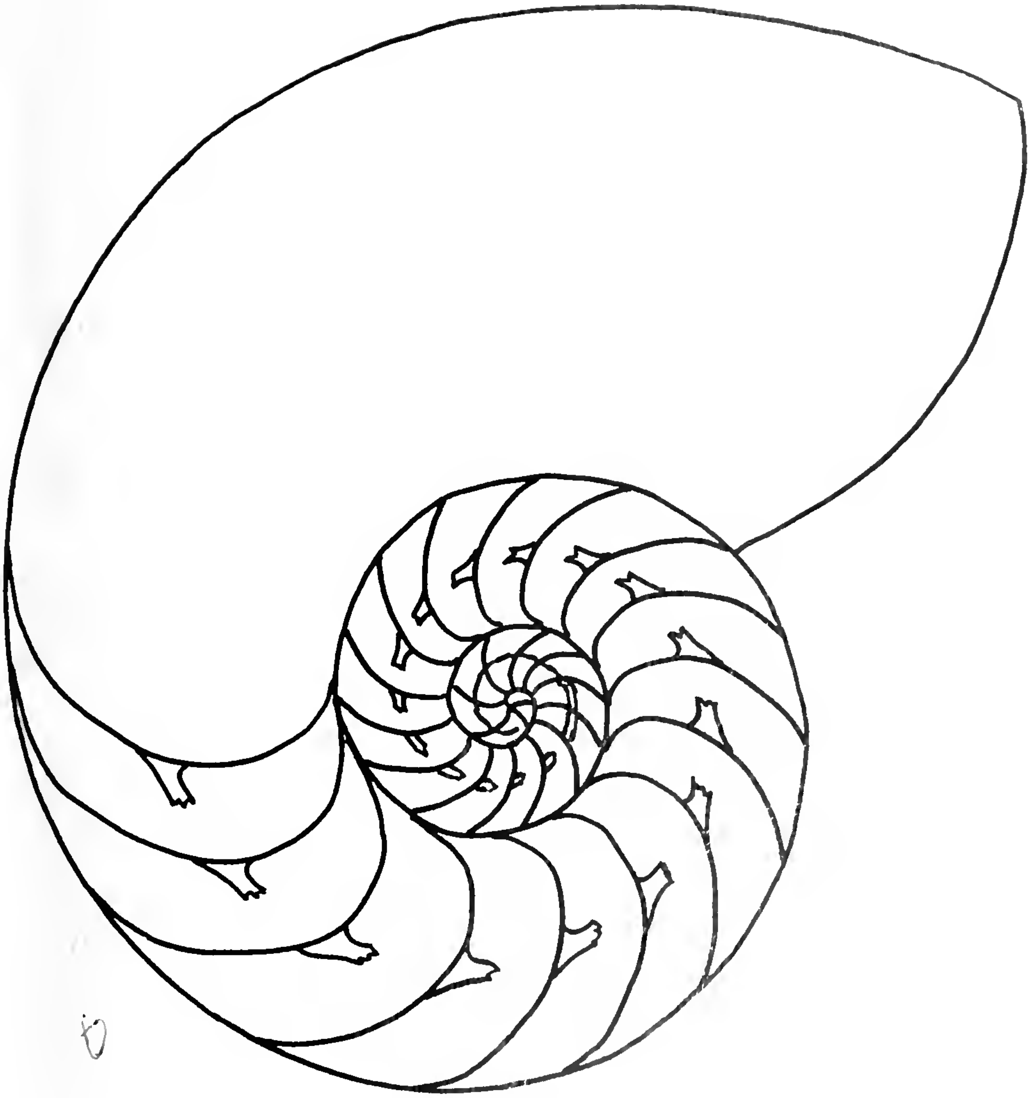

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CONTENTS

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NEWS

Disasterous Fire

The entire molluscan collections and library of the Barboza du Bocage Museum of the Faculty of Sciences of Lisbon were destroyed by fire on March 18, 1978. It was a tragic loss to future research on mollusks of the Cape Verde Islands and West Africa. Mr. Ilidio Felix Alves has volunteered to act as a temporary receptionist for much needed gifts of malacological books and reprints. Please help their rise from the ashes. The address of Mr. Alves is Praceta Eduardo Pereira Roque, lote 1, R/C, frente, Sao Pedro do Estoril, Portugal.

Brazilian Malacological News

1978 marks the tenth anniversary of the Malacological Section of the Universidade Federal de Juiz de Fora, Minas Gerais, Brazil. The curator is Dr. Maury Pinto de Oliveira, author of "As Conchas" and a Portuguese malacological dictionary. Exchanges of specimens are possible by writing to him at the Dept. Biologia, Univ. Fed. Juiz de Fora, 36100, Juiz de Fora, MG, Brazil.

QUATERNARY MARINE MOLLUSKS FROM TENERIFE, CANARY ISLANDS

F. G. Talavera,[1] Sigmund J. Kardas, Jr.[2] and Horace G. Richards

ABSTRACT

Seventy-six species of Gastropoda, 21 species of Bivalvia and one Cephalopod species are cited from the beach deposit at Tachero, near the eastern end of the north coast of Tenerife. Of these, 46, 8, and 1 species, respectively, are new to the Quaternary marine fauna of the Canary Islands. Species of special biogeographic significance include Ostrea (Ostrea) edulis *L., Nucella* lapillus *(L.),* Planaxis lineatus *da Costa and* Pisania variegata *(Gray). A Mellahian-Flandrian age (+ 2 m level) is established as an approximate chronology for the deposit.*

The discovery of this beach deposit containing an abundant marine fauna in a rather loosely consolidated limestone permits, for the first time, a stratigraphic-palaeontologic study of the marine Quaternary of the Island of Tenerife. Previous authors have referred to the existence of Pleistocene raised beaches on the island, but no mention of an associated fauna has been made.

Zeuner (1958) noted three Quaternary raised beach levels in Tenerife:

Epimonastiran—La Roqueta, Punta del Hidalgo, Bajamar.

Lower Monastiran—San Juan de la Rambla, Punta del Hidalgo.

Upper Monastiran—La Roqueta.

These divisions are based solely on altimetric data, without reference to the fauna, suggesting that the beaches were submerged somewhat lower than the normally established levels during the middle of the last interglacial.

Bravo (1965), in his study of the modifications of the littoral zone due to Quaternary volcanic effusions, refers to the Quaternary terraces of Lanzarote, Fuerteventura, and Gran Canaria, and the almost complete absence of raised shorelines in the westernmost Islands of Tenerife, Hierro, Gomera, and La Palma. Although Lecointre, Tinkler and Richards (1967) have investigated the marine Quaternary of the Canary Islands, they make no mention of Tenerife or the other western islands.

THE TACHERO DEPOSIT

The outcrop studied (Figs. 14 and 15) is situated about 200 m to the west of the beach of Tachero, in the north of the Anaga Peninsula (inset map, Fig. 16). The fossil-bearing stratum is limited in lateral extent, the extremes of which are covered by a great mass of talus deposits, very abundant in this part of the island. Its exposure is due to strong wave cutting during some heavy storms of 1973 and 1974, and may again, at any time, be covered by the overlying detritus during future periods of turbulent wave action.

The following stratigraphic sequence is observed (Fig. 16):

A—a volcanic substratum containing numerous wave-leveled dykes, constituting an ancient littoral platform.

B—a mass of rolled lava pebbles, some of which are rubefacted, forming the base of the beach under study. Very little fauna is present, fragments of *Patella* being the most conspicuous components.

C—a thin faunal-rich gravel layer in which small mollusks are common.

D—a semi-consolidated limestone stratum about 40 cm thick, formed largely by calcareous algae *(Melobesia)*, mollusks, coral, bryozoa and echinoderm fragments. The volcanic pebble content is poor, and increases toward the base. This layer stands out from the other components of the sequence due to its lighter color and greater compaction, thus forming a small terrace or step in relief at its upper surface (Fig. 15).

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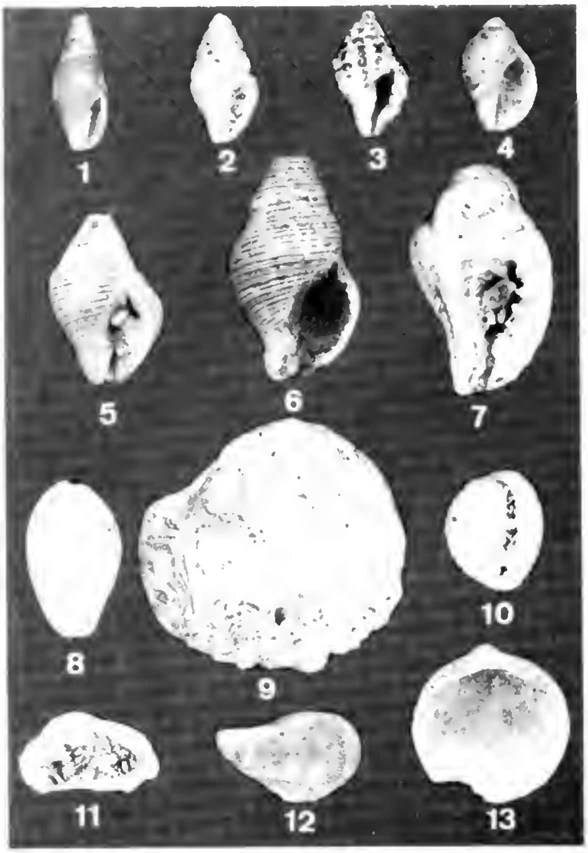
[1] Museo Insular de Ciencias Naturales, Santa Cruz de Tenerife.

[2] Paleontología, Facultad de Ciencias, Universidad de La Laguna, Tenerife.



FIGS. 1-13. *Quaternary marine mollusks from the Tachero deposit, Tenerife, Canary Islands.* **1,**Mitra (Fuscomitra) cornea *Lamarck;* **2,** Urosalpinx fusulus *(Brocchi);* **3,** Ocinebrina fusiformis *(Gmelin);* **4,** Nucella lapillus *(L.);* **5-6,** Pisania variegata *(Gray);* **7,** Cymatium (Septa) trigonum *Gmelin;* **8,** Erosaria (Ravitrona) spurca *(L.);* **9,** Ostrea (Ostrea) edulis *L.;* **10,** Pusula (Dolichupis) candidula *(Gaskoin);* **11,** Acar (Acar) nodulosa *(Müller);* **12,** Brachidontes puniceus *(Gmelin);* **13,** Glycymeris (Glycymeris) bimaculata *(Poli).*

E—a sandy layer containing very little fauna.

F—a great mass of talus detritus superior to 50 m in height, covering all of this sequence except for the isolated zone exposed by wave action.

PALAEONTOLOGY

While the complete list of mollusks identified from the Pleistocene outcrop of Tachero is given in Table 1, the following species are significant and deserve further note:

Ostrea (Ostrea) edulis Linné

(Fig. 9)

This species was cited by Dollfus (1911) for the Quaternary of Senegal, where it reached its southernmost range during the Pleistocene. The Tachero specimens have a greater diameter than the latter, about 50 mm on the average. More or less rounded shape, presenting small sharp-angled undulations on the shell border. Some fragments exhibit the original rose-violet coloration. Its present-day distribution extends south to Cape Ghir, Morocco (Pallary, 1920), not being found living in the Canary Archipelago.

Nucella lapillus (Linné)

(Fig 4)

The finding of this species is of special importance because we think it has been confused

FIG. 14 *North coast of Anaga, Tenerife. The arrow (lower right) indicates the Tachero Pleistocene outcrop (Photo: T. Bravo, 1974).*

TABLE 1 Marine Mollusks from the Quaternary of Tachero (Tenerife)

GASTROPODA

†*Amphissa costulata* (Cantraine)
†*Barleia rubra* (J. Adams)
†*Bela fuscata* (Deshayes)
†*Bittium incile* Watson
Bursa (Bufonariella) scrobiculator (Linné)
Calliostoma zizyphinum Linné
†*Cancellaria (Bivetiella) similis* (Sowerby)
†*Cancellaria (Bivetiella) cancellata* (Linné)

Cassis sp.
†*Cerithium (Lithocerithium) strumaticum* (Locard)
Clanculus bertheloti (Orbigny)
†*Conus (Lithoconus) papilionaceus* Bruguière
†*Conus guinaicus* Hwass

Conus sp.
Columbella rustica (Linné)
†*Coralliophila meyendorffi* Calcara
†*Cymatium (Monoplex) costatum* (Born)
†*Cymatium (Septa) ficoides* (Reeve)
†*Cymatium problematicum* Dautzenberg and Fischer
Cypraeacassis testiculus (Linné)
†*Charonia variegata* (Lamarck)
†*Cheila equestris* (Linné)
Diodora gibberula (Lamarck)
Erosaria spurca (Linné)
†*Eulimella pointelli* Folin
Fissurella nubecula (Linné)
†*Fossarus ambiguus* (Linné)
†*Gadinia garnoti* (Payraudeau)
†*Gibberula coelata* (Monterosato)
†*Gibbula candei* (Orbigny)
†*Haliotis (Sanhaliotis) coccinea* Reeve
†*Hinia (Telasco) ferrussaci* (Payraudeau)
Latirus armatus A. Adams
†*Littorina (Melaraph) striata* (King)
Luria lurida (Linné)
†*Manzonia crassa* (Kanmacher)

Melampus sp.
†*Mitra (Fuscomitra) cornea* Lamarck
†*Mitra (Fuscomitra) cornicula* (Linné)

Mitra sp.
†*Mitrella suelta* (Monterosato) Kobelt
†*Mitrella hidalgoi* Monterosato
†*Mitrolumna crenipicta* Dautzenberg
†*Naticarius dillwyni* (Payraudeau)
†*Nitidella ocellata* (Gmelin)
Nucella lapillus (Linné). (Fig 4)
Ocinebrina edwardsi (Payraudeau)
†*Ocinebrina fusiformis* (Gmelin). (Fig. 3)
†*Opalia* cf. *pumilio* Mörch
†*Osilinus atratus* (Wood)
†*Osilinus trappei* F. Nordsieck
Ovatella micheli Mittre
Patella aspera Lamarck
Patella caerulea Linné
Patella candei Orbigny
Patella lowei Orbigny
†*Patella ordinaria* Mabille
Pisania variegata (Gray) (Figs. 5, 6)
†*Pedipes afer* (Gmelin)
†*Philippia pseudoperspectiva* (Brocchi)
†*Propilidium scabrosum* (Jeffreys)
Petaloconchus subcancellatus (Bivona)
†*Petaloconchus vermicellus* (Lamarck)
†*Planaxis lineatus* (da Costa)
Pusula (Dolichupis) candidula (Gaskoin) (Fig. 10)
Semicassis (Tylocassis) undulata (Gmelin)
Strigatella zebrina (Orbigny)
Spiroglyphus glomeratus (Bivona)
†*Terebra lepida* Hinds
Thais (Stramonita) haemastoma (Linné)
Thais (Stramonita) haemastoma var.
Tricolia pulla (Linné)
†*Triphora obesula* Monterosato
†*Truncatella subcylindrica* (Linné)
†*Urosalpinx fusulus* (Brocchi). (Fig 2)
†*Zebina vitrea* (Adams)

BIVALVIA

†*Acar (Bentharca) obliqua* (Philippi)
†*Acar (Acar) nodulosa* Müller (Fig. 11)
Arca afra Gmelin
Arca noae Linné
Arcopsis (Galactella) lactea (Linné)

Barbatia sp
Beguina (Mytilicardita) calyculata (Linné)
†*Beguina (Glans) trapezia* (Linné)
†*Brachidontes puniceus* Gmelin. (Fig. 12)
†*Codakia eburnea* (Gmelin)
Chama (Chama) gryphina Lamarck
Chlamys corallinoides (Orbigny)
†*Donax (Hecuba) semistriatus* Poli
Glycymeris (Glycymeris) bimaculatus (Poli). (Fig. 13)
Lima (Radula) lima (Linné)
†*Lithophaga (Lithophaga) lithophaga* (Linné)
†*Lithophaga (Myoforceps) aristata* (Dillwyn)
Ostrea (Ostrea) edulis Linné. (Fig. 9)

Pseudochama sp
Spondylus gaederopus Linné
Venus (Venus) verrucosa Linné

CEPHALOPODA

†*Spirula spirula* Linné

(†) Species new to the Quaternary marine fauna of the Canary Islands. This material has been deposited in the Museo Insular de Ciencias Naturales, Santa Cruz de Tenerife with *Thais (Acanthina) crassilabrum* (Lamarck). Recently Lecointre (1952), Lecointre, Tinkler and Richards (1967) have recorded *T. crassilabrum* as being present in the Pleistocene of Morocco and the Canaries respectively, and they stress the fact that this species is found living now in the waters of Peru. We think that although it shows similarities with this species, it is simply a form of *Nucella lapillus* (L.), a species which is found today living in the waters of Europe, North Africa and North America, but not in the Canaries, and one that shows a great deal of variation in size, shape and color.

Planaxis lineatus da Costa

This small gastropod is very common in the Tachero outcrop. It is not present in the Recent molluscan fauna of the Canaries, but is found living on the coasts of French Guinea and Angola (Niclés, 1950), and in the western Atlantic, from the lower Florida Keys and the West Indies, on rocks in the intertidal zone (Warmke and Abbott, 1962).

FIG. 15 *The Quaternary deposit of Tachero; the fossiliferous stratum is seen as a light colored band at the lower right (Photo T Bravo, 1974)*

Pisania variegata (Gray)

(Figs. 5 and 6)

This species is characteristic of the fauna associated with *Strombus latus* Gmelin (formerly *S. bubonius* Lamarck) in the Quaternary of the Mediterranean. An abundant form at Tachero, found in two varieties: 1) very common, having varices and a thick labrum (outer lip); 2) much less frequent, smooth, and generally larger. It is presently found living in the Canaries and on the African coast from Mauritania to Angola.

AGE OF THE TACHERO DEPOSIT

Although no absolute chronology is presently available for the Tachero site, a relative correlation may be made with the deposits of the eastern Canaries, based on the fossil assemblage and similar level.

Lecointre, Tinkler and Richards (1967) relate the marine Quaternary of the eastern Canaries with that of Morocco, designating a Neotyrrhenian—marine Ouljian age for the Las Palmas outcrops (Alcaravaneras, Confital and Santa Catalina). They present a radiocarbon date of greater than 35,000BP for mollusk shells from the Confital locality, and a date of 100,000 ± 30,000 years for a Thorium-Uranium analysis, which may be correlated with the marine Ouljian of Morocco.

The fauna and level (+2 m) of the Tachero site suggests that it may be assigned to the European Mellahian: Flandrian, which corresponds to an approximate age of 6,000 BP (Lecointre, 1963), thus being more recent than the Las Palmas deposits.

We believe that the tectonic movements, generally of large blocks displaced toward the sea, the effects of which are observed in the north of Anaga, have not affected the Quaternary deposit to any great extent. Volcanic activity has not been recognized in this area since the early Quaternary. The only morphologic perturbations in this zone are due to erosion. A slight westward

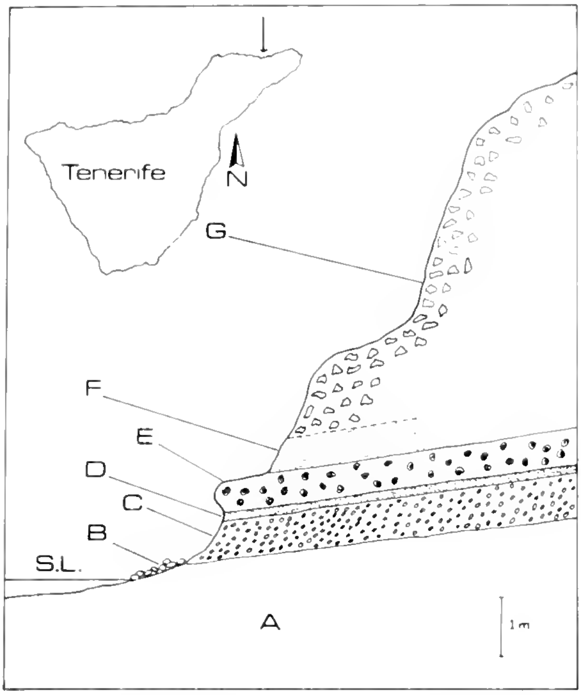


FIG. 16 *Schematic Section of the Tachero Deposit. A—volcanic substratum. B—present beach. C—rolled lava pebbles. D—gravel. E—fossiliferous limestone stratum. F—sand. G—talus deposit. SL—sea level. The arrow indicates the location of the Tachero site on the inset map of Tenerife.*

displacement of the entire surface unit is noted at the Tachero site, possibly due to a solifluction phenomena.

CONCLUSIONS

The Tachero beach site may be dated as Mellahian-Flandrian. It was deposited in shallow water, somewhat warmer than at present, during the Mellahian-Versilian (2 m) transgression. About 15% of the fauna collected now lives in more southerly areas of the African coast, being substituted by species of more recent appearance. The zone has not been affected by important tectonic movements, since at least the Late Pleistocene.

Although *Strombus latus* is not found, a number of associated species are observed: *Thais haemastoma*, *Pisania variegata*, etc. It seems probable that *S. latus* emigrated southward at the beginning of the Ouljian (it is now found living in the Cape Verde Islands, and the coasts of equatorial Africa), or that it disappeared from the waters of the Canary Archipelago when environmental conditions became more adverse, being able to survive in the warmer zones of Senegal and Cape Verde, where it lived in the Quaternary.

The discovery of *Nucella lapillus* in the Mellahian of Tenerife is most significant in that it is possibly the last epoch in which it lived in the Canaries before completely disappearing from this latitude.

Finally, it is necessary to record the extraordinary abundance of species in the deposit of Tachero. We think that it is an exceptional occurrence for so small a deposit.

ACKNOWLEDGMENTS

We must thank the following for their help in various phases of the work involved in this study: Prof. Dr. Telesforo Bravo and Mr. Jacinto Barquin, both of the University of La Laguna.

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FOSSIL *STROMBUS GIGAS* FROM SOUTHERN FLORIDA

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ABSTRACT

A rock pit near Naples, Florida, has yielded fossils of Strombus gigas, *probably of Pleistocene age. This species does not live today in the immediate ocean area.*

The western Atlantic "pink conch" is a large, abundant shallow water gastropod. Although very common throughout much of its range, it is quite rare as a fossil. So it was an object of great interest when found at Mule Pen Quarry, a rock pit northeast of Naples, Florida. Specimens have been collected by Axel Olsson, Robert and Shirley Hoerle, Donald Moore, John Meeder, and others. At this locality it is a fairly abundant fossil.

Mule Pen Quarry is northeast of Naples on state road 846, just east of the junction with state road 951. It is about 15 km east of the Gulf of Mexico, and has an elevation of 5.2 m above sea level. The fossils appear to be Pliocene and Pleistocene in age. Since they were all collected from spoil-banks piled up adjacent to the pit, stratigraphic relationships remain obscure. *Strombus gigas*, however, apparently comes from the upper part of the unit. This assumption is made since the species is not found in the older faunas in Florida, and because part of the Mule Pen fauna seems to be late Pleistocene in age. Other faunal elements (corals, bryozoans, mollusks) indicate shallow water for the upper part of the sediments. Possibly a current moved across south Florida from the Gulf to the Florida Straits at that time. This would create a favorable environment, including clear water, sea grasses, and lime sediments, for a large population of *S. gigas*.

Strombidae

Genus *Strombus* Linnaeus, 1758

Strombus gigas Linnaeus, 1758

Description: Shell solid, massive, spinose, color varying and roughly sculptured. Color of outer shell yellowish. Aperture long, comparatively narrow, oblique and with a slightly developed stromboid notch near base of the outer lip. Outer lip large and flaring, moderately thickened. Spiral sculpture on the first post-nuclear whorls

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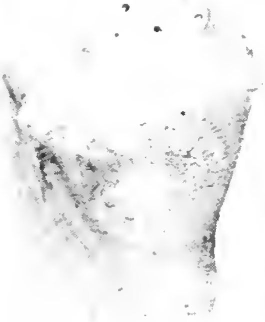

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FIGS. 1-8. *Fossil* Strombus gigas *Linneaus of probable Pleistocene age from Mule Pen Quarry, northeast of Naples, Florida. All specimens illustrated one-third natural size.* **1.** *and* **3.** *Adapertural and apertural views of a badly bored specimen. USNM No 244729.* **2.** *and* **7.** *Apertural and adapertural views of a well preserved specimen. USNM 244730.* **4.** *and* **5.** *Apertural and adapertural views of the largest specimen; the expansion of the aperture is overemphasized because the spire is broken back. USNM No 244731.* **6.** *and* **8.** *Apertural and adapertural views of a well preserved specimen, lacking the lower part of the aperture. USNM No 244732.*

consists of very fine striae which on the succeeding whorls become larger and more distinct. Often the most striking feature of *S. gigas* is a row of seven spines which separate the body whorl from the spire. The apex is relatively sharp.

Discussion: I have figured four specimens, and these are deposited in the National Museum of Natural History, Smithsonian Institution and catalogued number 244729-244732. These range in length (measured from the apex of the spire to the most distant edge of the siphonal canal) from 170 mm to 190 mm. Clench and Abbott (1941) recorded lengths of *S. gigas* to 300 mm. The range in length of 320 adult conchs from the Virgin Islands was 151 mm to 261 mm. (Randall 1964).

Distribution: Recent *S. gigas* ranges from southern Florida and Bermuda through the West Indies to northern South America (Clench and Abbott, 1941, p. 13).

Bathymetric range: All species in this genus live in comparatively shallow water, occurring in the intertidal zone and down to a depth of at least 36 meters. W. J. Clench and R. T. Abbott have seen *S. gigas* in eleven to fifteen meters of water in the Bahamas, though it generally prefers much shallower water. *Strombus gigas* was found at 36 m on Arrowsmith Bank ("Gerda" stations 883, 884, and 886, September, 1967), by Dr. Moore. Johnson (1965) reported *S. gigas* rarely in depths to 60 m. Johnson was a scuba diver who worked in the Bahamas, and his observations were probably made there; he does not state whether these specimens were alive or dead.

Strombus gigas is usually found in clear warm tropical water chiefly where calcium carbonate sediments predominate. Adult conchs are often encountered in beds of seagrass, primarily turtle grass and manatee grass, and on open sand bottom. Conchs are also found on gravel, coral rubble and hard coral rock bottom when it is relatively smooth. The west coast of Florida has areas that seemingly would support *S. gigas*, but the species has not been found there, perhaps due to cool temperatures during the winter.

Other fossil records: Fossil records of *S. gigas* are rare, and it is not mentioned in most works on Caribbean fossils. Usually very poor fossils are found in uppermost sediments around southern Florida. Two good shells of *S. gigas* are in the collections of History Museum, Basel, Switzerland. They were collected from part of the Coral Rock Formation of Barbados.

In 1969 the Geology Department of the University of the West Indies, Kingston, Jamaica, improved the outcrop of the Bowden shell bed with a bulldozer; this is the type locality of the Bowden Formation. Woodring (1928) assigned a late middle Miocene age to the Bowden Formation, though some later paleontologists working with Foraminifera consider it Pliocene. During the process of excavating, a large, almost complete specimen of *Strombus gigas* was uncovered from a thick, clay, and silty bed about 4 m above the present road (Jung, 1971). It seems to be the oldest fossil specimen known of this species, if it is of Bowden age.

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SCHISTOSOME DERMATITIS FROM *POMACEA PALUDOSA* (SAY) (PROSOBRANCHIA: PILIDAE)[1]

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ABSTRACT

A dermatitis-producing cercaria is reported from Pomacea paludosa *from Lake Okeechobee, Florida. Dermatitis was contracted from March-August and caused maculopapular eruptions of the skin which were accompanied by intense itching. This is the first report of schistosomes from* Pomacea *within the United States.*

Schistosome dermatitis occurs when man becomes the accidental host to cercariae of "nonhuman" schistosome trematodes. The cercariae penetrate the skin where they soon die, causing a hypersensitive reaction of the skin (Hoeffler, 1974). Such dermatitis is globally distributed and is widespread in the United States (Jarcho and Van Burkalow, 1952). In Florida, dermatitis has been reported from marine localities (Penner, 1953; Short and Holliman, 1961), and from an unspecified river near Tampa (Cort, 1936).

The adult trematodes live in the mesenteric veins of waterfowl, marshbirds, and small mammals (Cort, 1950). Eggs pass in the host's feces and hatch, in water, into miracidia which infect snails, their intermediate hosts. In the United States, schistosome cercariae have been reported from species of freshwater pulmonates *(Lymnaea, Physa, Planorbis [i.e. Helisoma], Stagnicola, Gyraulus, Hydrobia)* (Farley, 1971; Scott and Burt, 1976), marine prosobranchs *(Littorina, Batillaria, Nassarius [i.e. Ilyanassa], Cerithidea)*, and the marine opisthobranch, *Haminoea* (Farley, 1971).

While doing field research in Moonshine Bay, Lake Okeechobee, Glades County, Florida (26° 54′ N, 81° 02′ W), the senior author contracted dermatitis. The infection resulted from wading in the shallow, vegetation-choked airboat trails that cross the bay. The dermatitis, present from March—August, was most prevalent in June and July, as evidenced by a greater number of cercarial lesions.

The dermatologic response was similar to that described by Hoeffler (1974). Initial cercarial contact caused burning and itching for several hours. After a subsequent quiescent period of eight hours, maculopapular eruptions appeared, accompanied by intense itching that lasted for several days. Vesicles formed after two days and lasted for two weeks.

Adult apple snails, *Pomacea paludosa* (Say) (Prosobranchia: Pilidae) were isolated in glass jars and, after several hours of darkness, were subjected to direct incandescent light. The snails shed furcocercous, apharyngeate, brevifurcate, distome cercariae (Schistosomatidae: *Cercaria* sp.). These cercariae elicited a dermatologic response when placed on the authors' arms. A sample of three hundred and twenty-six snails, collected July 11, 1976 from Moonshine Bay, were isolated and found to have a three percent infection of schistosomes.

To our knowledge, this is the first record of a dermatitis-producing schistosome from *Pomacea* within the United States. The only previous record of a larval schistosome from *Pomacea* is *Cercaria heteroglandula* from *Pomacea glauca* in Venezuela (Nasir and Diaz, 1968).

Cort (1950) reported dermatitis-producing cercariae to be associated with shallow, warm, quiet waters that are thick with vegetation and have large snail and waterfowl populations. Moonshine

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[1] Supported by U. S. Fish and Wildlife Service Contract Number 14-16-008-905.

Bay provides a similar habitat. It is a backwater bay consisting of a wet prairie of almost pure stands of spikerush, *Eleocharis cellulosa*. The airboat trails contain large quantities of bladderwort, *Utricularia* sp., and white waterlily, *Nymphaea odorata*. During the summer, the water is warm (X = 26° C) and shallow (<0.5 m), and has a silt bottom which is overlayered with floculants. *Pomacea* is abundant in the area, where it forms an important food source for the limpkin *(Aramus guarauna pictus)*, the boat-tailed grackle *(Cassidix mexicanus)*, and the endangered Everglade kite *(Rostrhamus sociabilis plumbeus)* (Synder and Snyder, 1969).

In the freshwater lakes of Michigan and Wisconsin migratory waterfowl were found to be the predominant definitive hosts of the adult schistosomes (Cort, 1950). It is likely that the primary host in Moonshine Bay will be one of the many species of local and migratory waterfowl that makes extensive use of the area.

ACKNOWLEDGMENTS

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THREE INTRODUCED GASTROPODS IN IOWA

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ABSTRACT

Three introduced gastropods are reported from Iowa for the first time: Arion fasciatus *in Story and Allamakee Counties,* Lehmannia valentiana *from greenhouses in Ames, Story County, and* Viviparus malleatus *in Polk County, Iowa.*

The continuing expansion of the ranges of introduced gastropods in North America is an interesting but poorly documented phenomenon (Chichester and Getz, 1968). Recent collecting in central and northeast Iowa has revealed the following introduced species:

Arion fasciatus (Nilsson, 1822). This is the most widely distributed of three closely related species formerly considered conspecific with *A. circumscriptus* (Chichester and Getz, 1973). Two foci were found in Ames, Story County, Iowa: a sparse population in the Iowa State University Arboretum, and an extensive, apparently long-established colony in deciduous woods bordering Squaw and Onion Creeks (Pammel Woods and Emma Lee McCarthy Park). Associated gastropods were *Anguispira alternata, Deroceras laeve, Discus cronkhitei, Gastrocopta contracta, Helicodiscus parallelus, Retinella indentata, Stenotrema fraternum* and *Zonitoides arboreus.* Several stations in suitable habitat along the Squaw above and below this area did not yield *A. fasciatus* in the summer of 1976. A reasonably thorough survey of local molluscs in 1940 (Jones, 1941) did not mention this species. A third colony of *A. fasciatus* was discovered in July, 1976, in Paint Creek Unit of Yellow River State Forest, Allamakee County. Numerous specimens were collected from drift piles along Paint Creek, associated with the pulmonates mentioned above, as well as *Haplotrema concavum, Mesodon clausus, M. thyroidus, Stenotrema hirsutum, Triodopsis multilineata* and *Zonitoides nitidus.*

Lehmannia valentiana (Ferussac, 1823) is often reported as a synonym *L. poirieri* (Mabille) or as *L. marginata* (Müller) (see Walden, 1961). It is widespread in North America as a greenhouse pest but apparently does not survive out-of-doors except in California and the "South" (Getz and Chichester, 1971). Numerous specimens were taken in the greenhouses of the U. S. D. A. Regional Plant Introduction Farm in Ames, Story County, Iowa.

The freshwater Apple Snail, *Viviparus malleatus* Reeve, has been reported in several northeastern states and California (summarized by Perron and Probert, 1973), recently from Montreal (Bucci, 1974) and Michigan (H. van der Schalie, pers. comm.). A colony of this snail was found in the Riverview Park Lagoon (an oxbow of the Des Moines River) in Des Moines, Polk County in 1973. Subsequent collections in 1974 and 1975 indicate that it is well-established there. More recently this species has been identified as *Cipangopaludina chinensis* (Gray).

It is of interest that *Deroceras reticulatum,* the most widespread introduced gastropod in North America, has not been noticed in collecting at more than 50 localities in Iowa. The native *D. laeve* is frequently encountered.

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Obituary

We regret to announce the death of Mrs. James Denny at the age of 72, on March 12, 1978, on Sanibel Island, Florida. Originally from Dearborn, Michigan, Helen went to Florida in 1953 where she owned and operated the Jewel Box shell shop on Sanibel. She was the founder of the Southwest Florida Conchologist Society and was a member of several other shell clubs. Helen Denny was renowned for her shell art.

Literature Exchange

I have early issues of THE NAUTILUS and papers by Dall and others. Will *only* trade for THE NAUTILUS and papers, reprints or copies on northern mollusks that I need. Send your list of what you have and your wants to Rae Baxter, Box 96, Bethel Alaska 99559.

THE LATITUDINAL AND BATHYMETRIC RANGES OF LIVING AND FOSSIL *MESODESMA ARCTATUM* (BIVALVIA) WITH NOTES ON HABITS AND HABITAT REQUIREMENTS

A. S. Merrill[1] J. D. Davis[2] K. O. Emery[3]

ABSTRACT

Living adult Mesodesma arctatum *range from Belle Isle Strait between Labrador and Newfoundland south to the eastern shore of Long Island, New York. A companion species,* Mesodesma deauratum, *is restricted to the St. Lawrence Estuary and the western portion of the north shore of the Gulf of St. Lawrence. Both species are intertidal residents generally restricted to well-sorted sand and gravel in shallow water particularly adjacent to the mouths of streams and tidal inlets. Fossils of* M. arctatum *range from Hare Island, western Greenland, to Cape Hatteras, NC (and possibly even to Beaufort Inlet, NC). Fossils are common on the middle Atlantic shelf to a depth of 355 m, and they even have been transported beyond the shelf by strong currents to the floor of the Hudson Canyon at depths of at least 3,470 m. Radiocarbon dating indicates that many of these fossils now found at latitudes and depths beyond the present range lived during the Holocene Stage of the Quaternary.*

Occasionally in the literature, the range of a living species is based upon dead material that may be fossil, or upon juvenile specimens that may live outside their range but are not able to reach adulthood and reproduce in the areas in which they were captured. Such is the case for *Mesodesma arctatum* (Conrad, 1831). According to recent literature (Abbott, 1954, 1974; Richards and Ruhle, 1955; Richards and Werner, 1964), *M. arctatum* ranges from Greenland to Chesapeake Bay, VA, from low water to 90 m. These range extremities, however, are based upon Holocene or older fossil shells, and the extreme depth upon juvenile specimens. One of us (Davis) has collected *M. arctatum* through nearly its entire range. Northernmost living adult specimens were taken at Forteau Bay, Labrador, in Belle Isle Strait, by the *Blue Dolphin* Expedition (U. S. National Museum specimens—see Nutt, 1952). Major collections of live adult specimens were taken by Davis intertidally at Western Brook near Port Daniel on the western coast of Newfoundland.

The southernmost limit for adult specimens is Long Island. Jacobson and Emerson (1961) remarked that *M. arctatum* is common in eastern Long Island as far west as Patchogue. The U. S. National Museum contains adult specimens taken alive from "Long Island, NY" and fresh dead ones from Montauk, NY. The southernmost location at which we have collected substantial numbers of *M. arctatum* is at the mouth of Shinnecock Inlet on the south shore of Long Island. The Museum of Comparative Zoology (Harvard University) has specimens from 80 km south of Block Island, RI (depth about 80 m) taken alive—all very small, and a small live specimen taken intertidally at Sandy Hook, NJ in June 1962. No records are on file of live adult *M. arctatum* from New Jersey waters or from deeper ocean sites.

Davis also collected *Mesodesma deauratum* (Turton, 1822) throughout its range within the St. Lawrence Estuary and extending eastward along the north shore of the Gulf of St. Lawrence. Davis (1964, 1965) previously had determined the features that identify and separate the two species. All evidence indicates that the two

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species now occupy mutually exclusive distributional areas, with the separation extending from an undetermined point on the north shore of the Gulf of St. Lawrence to Anticosti Island and thence southwestward to the easternmost part of the Gaspé Peninsula. Curiously, Dionne (1977) reported fossil *M. arctica* [=*M. arctatum*] in gravelly sand at 4 m above sea level on the south side of the St. Lawrence Estuary. Its radiocarbon age of 2,240 ± 140 years before present (B.P.) implies species misidentification (if Dionne is referring to *M. arctatum*) or subsequent changes in environment in this region.

Emery and Garrison (1967) commented that *M. arctatum* is ". . . common on exposed beaches, especially adjacent to the mouths of streams and tidal inlets." Emerson and Jacobson (1976) stated that the species lives in shallow water in sand on the eastern shores of Long Island, tending to congregate around inlets and bays. According to our observations, *M. arctatum* is a species that definitely is intertidal to 10-12 m in depth range and whose habitat is restricted to high energy beaches such as those occurring at the mouths of rivers and tidal inlets. The species commonly inhabits beaches and bars of well-sorted sand, gravel, and shell where resident infauna must cope with frequent and sudden relocation of the substratum. With its wedge shape and well-developed foot, it is uniquely adapted to this type of environment. Davis (1963) determined that the average burial times of *M. arctatum* under laboratory conditions ranges from slightly more than ½ minute for young specimens (10-12 mm long) to less than 2 minutes for adults (longer than 30 mm). A comparative grain-size analysis of sediments from several areas commonly inhabited by the species showed a preference for well-sorted sand usually having median grain diameters between 0.5 mm and 1.0 mm; Davis concluded that the burrowing habit probably is facilitated by such substratum. The shell shape and habits are reminiscent of *Donax;* when exposed to wave action, both are remarkably adapted to promptly "dig in" again. Most family members of the Mesodesmatidae around the world exhibit essentially similar habits. Because of their restricted habitats, fossils of both *M. arctatum* and *M. deauratum* could be excellent indicators of former stream or lagoon mouths.

The reported northern extreme limit for *M. arctatum* is based upon two dead valves from off Hare Island (Hareøen), western Greenland in 65 m (USNM lot 194169), about 2,200 km north of Forteau Bay. The fossils are adult in size (longer than 25 mm) and badly eroded. Probably they lived in Greenland during the Sangamon interglacial stage when sea level was lower and temperatures higher than now.

The reported southern extreme limit is based upon a single dead valve (USNM lot 78351—USFS Sta. 1070 in 18-27 m, "off Chesapeake Bay"). The fossil is badly eroded, has been subjected to attack by both *Polinices* and *Polydora,* and has a length of 33.2 mm. Actually, USFS Sta. 1070 is within the Chesapeake Bay system at Lat. 38° 54′ N, Long. 76° 28′W off Thomas Point Light, MD. The fossil thus was deposited probably during the Pleistocene before the Wisconsin glaciation at a time in Maryland when sea level was higher and temperatures lower than now. Richards (1944) also recorded *M. arctatum* from spoil bank dredgings of the Cape May canal across the southern tip of New Jersey from the Atlantic coast to Delaware Bay. He placed them in his list of cold-water species and indicated deposition at the beginning of the Wisconsin glaciation. Even farther south, Porter (1974) found dead specimens from southeast of Beaufort Inlet, NC in 70 m that he identified as *M. arctatum* with a question mark. Extension south of Cape Hatteras is reasonable, because the annual temperature regime there during the past glacial advance would equate with temperatures today at about the latitude of the eastern shore of Long Island—the southernmost record of living adult *M. arctatum.*

Between the reported extreme latitudes, Bush (1885) listed mollusks dredged by *Fish Hawk* between the southern slope of Georges Bank and the region off the Chesapeake Bay. No attempt was made to show the distribution of species, but the vertical ranges of live and dead specimens were given. Live *M. arctatum* were reported in depths to 4 m, dead in depths to 355 m.

During a research cruise (R/V *Delaware* 60-7) fossil specimens of *M. arctatum* were taken by

Merrill at 24 stations in the Middle Atlantic Bight from south of Block Island, RI to near Cape Hatteras, NC in depths of 30 to 145 m. These data were briefly analyzed by Edwards and Merrill (1977). Relict shells were found at depths that were greater on the average at northern stations. At the 14 stations north of Lat. 38° N, the depths averaged 80 m, whereas from 10 stations south of Lat. 38° N, the depths averaged 47 m. The species was distributed in two or three narrow bands generally parallel to the coast, perhaps related to Holocene submerged shores (Fig. 1).

Even greater depths were reported by Richards and Ruhle (1955), who found fossil *M. arctatum* to be the most abundant species 70 to 100 cm within a core from a depth of 3,470 m in the floor of the lower gorge of the Hudson Canyon. Their presence at this site is explained by the action of strong currents transporting them with sand and gravel through the canyon during a marine transgression. A Wisconsin age was suggested.

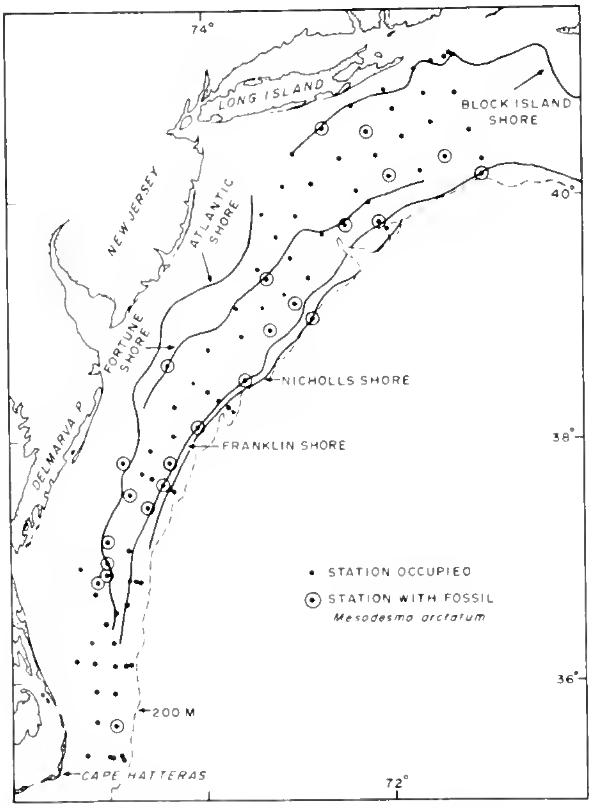

FIG 1. *Distribution of fossil specimens of* Mesodesma arctatum *(Conrad) along the continental shelf of the Middle Atlantic Bight. The Holocene shorelines are those described and modified in turn by Veatch and Smith (1939), Emery and Uchupi (1972, p. 30-33), and Dillon and Oldale (1978). Note the general correspondence of stations having fossil* M. arctatum *with the Holocene shoreline. See Merrill, Bullock, and Franz (1978) for station numbers and positions of major transects.*

Several radiocarbon dates of *M. arctatum* for the middle Atlantic Bight have been published. Oldest are the specimens reported by Richards and Werner (1964) within a core adjacent to the Hudson Canyon at a depth of 155 m. Fossil shells within the core gave a radiocarbon date of 15,000 ± 100 years B. P. A sample from a nearby core (with no *M. arctatum*) yielded a date greater than 35,000 years, indicating more than one ancient shelly deposit. Emery and Garrison (1967) dated *M. arctatum* from three cores. One was south of Block Island 86 m deep and two were south of Marthas Vineyard 122 and 130 m deep. The shells were in medium to coarse-grained sands with some gravel and within the core as deep as 117 cm below the ocean floor. A layer of the shells in one core was imbricated, implying placement by waves on a beach. Radiocarbon ages were 10,850 ± 150 years, 13,420 ± 210 years, and 14,850 ± 250 years B. P., respectively. The ages and water depths of the dated material correspond well with those of other dated shallow-water Holocene mollusks in the middle Atlantic Bight. Unfortunately, however, in a review of Holocene sea levels of the Atlantic shelf, Macintyre, Pilkey, and Stuckenrath (1978) discounted the evidence of the shallow-water sediments within these cores, accepted the deeper water bathymetric ranges of *M. arctatum* recorded in the literature, and chose not to use these radiocarbon-dated materials as evidence for very low sea levels at about 15,000 years ago. Probably, knowledge of the limited depth range of habitat documented here would have caused them to reject less readily these dates and depths for early Holocene sea levels.

Bloom (1960, 1963) reported fossil *M. arctatum* from a gravel pit 27-30 m above sea level in the Presumpscot Formation of southwestern Maine, a marine bed deposited after partial melting of the Wisconsin ice sheet and before isostatic rebound of the crust was completed. One of us (Davis) collected fossils of the species in coarse-grained obviously stream-mouth sediment of the Presumpscot Formation at Bloom's site near Cumberland, Maine. The fossils were in their natural positions, both valves intact, indicating that the area was undisturbed since being an intertidal habitat. Specimens collected at this site yielded a radiocarbon date of 12,210 ± 120 years B. P. (Yale-1775), confirming Bloom's (1963) date of 12,100 ± 300 years B. P.

One conclusion of this study is that it is essential to use only records of live adult specimens when establishing the latitudinal and bathymetric range of a species. Use of fossil adult records will increase the latitudinal range, while use of live juvenile records will increase the bathymetric range. Adventitous dispersal of juvenile specimens of estuarine mollusks into deeper water is common, but the absence of adult specimens in similar environments indicates inadequate areas for year-round residence and for reproduction.

Another conclusion is that a comparison of latitudinal and bathymetric distributional patterns of living and fossil adult mollusks of the same species often can lead to a better understanding of some of the dramatic environmental and climatic events of the past. For instance, fossil shells of estuarine species found at a higher elevation on land or in deeper offshore oceanic waters than the living specimens may denote habitations in these places when sea levels were higher or lower than at present. Similarly, a fossil of an oceanic species found north or south of its present range probably was alive when temperatures were either warmer or colder than now. During the late Wisconsin stage prior to about 15,000 years ago, much of the ocean water was bound in glacial ice, resulting in a relative sea level along the middle Atlantic coast of the United States more than 100 m lower than at present. Increased temperatures during the past 15,000 years (Holocene Stage) caused considerable melting of glacial ice and return of sea level to its present position. The gradual landward advance of the shore zone left behind a thin sheet of post-glacial coarse-grained relict sandy sediments generally less than 10 m thick. On the surface and within the relict sediments are fossil remains of former inhabitants that can be sampled easily by dredges or coring devices. These fossils can provide evidence regarding positions of former stream mouths, tidal inlets, and shorelines as well as indicating species that once inhabited areas now outside their environmental tolerances.

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OBSERVATIONS ON THE ABUNDANCE, DISTRIBUTION AND GROWTH OF POSTLARVAL SEA SCALLOPS, *PLACOPECTEN MAGELLANICUS*, ON GEORGES BANK[1]

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ABSTRACT

Two hundred and thirty-one newly settled sea scallops, Placopecten magellanicus, *were collected from Georges Bank at 16 of 41 stations in February, 1977, and 56 more postlarval scallops were collected at 12 of 42 stations in May, 1977. Mean lengths increased from 1.0 mm to 1.3 mm between February and May indicating a slower growth rate than has previously been reported. Correlation analyses of postlarval scallop abundance and the physical factors of sand grain size, water depth, salinity, and temperature suggested no significant relationships. The possible role of surface debris in the early life history of the sea scallop and the potential causes of the high early mortality are discussed.*

The sea scallop, *Placopecten magellanicus,* occurs only in the northwestern Atlantic from the Straits of Belle Isle to the Virginia Capes (Posgay, 1957). Marketable quantities are found in many areas, including Port-au-Port Bay, Newfoundland; Northumberland Strait, Prince Edward Island; Digby and Grand Manan areas of the Bay of Fundy; major estuaries and embayments of coastal Maine; Stellwagen Bank; Cape Cod Bay; Georges Bank, and the continental shelf near the Hudson, Baltimore and Norfolk Canyons (Altobello *et al.*, 1977). The largest fishery is on Georges Bank, which produced 232,000 metric tons of meat, representing 68% of the total catch of the U.S. and Canada, from 1940 to 1975 (Posgay, personal communication).

Although the sea scallop fishery is presently the most valuable fishery on Georges Bank, there is a dearth of information concerning the recruitment

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[1] Contribution number 78004 from the Bigelow Laboratory for Ocean Sciences.

and early life history of the species. The abundance and distribution of the sea scallop is only reported for specimens older than 2½ years (Posgay, 1957; Merrill, 1962; and Bourne, 1964). The spawning of the species has been observed by Posgay and Norman (1958) on Georges Bank, but the larvae have never been identified in the plankton (Culliney, 1974). Except for the few specimens described by Merrill and Posgay (1967), postlarval and juvenile scallops are virtually unreported from the benthic samples of Georges Bank and much of what is known about the early life history of this species is inferred from populations fouling navigational buoys (Merrill and Edwards, 1976). The purpose of this paper is to present information on the abundance, distribution and growth of newly settled sea scallops on Georges Bank.

METHODS

As part of the Bureau of Land Management's North Atlantic Environmental Studies Program, sediments of Georges Bank were sampled at 42 stations from February 11, 1977, to March 6, 1977, and from May 6, 1977, to May 26, 1977 (Fig. 1.). Six replicates at each station were taken with a 0.1 m² modified Smith-McIntyre grab. A subsample was removed from each replicate grab for sediment size analysis. The remaining contents of each grab were sieved on a 0.5 mm screen and the material remaining on the screen was placed in a 6% $MgCl_2$ solution for 30 minutes and then transferred to buffered 10% formalin. In the laboratory, the samples were transferred to 70% ethyl or isopropyl alcohol. Except for the 5th and 6th replicates of the May cruise, all organisms were separated from the sediment, counted, and identified to species. Identifications of the postlarval scallops were made referring to the papers of Merrill (1959, 1961). The lengths of the undamaged sea scallops were measured to the nearest 0.1 mm using an ocular micrometer.

At each station depth, bottom temperature, and bottom salinity were recorded using a Neil Brown Instrument Systems Mark III CTD. In addition, a series of bottom photographs were taken at each station using a camera and flash, Models 371 and 381 respectively, manufactured by Benthos Inc.

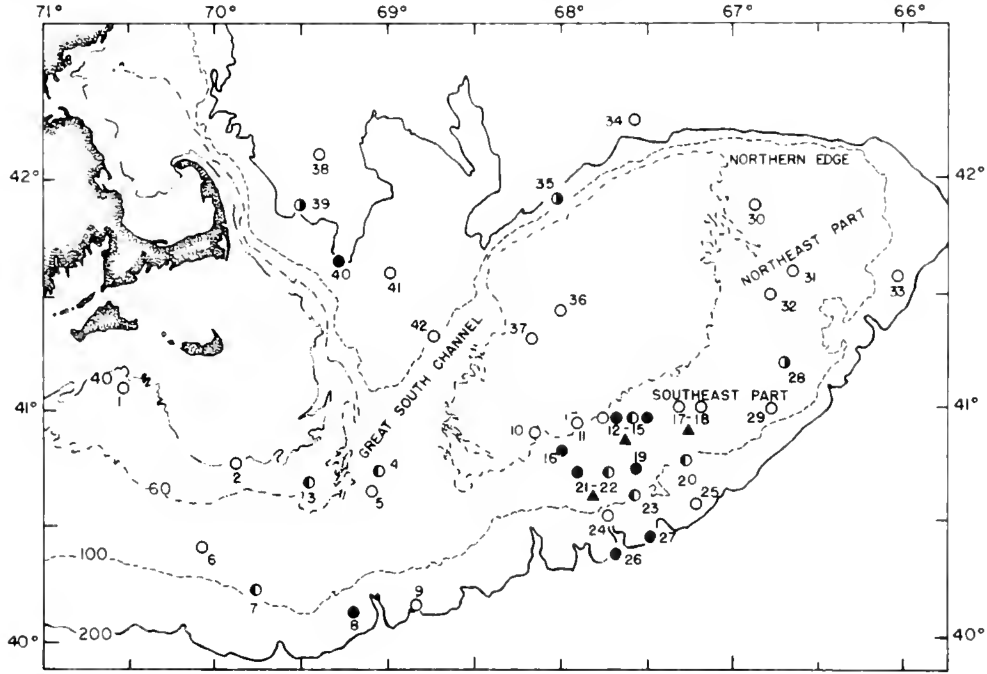

FIG. 1. *Distribution of benthic stations on Georges Bank. Solid circles indicate the presence of postlarval sea scallops in both February and May 1977; circles filled on left half indicate stations at which postlarval scallops were found only in February; circles filled on the right half indicate stations at which postlarval scallops were found only in May; and at stations marked by open circles, no postlarval scallops were found.*

TABLE 1 *Density of postlarval sea scallops and environmental parameters observed at stations on Georges Bank during the winter and spring of 1977 A) February cruise, B) May cruise*

A. February Cruise

Station	*Postlarval sea scallops (Number m^{-2})*	*Depth (m)*	*Bottom Temperatures (°C)*	*Bottom Salinity (‰)*	*Median Grain size (Φ)*
3	1.7	51.76	3.94	33.67	2.7
4	1.7	73.55	4.90	33.82	2.5
7	3.2	83.18	6.28	34.13	1.9
8	1.7	114°	—	—	1.9
13	46.4	81°	5.46	33.93	1.7 - 2.3
14	3.2	73.59	4.70	34.06	2.0
15	43.2	75.83	4.95	34.08	1.8 - 2.0
16	122.8	77.20	4.92	34.08	1.9 - 2.0
19	3.2	75.38	5.30	34.12	1.7 - 2.6
20	1.7	69.46	6.09	34.21	2.8
21	21.6	86.70	5.29	34.03	1.6 - 1.7
22	117.9	165.11	7.97	34.71	2.5 - 2.8
23	5	125.09	8.80	34.90	2.2
26	1.7	129.59	10.60	34.30	2.8
27	1.7	116.61	8.95	34.90	2.6 - 2.7
40	3.2	114.2	5.23	33.97	−2.4 -3.0

B. May Cruise

Station	*Postlarval sea scallops (Number m^{-2})*	*Depth (m)*	*Bottom Temperatures (°C)*	*Bottom Salinity (‰)*	*Median Grain size (Φ)*
8	2.5	98.34	7.25	34.12	2.6
13	7.5	76.59	6.55	33.75	1.6
15	7.5	76.81	6.37	33.85	1.7 - 1.9
16	62.5	79.81	6.37	33.85	2.0 - 2.2
19	22.5	87.51	6.95	34.07	1.5 - 1.6
21	12.5	85.58	6.57	33.88	1.5 - 1.7
26	2.5	132	—	35.33	2.6
27	12.5	132.44	11.25	35.34	2.6
28	2.5	84.19	6.25	33.74	1.7
35	2.5	226.47	7.23	34.85	1.2
39	2.5	86.27	4.42	33.11	1.4
40	2.5	113.62	4.95	33.71	2.6 - 2.9

° Hydro Wire Reading.

RESULTS AND DISCUSSION

Two hundred and thirty-one newly set sea scallops were collected at 16 of 41 stations in February and 56 more postlarval scallops were collected at 12 of 42 stations in May (Fig. 1). Population densities ranged up to 122.8 m^{-2} in February and 62.5 m^{-2} in May (Table 1). Seventy-eight percent of the scallops collected on the February cruise and eighty-nine percent of the scallops collected on the May cruise were located within the southeastern part of Georges Bank between 67°30′W and 68°00′W longitude and 41°00′N and 40°30′N latitude. Although this section is one of the four major population centers of adult scallops on Georges Bank, it has only supported a sporadic fishery. The Northeast Peak, the Northern Edge, and the Great South Channel have been consistently productive but, unfortunately, these areas were not sampled adequately enough to allow meaningful comparisons of spatfall abundance between the major population centers.

The postlarval scallops in these collections are, to our knowledge, the smallest specimens of this species ever collected in the field. They are members of the 1976 year class which will enter the Georges Bank scallop fishery in 1980 or soon thereafter. The size distribution of the 231 postlarval scallops collected during the February cruise ranged from 0.2 mm to 2.8 mm in length with a mode at 0.8 mm and a mean length of 1.0 mm. The 56 specimens recovered during the May cruise ranged in length from 0.5 to 2.5 mm with a mode at 0.9 mm and a mean length of 1.3 mm. A test for homogeneity of variance in length distributions of the two groups was applied to determine if a t-test could be employed to test the differences in the means. Since homogeneity of variance did exist, we can assume that recruitment was minimal between February and May and that the difference in length between the two seasons represents growth. A significant difference ($P < 0.05$) between the mean lengths of the two collections was demonstrated by the t-test which indicates that a mean shell growth of 0.3 mm or a 30% increase of length, occurred in the 11 weeks between the two samplings on Georges Bank.

If we assume that the majority of the sea scallop larvae on Georges Bank have settled to the benthic environment by mid-December, as has been previously postulated by Merrill and Edwards (1976), then our results indicate a mean shell growth to 1.0 mm two months after settlement and to 1.3 mm five months after settlement. These rates are slower than those reported for postlarval sea scallops found on a Nantucket Shoal's navigational buoy, which grew to an average of 2.5 mm within six to seven months of settlement (Merrill and Edwards, 1976). Merrill and Posgay (1967) found that benthic populations of juvenile sea scallops grew to 25 mm within 18 months of settlement while populations from navigational buoys only reached a length of 20 mm in an identical period of time. Unpublished data of Merrill (*personal communication*) suggests an even faster growth rate. From eight buoy collections taken in May and eight bottom samples, also taken in May, the lengths of juvenile scallops ranged in size from 2.0 to 10.0 mm and 3.0 to 14.0 mm, respectively. These wide variations in the apparent growth rate cannot be explained with the limited data that exists on postlarval and juvenile scallops, but geographical and interannual variations in growth rate, as well as differences in sampling methods, may all be involved.

The early stages of benthic life are periods of high mortality for many species (Thorson, 1966) and *Placopecten* seems to be no exception. The reduced densities found at most stations between the February and May cruises (Table 1) are indicative of natural mortality. The causes of the mortality are not fully known. Postlarval sea scallops have been found in the stomach contents of the asteriod starfish, *Astropecten americanus* (David Franz, *personal communication*), and undoubtedly several species of crabs and demersal fish also prey on them. Our collections contained several clappers (empty valves) which might indicate predation by sea anemones or sea cucumbers, or might also indicate another source of mortality. It is possible that these very small individuals succumbed to sediment movements that buried them slightly or fouled their respiratory apparatus. We do not have a quantitative estimate of the dead to live ratio which might be used as an estimate of the natural mortality rate (Merrill and Posgay, 1964) because many clapper shells were probably separated during the sieving process, and others were surely passed over during the presorting process since the emphasis of the project was on the living community at the time of sampling. Given these limitations, it may still be contended that the natural mortality rate is high since postlarval scallop valves are known to separate shortly after death (Merrill and Edwards, 1976) and, therefore, the presence of any postlarval clappers can be considered indicative of a relatively high mortality rate.

The relationship between settling sea scallop larvae and sedentary bottom organisms and debris had been previously described. Baird (1953) found scallops set in the branches of the bryozoan *Gemellaria*. Merrill and Edwards (1976) theorized that there would be a selective advantage for those individual larvae that settled on any upright structure on the bottom because they would be protected from the shifting bottom sediments until they were old enough to cope.

In the present study, we found a few postlarval scallops attached by their byssus to the colonial hydrozoan *Hydrallmania*, to amphipod tubes and to grains of sand. A large number of the byssus attachments in our samples were probably broken by the sieving and sorting processes so we do not have an estimate of what percentage of the spat attached themselves to objects on or above the sediment surface and what percentage survived on the surface itself.

Surface debris may serve in another way to enhance the survival of post-settlement sea scallops. Castagna and Kraeuter (1977) have shown that a layer of gravel over a bed of young clams serves to protect them from predation. The gravel allowed sufficient water to pass to the individuals while acting as a barrier to crabs and other predators. Culliney (1974) did a series of experiments with laboratory raised *Placopeeten* larvae which indicated that the larvae settled more quickly in the presence of shell, pebble, or glass fragments on the bottom of their containers, and furthermore, they tended to metamorphose on the underside of those fragments. If this behavior occurs in the scallop's natural environment, it may provide the postlarval scallops a degree of protection from predation. Therefore, objects on the bottom may enhance the survival of post-settlement scallops by providing them protection from shifting sediments and/or providing them with protection from predation. We examined the bottom photographs taken during the sampling process, but they were of too gross a nature to make any correlation with the amount of debris on the bottom and the number of postlarval scallops recovered there.

The February distribution of the postlarval scallops was examined relative to the abiotic (physical) factors of median sediment grain size, depth, temperature, and salinity to determine if the scallop distribution was in any way related to these factors. Postlarval scallops were recovered from sediments with median grain sizes ranging from 3.0 to -2.4 on the phi scale. In Wentworth size class terminology, this range translates to fine sand to pebble sized gravel. A linear correlation was performed between the median grain size and the abundance of newly set scallops and the resulting correlation coefficient was insignificant ($r = 0.02$). In other words, based on this sampling program, it would seem that larval scallops do not respond to mean grain size during settlement.

The ranges of the other abiotic factors at the stations yielding postlarval scallops are 51.7 to 226.5 m for depth, 3.94 to 11.25°C for temperature and 31.11 to $35.34^{0}/_{00}$ for salinity. As with the median grain size, linear correlation analyses of the February data suggested that no relationships exist between these factors and postlarval scallop abundance.

It is interesting to note that station 25 in February and stations 22, 23, 25, 26, and 27 in May appear to be under the influence of slope water which is defined by Wright (1976) as having a salinity greater than $35^{0}/_{00}$ and a temperature in excess of 10°C. Stations 26 and 27 contained postlarval scallops in both February and May. Posgay (personal communication) has stated that adult scallops living below 100 m have slow growth rates probably due to lack of food, and Wright (1976) indicates that this same depth is the usual bottom boundary between shelf and slope water off the southern coast of New England. It follows, therefore, that the scallops at depths greater than 100 m, such as those at stations 26 and 27 on the south side of Georges Bank, settled successfully during extensions of shelf water over that bottom, but are then food limited and hence grow slowly in the nutrient poor slope water when the normal boundary is reestablished.

These preliminary observations on the early life history of the sea scallop in its natural environment raise some very interesting questions. For instance, do the larvae just rain indiscriminately to the sediment as metamorphosis is approached or do they respond to some parameter of the sediment surface, such as the presence of adults, shell debris, or biotic structures? If the larvae are indiscriminate in settlement, are adult beds formed by differential mortality in different areas? Are growth rates of the very young scallops significantly different between different geographic areas or between years?

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TWO NEW EASTERN PACIFIC SPECIES OF *CADULUS*, WITH REMARKS ON THE CLASSIFICATION OF THE SCAPHOPOD MOLLUSKS

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ABSTRACT

Cadulus (Polyschides) nedallisoni, *n. sp., and* C. (Platyschides) macleani, *n. sp., from the Gulf of California and off the coast of Nicaragua, respectively, are described and compared with related New World species. The supraspecific categories of the Class Scaphopoda are reviewed in the light of recently proposed taxonomic units.*

Two previously unrecognized species of *Cadulus* from the Panamic faunal province are described, illustrated and compared with related New World species. The present specimens, collected 12 to 40 years ago, were uncovered during an examination of scaphopod material in the Los Angeles County Museum of Natural History and in material obtained by the *Zaca* Expedition to the eastern Pacific Ocean (Beebe, 1938) and transferred to the American Museum of Natural History by the New York Zoological Society. The minute size of these specimens, less than 5 mm in length, apparently has resulted in them being overlooked in the past.

It is an honor to name these new species for two valued friends and respected colleagues, respectively, James H. McLean of the Los Angeles County Museum of Natural History and the late Edwin C. Allison (1926-1971), whose untimely death deeply saddened all who knew him.

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SCAPHOPOD CLASSIFICATION

Before undertaking the description of the new species, a review of the present status of the classification is in order. The modern classification of the scaphopod mollusks dates from Pilsbry and Sharp (1897-1898), who, following Paul Fischer (1885), recognized these animals as a distinct class of the Phylum Mollusca. They followed the two-fold division used by previous workers, placing the forms with relatively large shells and a conical foot in the family Dentaliidae. The other forms with relatively small shells and a vermiform foot with a distal disk were placed in the family Siphonodentaliidae. This division of the Scaphopoda was accepted by most subsequent workers, who have in recent years followed the fundamentally similar classifications proposed by Ludbrook (1960) and Emerson (1962). In the past few years, however, this basically pragmatic classification has been radically expanded and somewhat modified by other students.

Two authors independently presented new classificatory schemes in 1974. In the first of these, Starobogatov (published February 25, 1974), suggested that the xenochonchias were the common ancestors of the scaphopods and monoplacophorans. On the basis of what he considered to be a close similarity between the xenochonchias and the scaphopods, he recognized the Scaphopoda and Xenochonchia as subclasses of the molluscan class Solenoconchia. He continued the previous two-fold division of the scaphopods by the use of two ordinal categories within the Subclass Scaphopoda. To the order Dentaliida da Costa, 1776 (*ex*-Dentalia), he assigned the families Prodentaliidae Starobogatov, 1974[1] (with the nominate genus only included), Plagioglyptidae

Starobogatov, 1974[1] (with the nominate genus only included), and Dentaliidae Gray, 1834 (with the nominate genus and 20 other genus-group taxa afforded full generic status). Thus the genus-group taxa formerly assigned to the family Dentaliidae were retained and divided into familial groups to comprise an ordinal unit. The genus-group taxa that formed the family Siphonodentaliidae in previous classifications were also elevated by him to form an ordinal category, in which three familial units were recognized. In the order Gadilida Starobogatov 1974[1], he placed the following families: 1. Siphondentaliidae Simroth, 1894 (including the genera *Siphonodentalium* M. Sars, 1859; *Pulsellum* Stoliczka, 1868; *Entalina* Monterosato, 1872; *Compressidens* Pilsbry and Sharp, 1897; *Entalinopsis* Habe, 1957; and *Megaentalina* Habe, 1963; 2. Loxoporidae Starobogatov, 1974[1], (nominate genus only included); and 3. Gadilidae Stoliczka, 1868 (including the genera *Cadulus* Philippi, 1844; *Gadila* Gray, 1847; *Helonyx* Stimpson, 1865; *Dischides* Jeffreys, 1867; *Polyschides* Pilsbry and Sharp, 1897 [*sic* = 1898]; *Platyschides* Henderson, 1920; *Gadilopsis* Woodring, 1925; *Striocadulus* Emerson, 1962; and *Sagamicadulus* Sakurai and Shimazu, 1963).

Later in the same year, Palmer (published October 1, 1974) reassessed and redistributed supraspecific taxonomic units within the systematic arrangement of the class Scaphopoda that was proposed by Emerson (1962). He erected the order Dentalioida Palmer, 1977[1], with two familial categories to receive the genus-group taxa formerly placed in the family Dentaliidae. He restricted the Dentaliidae Gray, 1847 [*sic* = 1834] to dentaliid-like forms with longitudinal sculpture and recognized 10 genera (3 of which are polytypic). The family Laevidentaliidae Palmer, 1974[1], was proposed for the forms with annulated sculpture of those lacking sculpture. To this family he assigned 11 genera (2 of which are polytypic), including a new genus *Progadilina* Palmer, 1974[1], (type species by original designation: *Dentalium undulatum* Münster, 1844, from the Jurassic of England). For the genus-group taxa formerly placed in the family Siphonodentaliidae, he erected the order Siphonodentalioida Palmer, 1974[1]. The family Siphonodentaliidae Simroth, 1894 was restricted by him to forms with non-constricted apical orifices. He included in this family the genera *Entalina* Monterosato, 1872 (including the non-nominate subgenera *Entalinopsis* Habe, 1957, and *Megaentalina* Habe, 1963); *Siphonodentalium* M. Sars, 1858 [*sic* = 1859]; *Pulsellum* Stoliczka, 1868; and *Calstevenus* Yancey, 1973. The siphonodentaliid-like forms with constricted apical orifices that were previously placed in the family Siphonodentaliidae were placed by him in the family Cadulidae Grant and Gale, 1931, to which five genera were assigned. These are *Gadila* Gray, 1847 (including the non-nominate subgenus *Gadilopsis* Woodring, 1925); *Polyschides* Pilsbry and Sharp, 1898 (including the non-nominate subgenus *Platyschides* Henderson, 1920); *Cadulus* Philippi, 1844; *Dischides* Jeffreys, 1867; *Striocadulus* Emerson, 1962; and *Sagamicadulus* Sakurai and Shimazu, 1963.

An additional genus-group taxon, *Paleodentalium* Gentile 1974, (type species by monotypy, *Dentalium (Paleodentalium) kansasense* Gentile, 1974, from the Carboniferous of Kansas) was also proposed at this time for Paleozoic dentaliid-like forms with strong longitudinal sculpture (Gentile, 1974).

In the following year, Chistikov (1975) presented a brief review of the classification of the taxa formerly assigned to the family Dentaliidae. His work was stated to be based largely on a study of the morphology of the soft parts and especially the radular characters of "24 species in 11 genera of Dentaliidae," but the species studied were not specified, with the exception of the new species he described. He referred these taxa to the order Dentaliida da Costa, 1776, excluding the family Plagioglyptidae Starobogatov, 1974, which he stated should be placed in a separate, but unnamed ordinal unit. Within the order Dentaliida, he recognized three superfamilies. The first, the superfamily Quasidentalioidea Chistikov, 1975[1], was established by him for the family Quasidentaliidae Chistikov, 1975[1], based on the genus *Quasidentalium* Shimansky, 1974 (type species by O. D., *Q. opirarum* Shimansky, 1974, from the Carboniferous of Russia, which has questionable scaphopod affinities, in my opinion).

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[1] Denotes the proposal of a new supraspecific taxon by the author cited by year of publication

In the second superfamily, Dentalioidea Gray, 1834, (in which the family Prodentaliidae Starobogatov, 1974, was placed in synonymy), Chistikov recognized three subfamilies in the nominate family Dentaliidae Gray, 1834. These are the subfamily Dentaliinae Gray, 1834 (genera included: *Dentalium* Linné, 1758, *Coccodentalium* Sacco, 1896, *Fissidentalium* Fischer, 1885, *Compressidentalium* Habe, 1963, and *Schizodentalium* Sowerby, 1894); the subfamily Antalinae Stoliczka, 1858, (genera included; *Antalis* H. and A. Adams, 1854, *Lentigodentalium* Habe, 1963, *Paradentalium* Cotton and Godfrey, 1933, *Striodentalium* Habe, 1964, *Heteroschizmoides* Ludbrook, 1960, and *Spadentalina* Habe, 1963; and genera questionably referred: *Tesseracme* Pilsbry and Sharp, 1898, *Graptacme*, Pilsbry and Sharp, 1897, and *Fustiaria* Stoliczka, 1868); and the subfamily Calliodentaliinae Chistikov 1975[1] (genera included: *Calliodentalium* Habe, 1964, *Pseudantalis* Monterosato, 1884, and questionably *Laevidentalium* Cossman, 1888). Within the superfamily Dentalioida, he also recognized two non-nominate families. He questionably assigned here the family Gadilinidae Chistikov, 1975[1], based on the genus-group taxa *Gadilina* Foresti, 1895, and *Bathoxiphus* Pilsbry and Sharp, 1897. He allocated the taxa formerly placed in the genus-group taxon *Episiphon* Pilsbry and Sharp, 1897 to form the family Episiphonidae Chistikov, 1975[1], with the nominate subfamily Episiphoninae Chistikov, 1975[1], together with two other subfamilies. These are the subfamily Anulidentaliinae Chistikov, 1975[1], which is based on the genus *Anulidentalium* Chistikov, 1975[1], type species *A. bambusa* Chistikov, 1975, (a Recent species from the Gulf of Tonkin, Viet Nam) and the subfamily Lobantalinae Chistikov, 1975[1], for the genus group taxon *Lobantale* Cossman, 1888).

In the third superfamilial unit within the order Dentaliida, Chistikov established the superfamily Rhabdoidea Chistikov, 1975[1], with three familial units. In the family Rhabdidae Chistikov, 1975[1], he placed the taxa formerly referred to the genus-group taxon *Rhabdus* Pilsbry and Sharp, 1897, which were restricted to the nominate subfamily, and he proposed the family Eboreidentidae Chistikov, 1975[1], to include the genus *Eboreidens* Chistikov, 1975[1], (type species by original designation: *Dentalium lacteum* Deshayes, 1825) and the family Omniglyptidae Chistikov, 1975[1], for the genus *Omniglypta* Kuroda and Habe, 1953. The taxa formerly placed in the family Siphonodentaliidae were not covered by Chistikov.

Starobogatov's (1974) recognition of the scaphopods and xenoconchias as subclasses (Scaphopoda Bronn, 1862, and Xenochonchia Shimansky, 1963) within the class Solenoconchia Lacaze-Duthiers, 1857, was based largely on the common presence in these groups of a non-spiral, variously shaped, tube-like shell, which is either open at both ends or is closed at the apical end. As the phyletic relationships of these taxa are still not clear, these diverse organisms can be taxonomically united only on the basis of extreme speculation. Therefore, until more compelling paleontological and neontological data can be marshalled, the scaphopods are best treated as a distinct class of mollusks. With this major exception, the classification outlined for the scaphopods by Starobogatov (1974), and those presented by Palmer (1974) and Chistikov (1975) are largely expansions and modifications of the basic duo-system (families Dentaliidae and Siphonodentaliidae) utilized in the previous classifications. These authors have filled unoccupied ordinal ranks in the former system, and they have assigned higher hierarchical rankings to most of the previously supraspecific categories.

Unfortunately, much more information on the soft anatomy and the radular characters will be required in order to establish the biological and typological validity of many of the familial and generic units proposed by these workers. Starobogatov (1974: 12), for example, concedes that the family Dentaliidae, to which he referred 21 generic taxa, is a composite; "Judging by the structural diversity of the shell and the foot, . . . which has been investigated in only 3-4 genera." Chistikov (1975) based his revision of the "Order Dentaliida" largely on the knowledge of the radular and soft-part morphology of 24 species (only one of which was nomenclaturally identified), that he believed were referable to 11 genus-group taxa. Hopefully, his data will eventually be presented in more detail. In the meantime students have the option of incorporating elements of these schêmes into a revised classification, or to await the publication of better documented investigations. Habe (1977), in a review of the Japanese fauna, utilized some of the higher categories proposed by Palmer and by Chistikov, but he apparently was not aware of Starobogatov's work, which was published a few months prior to that of Palmer. The new taxa proposed by Starobogatov, below the ordinal rank would, of course, have priority over those erected by Palmer.

DESCRIPTIONS

CLASS **Scaphopoda** Bronn, 1862
ORDER **Gadilida** Stoliczka, 1868
[*nom. transl., ex* Gadilinae Stoliczka, 1868]
Syn. Gadilida Starobogatov, 1974; Siphonodentalioida Palmer, 1974
FAMILY **Gadilidae** Stoliczka, 1868
Syn. Cadulidae Grant and Gale, 1931
Genus *Cadulus* Philippi, 1844
Subgenus *Polyschides* Pilsbry and Sharp, 1898

Type species: By O. D., *Cadulus (Polyschides) tetraschides* Watson, 1879, Recent, western Atlantic Ocean.

Cadulus (Polyschides) nedallisoni, *n. sp.*

Figs. 4-6

Shell is minute, fragile, slender and slightly curved; the convex side is nearly evenly arched; the concave side is straighter, with the maximum diameter of the tube about one-third the distance above the oral aperture (Fig. 4). The swelling is gradual and only slightly inflates the curvature, from which the shell tapers gradually to the apical and oral apertures. The oral aperture is oblique, round and slightly constricted for a short distance above the rim. The lateral sides of the apical rim are indented by four slits, producing four sub-triangular lobes, the two fronting the concave side being slightly deeper and more rounded than those fronting the convex side (Fig. 5). The terminal edges of the lobes are beveled externally to form a planed surface (Fig. 6). Shells of fresh specimens are glossy, and the tube is translucent; worn specimens are clouded and opaque.

Measurements: holotype 4.56 mm long; outer diameter of apical orifice 0.31 mm, apertural outer diameter 0.56 mm. (Figs. 4, 5). Largest paratype 4.93 mm long; smallest paratype 3.81 mm long (Fig. 6).

Type locality: Corinto, Nicaragua, 12°28′03″ N., 87°12′39″ W., in 22 to 24 meters, "Zaca" Expedition, Sta. 200-D-19, January 5, 1938.

Type depository: holotype: AMNH no. 160349; 30 paratypes AMNH no. 183875.

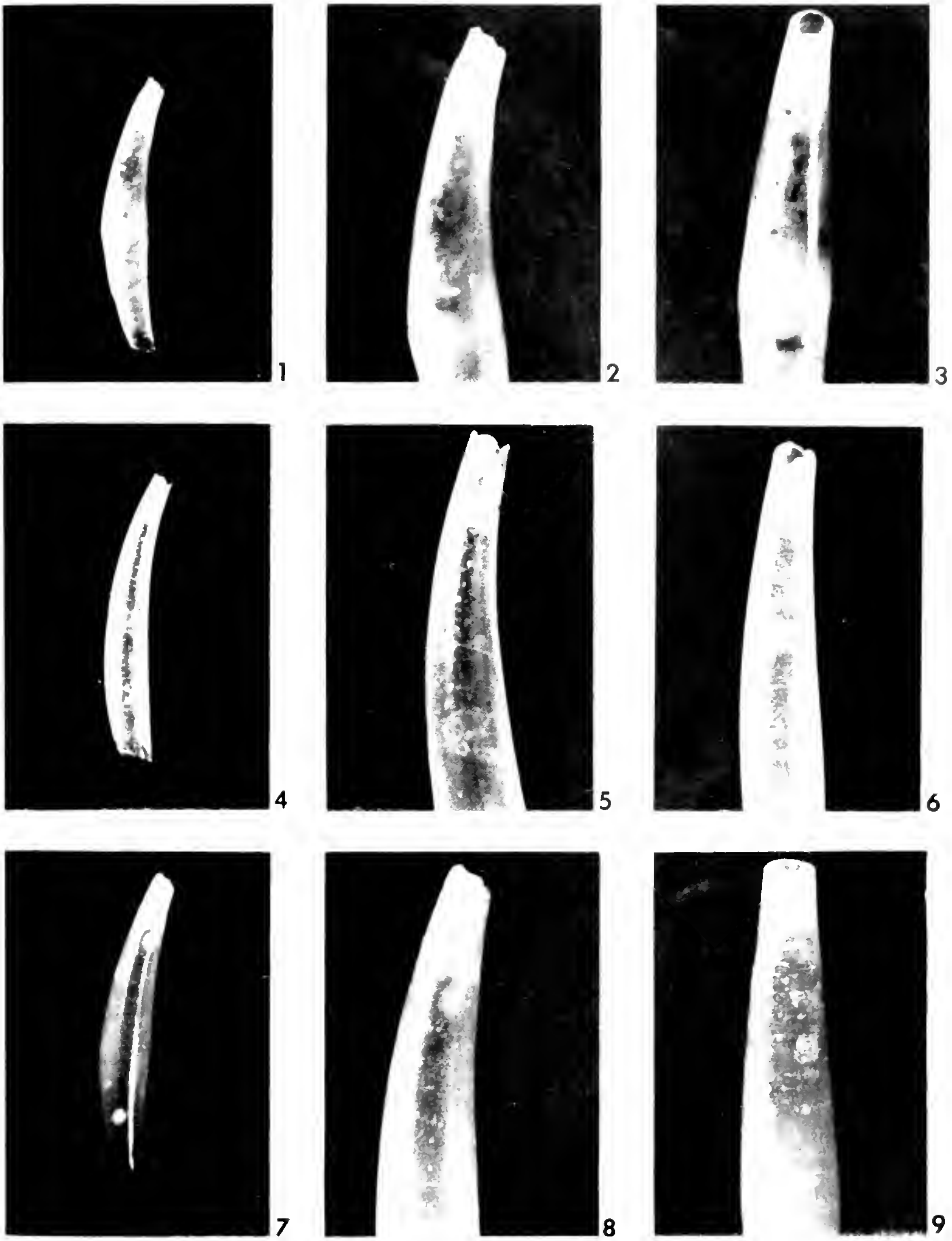
Referred specimens: known only from the typological lot.

Range: known only from the type locality.

Remarks: of the eastern Pacific species, this cadulid approaches *Cadulus (Platyschides) austinclarki* Emerson, 1951, in general appearance, but it differs in having different and more prominent apical features and a more fusiform outline, with a less inflated equatorial swelling (cf. Figs. 4-6 with 7-9). The shell of the slightly larger, *C. (P.) tetrodon* Pilsbry and Sharp, 1898 (p. 151, pl. 29, Figs. 14-18) from the western Atlantic is morphologically similar to the present species and may be an east American cognate, or twin species.

Neither of the two species described herein should be confused with specimens of the frequently dredged *Cadulus (Gadila) perpusillus* (Sowerby, 1832), a species which also occurs in the inner sublittoral zone within the Panamic faunal province. Sowerby's taxon, a senior synonym of *C. (G.) panamensis* (Sharp and

FIGS. **1-3** Cadulus (Platyschides) macleani *n. sp.*, **1.** *Holotype, lateral view of entire specimen, approx. 10×.* **2** *Holotype, lateral view of posterior end enlarged to show apical characters, approx. 20×.* **3.** *Paratype, concave side of posterior end enlarged to show apical characters, approx. 20×.* FIGS. **4-6** Cadulus (Polyschides) nedallisoni *n. sp.*, **4.** *Holotype, lateral view of entire specimen, approx. 10×.* **5.** *Holotype, lateral view of posterior end enlarged to show apical characters, approx. 20×.* **6.** *Paratype, ¾ oblique view with the concave face on the right side enlarged to show apical characters, approx. 20×.* FIGS. **7-9** Cadulus (Platyschides) austinclarki *Emerson, 1951; off San Marcos Island, Baja California del Sur (Gulf of California), in 9-13 meters on sandy bottom, "Puritan" Expedition, Sta 150, May 10, 1957 (Emerson, 1958), AMNH no. 147140* **7.** *Lateral view of entire specimen, approx 10×.* **8.** *Lateral view of posterior end of same specimen (Fig 7) enlarged to show apical characters.* **9.** *Concave side of posterior end of a specimen enlarged to show apical characters, approx. 20×. (Photography by G. R. Adlington)*



Emerson: New Eastern Pacific Cadulus *(explanations on opposite page)*

Pilsbry, 1898), has a much larger shell (8+ mm) that is characterized by a simple apical orifice, a conspicuous zone of constriction above the oral aperture, and the common presence of wrinkle like, annular sculpture (Emerson, 1971).

Subgenus *Platyschides* Henderson, 1920

Type species: By O. D., *Cadulus grandis* Verrill, 1884, Recent western Atlantic Ocean.

Cadulus (Platyschides) macleani, *n. sp.*

Figs. 1-3

Shell is minute, fairly solid, slender, moderately curved and markedly swollen below the posterior half of the tube, especially on the convex side, to form an obtusely angled mid-section (Fig. 1). The concave outline presents a "bent" appearance at the angled equator. The posterior end of the tube is only slightly more attenuated than the anterior end. The circular oral aperature is obliquely contracted. The general appearance of the shell is reminiscent of a miniature canine tooth of a carnivore. The apical orifice is obtusely angled and weakly interrupted on the lateral sides by two shallow indentations on each face that divide the rim into four low lobes with externally beveled edges (Figs. 2, 3). Shells are glossy, semitranslucent.

Measurements: holotype, 4.25 mm long; outer diameter of apical orifice 0.38 mm; apertural outer diameter 0.44 mm. Largest paratype 4.63 mm long; smallest paratype 4.19 mm long.

Type locality: (holotype and 3 paratypes): Muertos Bay, Baja California del Sur, Mexico (Gulf of California), 24° 55′ N., 109° 46′W., in 18 to 55 meters on sand and shell bottom; McLean, Oringer and Marincovich, collectors, April 8, 1966, LAMNH (Los Angeles Museum of Natural History) sta. no. 66-22.

Type depository: holotype: LAMNH no. 1886 (Figs. 1, 2); 3 paratypes (1 broken) LAMNH no. 1887, one illustrated, Fig. 3.

Referred specimens: Gulf of California, east coast of Baja California del Sur: Muertos Bay (typological specimens); between Rancho el Tule and Rancho Palmilla, 22° 58′ N., 109° 48′ W., in 18 to 33 meters on sandy bottom, McLean and Oringer, April 5, 1966, LAMNH no. 66-17, 3 specimens; AMNH no. 183775, 1 specimen.

Range: known only from the east coast of Baja California, from Muertos Bay (24° 55′ N.) to near Rancho Palmilla (22° 58′ N.), in 18 to 55 meters.

Remarks: This is the smallest of the known eastern Pacific gadilian species. None of the other west American species possesses a "bent" appearance resulting from the obtusely angled equator. Henderson (1920, p. 122) refers to similar shaped specimens in the western Atlantic as "wolf-tooth" species, namely: *Cadulus (Platyschides) vulpidens* Watson, 1878 and *C. (P.) providensis* Henderson, 1920. Both of these east American taxa have much larger shells (more than twice the length of the present species), and they are recorded from much deeper water, 713 and 699 meters, respectively.

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A CASE OF DOUBLE PRIMARY HOMONYMY IN EASTERN PACIFIC LITTORINIDAE

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ABSTRACT

Littorina keenae, *new name for* Litorina planaxis *Philippi, 1847, non* Littorina planaxis *Sowerby, 1844; and for* Littorina patula *Gould, 1849, non* Littorina patula *Thorpe, 1844.*

In the course of a systematic study of West African Littorinidae a case of double primary homonymy was discovered which unavoidably necessitates that a replacement name be provided for the well-known eastern Pacific species, *Littorina planaxis* Philippi, 1847.

The facts are these:

A. 1.) The combination *Littorina planaxis* 'Nuttall' Jay, 1839, p. 73, published in association with the locality, "Upper California", is a *nomen nudum* and is not available as a contender for priority.

2.) *Littorina planaxis* Sowerby, 1844, p. 153, was validly introduced for a Tertiary fossil species from St. Jago, Cape Verde Islands (see Sherborn, 1929, p. 5007).

3.) *Litorina planaxis* Philippi, 1847, p. 201, from "California Superior," was validly introduced for the Recent eastern Pacific species which has been reported to occur from Oregon to Baja California (Yamada, 1977).

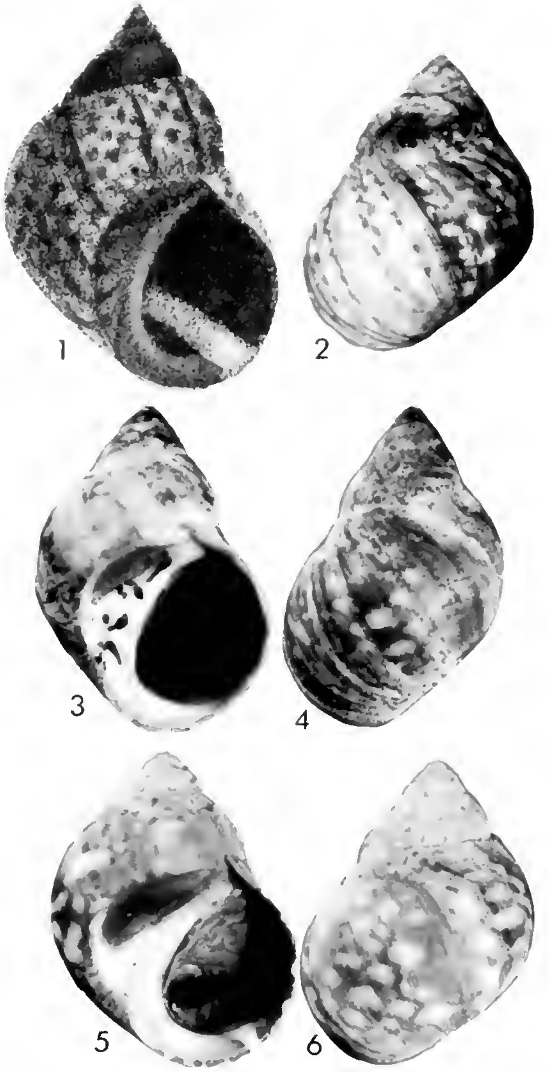

FIG. **1.** Litorina planaxis *Philippi, 1847 (original figure of Holotype)* **2.** Litorina planaxis *Philippi (Holotype, BM(NH) 1912412. 30-4; 17.4 mm length).* **3-4.** Littorina patula *Gould (Holotype, USNM 5336; 17.8 mm length).* **5-6.** Littorina keenae *Rosewater (USNM 47109; Monterey, California; 17.4 mm length).*

B. 1.) *Littorina patula* 'Jeffreys' Thorpe, 1844, p. 259, was validly introduced for a species collected at "Eddystone Rock" [SW of Plymouth, England]. This name has been used most recently for an element of the *Littorina saxatilis* Olivi species complex in Wales (Heller, 1975).

2.) *Littorina patula* Gould, 1849, p. 83, was introduced for a species from "San Francisco". It is an obvious synonym of *L. planaxis* Philippi.

As can be seen from the foregoing, *Litorina planaxis* Philippi, 1847, is a junior primary homonym of *L. planaxis* Sowerby, 1844. As such it must be rejected permanently (I.C.Z.N. Article 57 and 59a). Ordinarily, it would be replaced by its next available synonym, *Littorina patula* Gould, 1849, except for the fact that the latter is itself a junior primary homonym of *L. patula* Thorpe, 1844! Since, to my knowledge, there are no further existing available names for the *taxon*, *L. planaxis* Philippi, 1847, a new name is needed. I propose *Littorina keenae* as a replacement name for the eastern Pacific species formerly known as *L. planaxis* Philippi. It is named for Dr. A. Myra Keen, Department of Geology, Stanford University, who has contributed so much to malacology.

It is strange that a case of homonymy involving a common intertidal species has not been corrected previously. This may be due to the fact that Sowerby (1844) appears to be an uncommon, if not rare publication. It is missing from the library of the British Museum (Natural History) (see notation under "Sowerby, G. B. I, 1844" below in Literature Cited"). The work was reissued later in combination with two other publications of Darwin (see Darwin, 1851) which seem to be more readily available. The name *L. planaxis* was, without doubt, published by Sowerby in 1844, making it the senior primary homonym. Unfortunately, according to R. J. Cleevely, Department of Palaeontology, British Museum (N.H.), the type-specimen of Sowerby's species probably must be regarded as lost (personal communication), and the identity of the species is in doubt, but that in no way affects its status in homonymy.

ACKNOWLEDGMENTS

Thanks are due J. R. Taylor and R. J. Cleevely, British Museum (Natural History) for providing information on type-specimens of Recent and fossil Littorinidae, and to H. A. Rehder for his comments.

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OBSERVATIONS ON *ANODONTA GRANDIS* (UNIONIDAE) IN GREEN RIVER LAKE, KENTUCKY

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ABSTRACT

A non-reproducing colony of Anodonta grandis *Say was discovered in Green River Lake, a man-made impoundment in Taylor, Adair and Casey Counties, Kentucky. The clams inhabited a 5-meter-wide zone, within the epilimnion, at a depth of 7 to 8 meters, along the entire front face of the dam. The authors have previously found no living unionids in this lake. All of the living specimens were in good condition and were aged at 6 to 7 years. A single introduction by host fish, at the time of inundation, is judged to be the explanation for the presence of this grouping of mussels. Although 77 species of unionid mollusks have been reported from Green River proper, this was the only species found in the lake and it is apparently restricted to a single site.*

Dramatic alteration of a segment of a riverine ecosystem by its conversion to a lacustrine habitat is detrimental to many species of unionid mollusks (Harman 1974, Isom 1971). Sedimentation, deep water, poor water circulation and lack of suitable substrate are some of the reasons why these typically lotic organisms do not find conditions favorable in man-made impoundments. The Tennessee River and its tributaries at one time supported at least 64 species of freshwater mussels (Ortmann 1918). Recently Isom (1971), found only four species in Fort Loudon Reservoir on the Tennessee River. Siltation and anoxic conditions during most of the year were considered the major deterrents to further establishment of

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the Unionidae in this lake. In Kentucky Lake on the Kentucky River, Williams (1964), determined that only 2 species of clams, *Quadrula quadrula* and *Megalonais gigantea*, have been able to survive under conditions of reduced current and siltation. Bates (1962) found no evidence of recruitment in the preimpoundment mussel beds in Kentucky Lake. In his study Bates determined that three species of *Anodonta*, and two species of *Leptodea*, which had invaded recently deposited muck outside of the old river channel, were exhibiting normal reproductive activity. This paper deals with the authors' personal investigation into the fate of the Unionidae in Green River Lake, a man-made impoundment on the Green River in Taylor, Adair and Casey Counties, Kentucky. Isom (1974), listed 77 species of Unionids, in addition to the Asiatic Clam *Corbicula*, from the Green River system.

DESCRIPTION OF THE STUDY AREA

Green River Lake lies in the eastern section of the Mississippian Plateau in south-central Kentucky. This area is characterized by Mississippian limestone, mudstone and shale, with some deposits of chert and limestone. The earth and rock fill dam is 141 feet high and 2,350 feet long. The gates on the dam were closed on 17 February 1969. By mid-July of the same year the lake reached 670 msl. Seasonal pool (675 msl) was not achieved until the summer of 1970. The impounding structure features multiple outlets which allow water to be released from any chosen elevation between 635 and 670 msl.

Seasonal or summer pool is maintained at 675 msl. This pool is usually achieved by 12 April. When at seasonal pool the lake is 21 to 25 miles long and covers 8,210 acres. Winter drawdown, commencing about 16 October, brings the pool to 664 msl, usually by 1 December. Green River Lake stratifies during the summer. Hypolimnial and epilimnial waters exhibit specific physicochemical differences.

RESULTS

Under-water scuba reconnaissance of a relatively new man-made lake was begun by one of the authors in 1970. Gross observations were that the embayments and upper reaches were underlain by mud and many of the mainstem locations consisted of calcareous rockwall which descended rather steeply into the hypolimnion. In July 1972, a small colony or grouping, of clams in Green River Lake was discovered near the outlet tower at the front of the dam, at a depth of about 7 meters. All specimens appeared to be of the same age class and about 8 to 10 cm long. On 11 July 1976, 15 live clams were collected from the right or north half of the lake front, along the dam face (11 were returned to the lake). On 1 August 1976, 14 specimens were taken from the left or south half of the lake front, along the dam face (13 were returned). An additional 15 to 20 clams were observed in this area, but were not collected.

All of the clams were identified as the floater, *Anodonta grandis* Say. This species was previously collected from the Green River by Ortmann (1926), and Clench and van der Schalie (1944). Floaters have been taken elsewhere from lacustrine habitats (Parmalee 1962, Starrett 1971). All of the Green River Lake individuals inhabited a 5-meter-wide zone along the front face of the dam, at a depth of 7 to 8 meters. Distribution of the floaters within this zone was spotty; specimens occurred singly or occasionally in clusters of 3 or more. The substrate consisted of clean, coarse gravel with very little sand or organic matter. Scattered along the bottom were small-to medium-sized rocks, ranging in size from 10 to 50 cm in diameter. It was noted that *A. grandis* were either hidden among the larger of those rocks or partially submerged in the gravel bottom. Silt deposits at the times of collection were minimal, usually less than 2 or 3 mm thick. The length of the lake, distance from feeder streams, and current in the vicinity of the outlet works precluded a substantial silt buildup in this section of the lake.

The largest *Anodonta* taken was 15.4 cm long and 8.7 cm wide; the dry shell weighed 128 grams. The majority of the shells were 12 to 14 cm long and in good physical condition: the periostracum was undamaged and covered most of the umbones. Based on annular ring counts, all individuals appeared to be in the sixth or seventh year of development. A single dead specimen was collected at the front of the dam. The viscera were absent although both shells were intact and in good condition. This shell was 7.6 cm long and was 3 or 4 years old at the time of death.

Teleost fish observed in Green River Lake, in 1972 and 1976 were: bluegill, largemouth bass, carp, gizzard shad, crappie, black bullhead, logperch, white sucker, and a centrarchid, probably the orange-spotted sunfish. Carp, bluegill, and white crappie have been reported as host fish for the glochidia of *A. grandis* (Baker 1928).

Based upon onsite observations and data provided by the U. S. Army Corps of Engineers (See Table 1), Green River Lake water is low in suspended solids, medium hard, with low levels of dissolved chloride and sulfate. These waters are clean and for the most part low in dissolved nutrients. Average nitrate nitrogen in surface and hypolimnial waters was less than 0.5 mg/1 and total dissolved phosphate in all samples was less than 500 ug/1.

TABLE 1. *Selected physicochemical data for Green River Lake, collected near the outlet tower, Taylor County, Kentucky. All readings are in mg/1 unless noted otherwise. Samples were taken within the epilimnion at 10 feet (E), and within the hypolimnion at 65-90 feet (H). Data collected by U. S. Army Corps of Engineers, Louisville District.*

Parameter	*Location*	*Maximum*	*Minimum*	$\bar{X}$	*N*
Specific Conductance (umho/cm)	E	160	80	121	143
	H	190	70	134	129
Dissolved Oxygen	E	14.0	5.6	8.9	191
	H	11.5	0.0	3.1	138
Total Alkalinity (mg/1 $CaCO_3$)	E	71.0	31.0	45.4	19
	H	82.0	33.0	53.2	16
Total Hardness (mg/1 $CaCo_3$)	E	78.8	25.0	55.1	19
	H	84.7	25.0	60.8	17
Nitrate Nitrogen	E	1.00	0.10	0.46	21
	H	1.20	0.10	0.44	19
Chloride	E	0.8	5.9	2.5	10
	H	2.7	0.6	1.7	9
Sulfate	E	21.0	2.7	11.1	10
	H	29.6	1.9	11.2	9
Turbidity (JTU)	E	46.0	1.0	10.6	9
	H	480.0	43.0	118.2	8
Total Solids (105 °C)	E	101.0	57.0	77.3	19
	H	409.0	72.5	162.8	17
Total Phosphate (ug/1)	E	105.0	10.0	27.2	20
	H	300.0	30.0	108.1	18

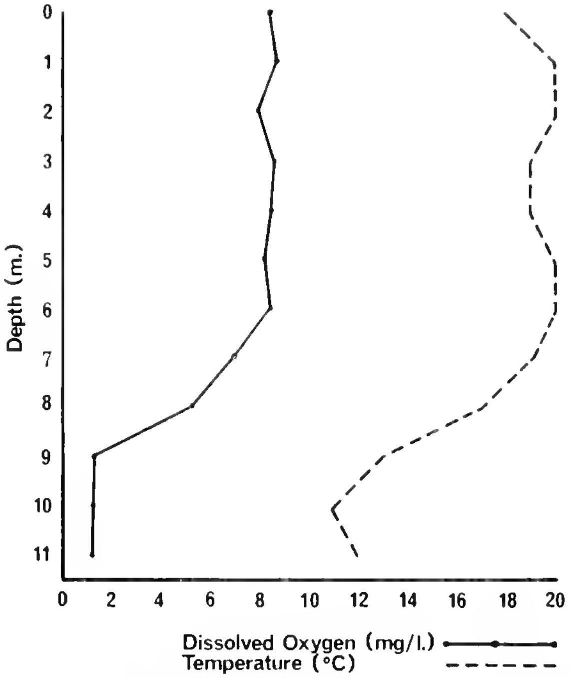

FIG. 1. *Dissolved oxygen in mg/1* (solid line), *and water temperature in °C* (dotted line), *at various depths in Green River Lake, Taylor County, Kentucky, near the outlet tower, 1 August 1976.*

In the hypolimnion, on the average, values for specific conductance were 11 percent higher, for dissolved oxygen were 65 percent lower, for total alkalinity were 17 percent higher, and for total hardness were 10 percent higher than in the epilimnion. Average values for total solids, total phosphate, and turbidity were greater (2, 4, and 11 times higher, respectively) in the hypolimnion than in the epilimnion. In the epilimnion maximum turbidity did not exceed 50 units (JTU), and total solids averaged less than 100 mg/1. Visibility was fair to good in the epilmnion; however, visibility was poor in the hypolimnion.

Dissolved oxygen and water temperature were measured with YSI meter at one-meter depths a short distance from the front of the dam on 1 August 1976 (See Fig. 1). Mixing of the water column (caused by the outlet works) as well as problems keeping the inflatable boat stable, caused some difficulties in collecting these data. The maximum drop in dissolved oxygen occurred between 8 and 9 meters (4.0 mg/1). The maximum temperature changes took place between 7 and 8 meters (3° C), and 8 and 9 meters (2° C). Because of the difference in turbidity and water temperature, it was not difficult to distinguish the thermocline while searching for mussels. All of the *A. grandis* were taken in epilimnial waters. The hypolimnial waters, turbid and deficient in dissolved oxygen, were thought to be inimical to *A. grandis*. This was borne out by repeated visual examinations of the hypolimnion.

DISCUSSION

Indications are that this colony of *A. grandis* is non—recruiting, and, based on its same-aged aspect, was established by one-time stocking or placement. There are three possible mechanisms which could account for the existence of the *Anodonta* at this particular elevation and location in Green River Lake:

1. Direct introduction by fishermen emptying a bait bucket. This can be discounted at the outset, since fishing is prohibited in this section of the lake. In addition, the number of clams, all the same age, greatly exceeds the amount which could be readily transported in viable condition by fishermen. Finally, the widespread dispersal of the specimens (along the entire front of the dam) cannot be accounted for by the physical act of emptying a bait bucket.
2. Introduction of centrarchids or other previously parasitized host fish by bait bucket. This hypothesis is largely discountable as most bait fish are generally small cyprinids and not centrarchids. Likewise there is little possibility that a suitably infected host fish could survive the bait bucket (or the fisherman's hook) and then disperse glochidae along the front of the dam.
3. Establishment of the clams via host fish which were present in the river during the time of the original inundation of the lake. This appears to be the most tenable hypothesis. The estimated age of the clams correlates well with the period of initial inundation and the presence of host fish for *A. grandis* provides a reasonable explanation for the establishment of the clams at an elevation higher than that of the original stream. This hypothesis would also account for the same-aged aspect of the *Anodonta* observed and collected.

CONCLUSIONS

During inundation glochidia of *A. grandis* were released from host fish which persisted near the face of the Green River Lake Dam. While distribution of larvae was most probably random, only a rather narrow zone was suitable for development of the immature clams. The sole evidence of further introduction of this species was a single juvenile shell which was devoid of soft parts. This grouping of *A. grandis* has exhibited no evidence of recruitment. This although potential host fish are present, infers that the present density is too low for successful reproduction to occur. It is possible, however, that reproduction is successful, but recruitment is not. If this is the case, the glochidea may be produced but have been unable to implant on host fish. As *A. grandis* exists in the river above the lake, the lake itself may be a barrier (probably a function of distance) to replenishment of the clams via host fish from upstream. Thus, if the group continues to fail at recruitment, it is likely to disappear.

Future study will involve additional observations of this group of floaters to determine if successful recruitment ever occurs.

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THE EFFECTS OF SIMAZINE ON THE MOLLUSCAN FAUNA OF MORIANE LAKE, NEW YORK[1]

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ABSTRACT

The CIBA-Geigy Chemical Company treated Moriane Lake, Madison Co., N. Y. with Simazine (Princep 80W®, or Aquazine 80W®) [2-chloro-1,6-bis (ethylamino)-s-triazine] to control undesirable blue-green algal populations in 1974 and 1975. I was to determine the effects of these treatments on the benthic fauna. The lake was not completely satisfactory for the analysis because typical benthic communities were not present, possibly because of previous applications of copper sulphate ($CuSO_4$) *and Diquat (1,1'-ethylene-2,2'-depyridylium dibromide). Simazine applications theoretically equalling concentrations of 0.25 and 0.5 ppmw after dispersal throughout the epilimnion did not have an important effect on profundal arthropod (Diptera: Chironomidae) biomass. However, applications of 0.5 ppmw (after dispersal throughout the epilimnion) did have debilitating effects on littoral mollusks. Populations of* Goniobasis livescens *(Menke), that normally reproduce throughout the summer, recovered by the spring following treatment. Simazine applications of 0.5 ppmw had severely debilitating effects on sublittoral populations of* Viviparus georgianus *(Lea), killing most immature individuals. At concentrations of 0.25 ppmw populations were not as affected because newly born snails did not sustain high mortality. Short term toxicity tests conducted in the laboratory resulted in no mortality to mollusks in concentrations of Simazine up to 5.0 ppmw. It is hypothesized that synergestic reactions with dying algal cells were responsible for* in situ *mortality of these prosobranch gastropods.*

Simazine is a herbicide that has been used commonly for control of weeds in corn, in many grasses and in fruit orchards. Recently it has been used for control of algae in swimming pools and algae or rooted aquatic plants (depending on dosage) in farm ponds.

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[1] This research was funded by CIBA-Geigy Chemical Company.

TABLE 1. *The molluscan fauna of Moriane Lake.*

Bivalvia

Pisidium compressum, (Prime, 1852)
Pisidium casertanum, (Müller, 1776)
Pisidium nitidum Jenyns, 1832

Gastropoda

Physa heterostropha Say, 1817
Helisoma trivolvis (Say, 1817)
Helisoma anceps (Menke, 1830)
Gyraulus parvus (Say, 1817)
Amnicola lustrica (Pilsbry, 1890)
Amnicola limosa (Say, 1817)
Amnicola integra (Say, 1821)
Bithynia tentaculata (Linnaeus, 1758)
Viviparus georgianus (Lea, 1834)
Goniobasis livescens (Menke, 1830)

In 1974 and 1975 the CIBA-Geigy Chemical Company applied Simazine to Moriane Lake (Madison Reservoir), Madison Co., N.Y., to determine its action as a algacide in dimictic lakes. The herbicide was applied over littoral areas in such a way that concentrations of 0.5 ppmw (1974) and 0.25 ppmw (1975) were theoretically attained throughout the epilimnion, due to diffusion and mixing, after several hours. It was my responsibility to evaluate the effects of these applications on the benthic fauna.

Lake Moriane has a surface area of approximately 94 ha with a maximum depth of 13 m. A rather high shore development combined with many substrate types indicates a potentially high diversity of littoral, benthic organisms despite an advanced tropic condition. The Lake is situated just south of the divide between the Oswego and Susquehanna watersheds in central New York, draining south via the Chenango River into the North Branch of the Susquehanna. Chemical characteristics recorded during 1974 were typical of local dimictic lakes of its morphology, with the exception of rather high concentrations of phosphorus (Oglesby, 1975).

The molluscan fauna (Table 1) is unique for several reasons. No living bivalves other than sphaeriids were found. Many of the snails present are normally not encountered in the Susquehanna drainage basin, but are common in the Oswego watershed. They apparently were given access to Moriane Lake when the Chenango River was joined to the Erie Canal during the middle 1800's. Atypically, the littoral biomass was made up almost entirely (96%) of Mollusca (Fig. 1). The profundal areas averaged 90% Arthropoda (Fig. 2). The more normal situation in these types of waters is illustrated by Otsego Lake (Fig. 3 and 4) where the littoral biomass is about equally divided between the Arthropoda and Mollusca,

Figure 1 Composition of pretreatment littoral benthic biomass in Moriane Lake

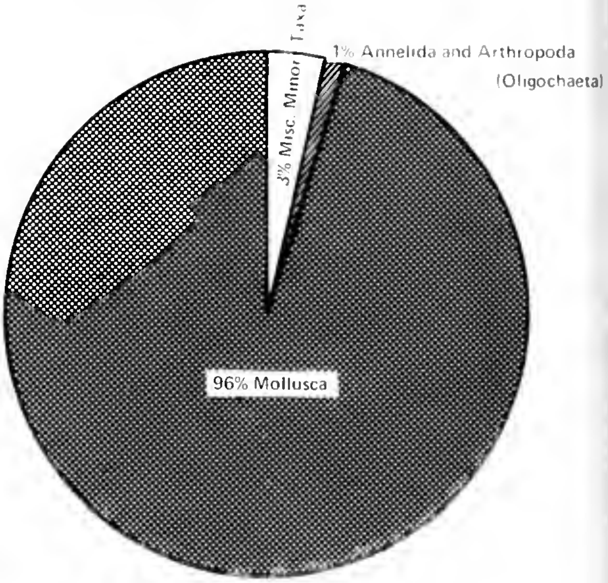
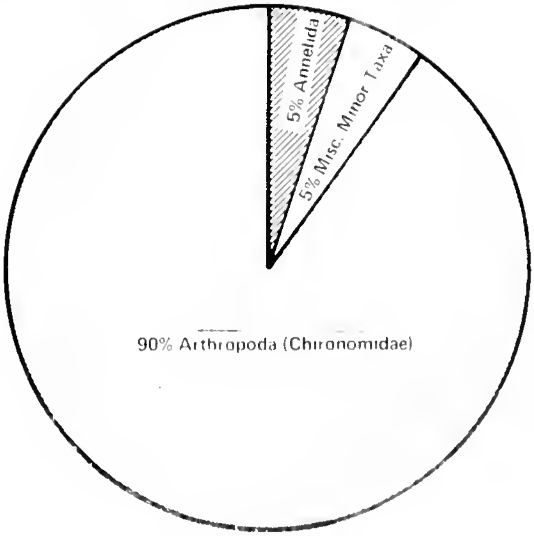


Figure 2 Composition of pretreatment profundal benthic biomass in Moriane Lake



and the profundal biomass is dominated by Annelids. The relationship between total benthic biomass and depth in Moriane Lake appears typical for lakes with high hypolimnion oxygen deficits (0-2 m = 90.96 g/m²; 5-15 m = 4.83 - 5.53 g/m²).

On 22 July 1974 the development of a bloom of blue-green algae had reached the point where a quantity of Simazine, equivalent to a concentration of 0.5 ppmw throughout the epilimnion waters, was applied. The following year, conditions were appropriate for application on 17 July. At that time the equivalent of 0.25 ppmw Simazine throughout the epilimnion was applied. The latter concentration was utilized because damage had occurred to rooted aquatic plants (predominately eel grass [*Vallisneria americana*, Michx.]) after the 1974 treatment.

Figure 3. Composition of littoral benthic biomass in Otsego Lake

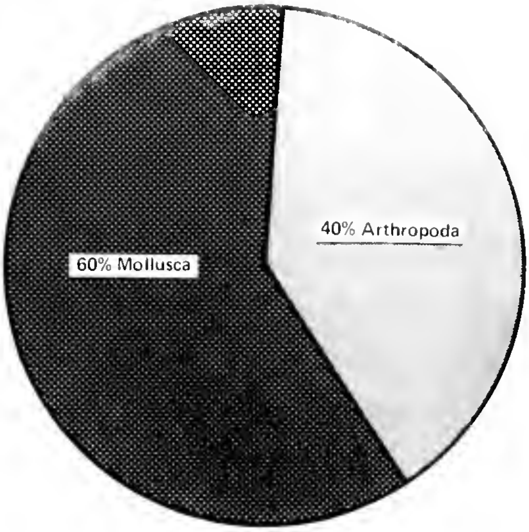
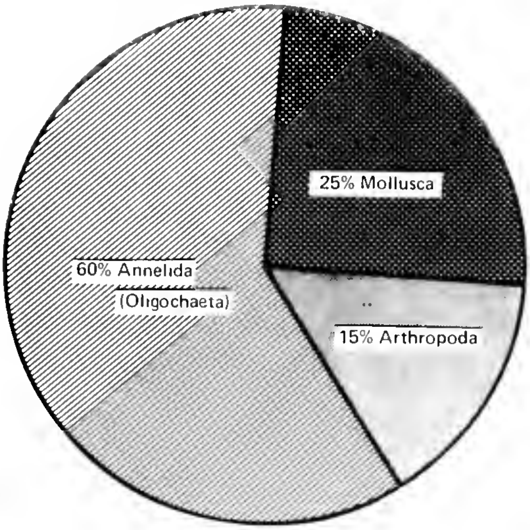


Figure 4. Composition of profundal benthic biomass in Otsego Lake.



Changes in water quality correlated with the application of Simazine included an increase of the pigment phaeophytin in the bottom waters which was attributed to the decomposition of algal cells (Oglesby, 1975). This indicates the presence of other metabolytes of decomposing blue-green algae which are potentially toxic to many benthic organisms.

METHODS OF STUDY

On the date of first application of Simazine (22 July 74) collections were made in 6 locations throughout the lake (Fig. 5.) 1: The control; in an area separated by a causeway, north of the main basin of the Lake, where no algacide was applied. In that area a profundal sample was collected at about 5 m in depth using an ekman dredge. 2: Three profundal ekman samples at stations #1, #3, and #6 (8 m, 5 m, and 15 m in depth respectively); in the main basin. 3: A ½ m² littoral sample at Sunny Point; in 0.5 m of water on a rocky shore, and lastly 4: a ½ m² sub-littoral collection of *V. georgianus* (4.5 m) taken by divers between Snake Island and the eastern shore. Sampling was repeated in each area on 25 July 74, 8 Aug. 74, 13 Sept. 74, 21 Oct. 74, and 6 June 75.

The control and all 3 profundal samples were treated in the following manner: 1. The substrate was removed from the dredge and placed into a plastic tub. 2. Approximately eight L of 70% ethyl alcohol were added to bottom materials to fix any included organisms. 3. Ten ml of rose-bengal dissolved in 95% ethyl alcohol was added to stain any organisms present. 4. The sample was then mixed to form a slurry and placed in sealed, labelled containers for transportation back to the laboratory. 5. Immediately upon return to the laboratory the contents of the containers were diluted with an equal volume of 70% ethyl alcohol for long term fixation.

The ½ m² littoral sample was taken by inserting a galvanized, sheet metal frame into the substrate. All surficial rocks and sediments were removed by hand and placed in a plastic tub. About eight L of 70% ethyl alcohol and 10 ml of the rose-bengal solution were added. Back at the laboratory all rocks larger than 2 cm in diameter were scraped to remove aufwuchs and placed in sealed bottles for future processing. The ½ m² sub-littoral sample of *Viviparus* was collected by a diver who placed the ½ m² frame on the substrate in the collection area. All specimens of *Viviparus* were individually picked from the bottom enclosed by the frame, placed in a specimen container and brought to the surface. The container was then filled with 95% ethyl alcohol, labelled and returned to the laboratory.

On 17 July 75, the date of the second application of Simazine, samples were taken as in 1974, except that only one profundal sample (#3) was collected to reduce expenses. Further sampling, in like manner, took place on 17 July 75, 21 July 75, 8 Aug. 75, 15 Sept. 75 and 24 Oct. 75.

Samples taken both years were processed identically in the laboratory. A small amount of substrate (about five ml) was placed in a white enamel pan. The pan was then flooded with a sugar-water solution (Anderson, 1959). The small organisms, less dense than the solution and stained red by the rose-bengal, would then float to the surface, be grasped by forceps or collected by pipette and placed in vials. Larger, more dense organisms were easily separated from the substrate because of their size and red color. They were then determined and weighed by traditional methods. Short term toxicity tests in the laboratory were also conducted using standard methods.

RESULTS

The profundal biomass, dominated by midges (Insecta: Chironomide), did not appear to be seriously affected by the Simazine treatments. However, there were alterations in the littoral community. In 1974 there was a decline in total littoral biomass from 22 July to 25 July of more than 60%. Although many organisms were effected, the greatest impact was on *Goniobasis livescens* (Menke), a prosobranch that composed 96% of the biomass in the sample area (Fig. 6). By spring of 1975 the population had recovered, due in large part to reproduction in July and August. The apparent increase in population size over the winter is assumed to have occurred because a large percentage of newly hatched immature specimens were undoubtedly overlooked

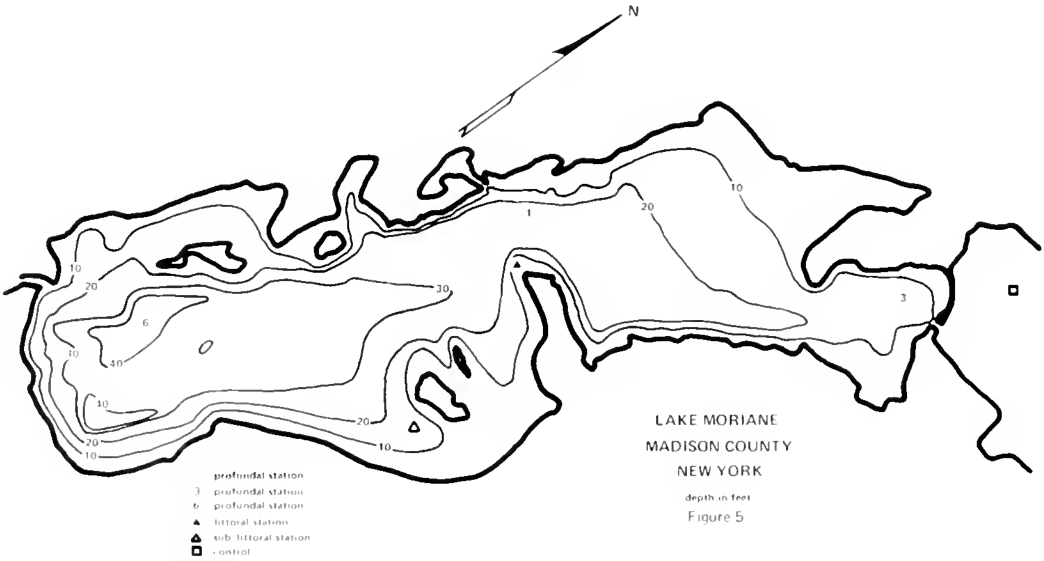


Figure 5

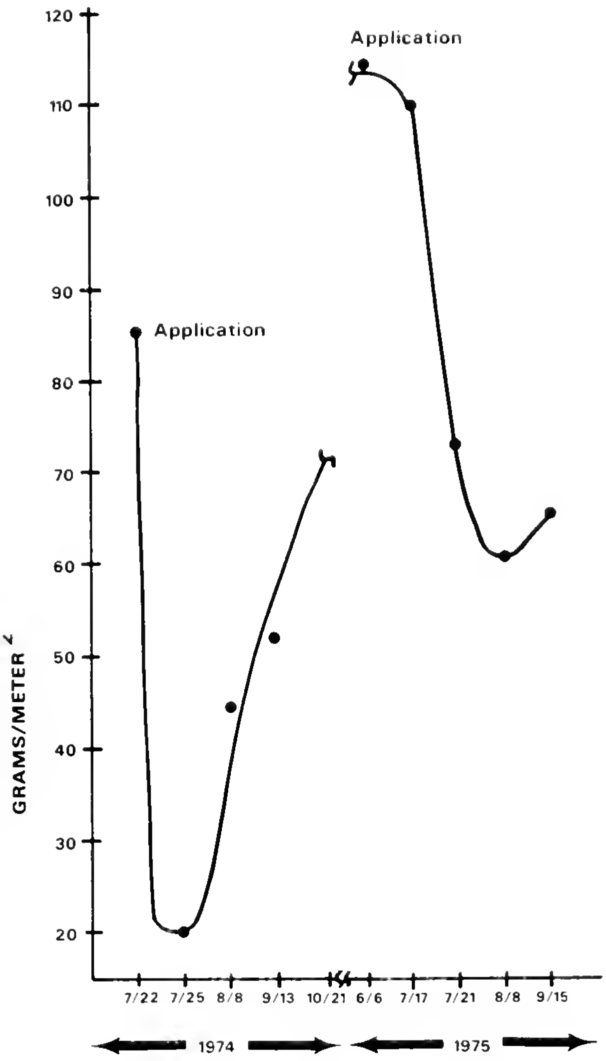


FIG. 6. *Grams/m² of* Goniobasis livescens *(Menke) in Moriane Lake.*

in the collections. The application of 0.25 ppmw on 17 July 75 resulted in the reduction of total littoral biomass by 25%. By autumn 1975 the total littoral biomass was approximately 75% of the pretreatment biomass in July 1974.

The sublittoral community of *V. georgianus* was almost eliminated after the 1974 application of Simazine (Fig. 7). Adults aborted young and all individuals were very lethargic 2 days after treatment. It appeared that an extremely high percentage of the immature specimens were killed. As is typical of this species no further reproduction took place during the summer. The 1975 application of 0.25 ppmw did not result in high mortality and by autumn records indicated that the population had increased beyond its 1974 pretreatment density.

Despite their high mortality in Moriane Lake, when *V. georgianus* and *G. livescens* were exposed to solutions of Simazine in the laboratory, up to 5.0 ppmw in periods in excess of 96 hours, no mortality was observed. Further tests were run using substrate from Moriane Lake in containers to ascertain the effects, if any, of synergistic reactions between Simazine and the substrate. No mortality was observed.

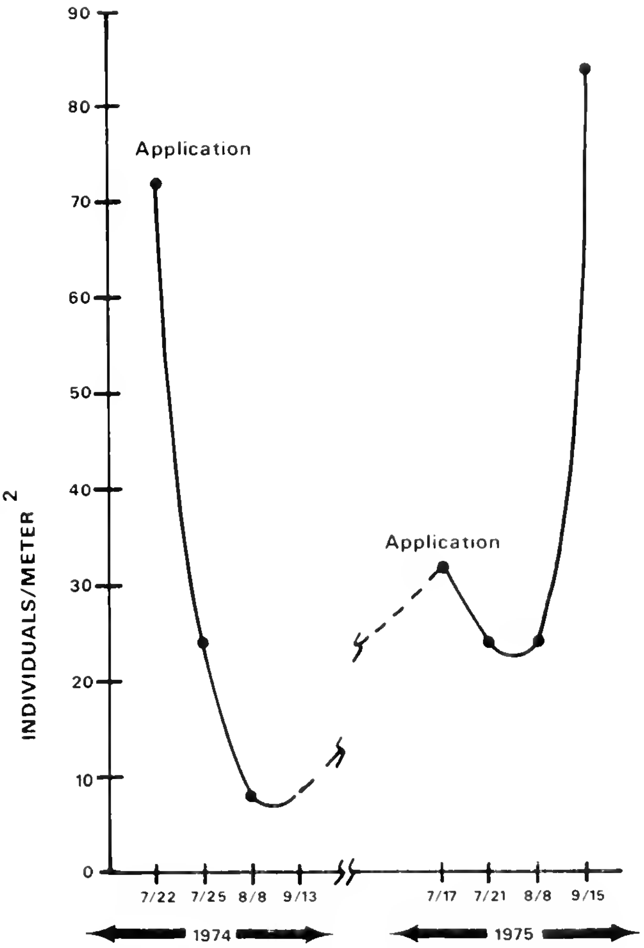


FIG. 7. *Individuals/m² of* Viviparus georgianus *(Lea) in Moriane Lake.*

DISCUSSION

The unusual distribution of faunal elements in Moriane Lake results from former artificial drainage to the north, and because of the essential lack of entire taxa; Arthropod groups in the littoral areas and Annelids in the profundal substrates. The latter may be the result of previous pesticide treatments. According to Kastens (1974), 1 gal. of Diquat/surface acre (1 L/ha) were used to treat the lake in 1972 and 1973. During the same period a total of 2,157 lbs. (*ca* 10 x 10^5g) of copper sulfate were applied.

It is hypothesized that the high mortality of prosobranch snails in the lake came about because littoral populations of *Goniobasis* were sensitive to the Simazine application as a result of their total dependence for food on a 1-3 mm thick layer of blue-green benthic, encrusting algae that covered the cobbles making up the substrate in the littoral environment. As this flora decomposed, organic compounds were released that were potentially toxic to snails. The sublittoral *Viviparus* population may also have been severely stressed by synergestic effects as dying limnetic algal cells rained into that environment from the epilimnion waters and then were ingested.

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THE ASIAN APPLE SNAIL, *CIPANGOPALUDINA CHINENSIS* (VIVIPARIIDAE) IN ONEIDA LAKE, NEW YORK

Arthur H. Clarke

National Museum of Natural History
Smithsonian Institution, Washington, D.C. 20560

On September 11, 1977, about 60 specimens of *C. chinensis* (Gray, 1834) (= *Viviparus japonicus* (von Martens) and *V. molleatus* (Reeve)) were found washed up along a quarter mile stretch of beach at Sylvan Beach, Oneida County, New York, at the eastern end of Oneida Lake. Many of the specimens contained decaying soft parts but circumstances prevented a proper search for live animals. On April 30, 1978, the site was revisited and additional, apparently freshly-dead, specimens were found. On this occasion also diving for live specimens could not be attempted but the presence of an established colony in Oneida Lake, and probably at Sylvan Beach, appears certain.

Although *C. chinensis* occurs elsewhere in New York State, i.e. near Niagara Falls and near New York City (Jacobson and Emerson, 1961); (Dundee, 1974), it has not been found previously in Oneida Lake (Harman and Forney, 1970) nor in the Finger Lakes region (Harman and Berg, 1970). Expansion of its distribution throughout central New York, by way of the Erie Barge Canal, is probably now to be expected.

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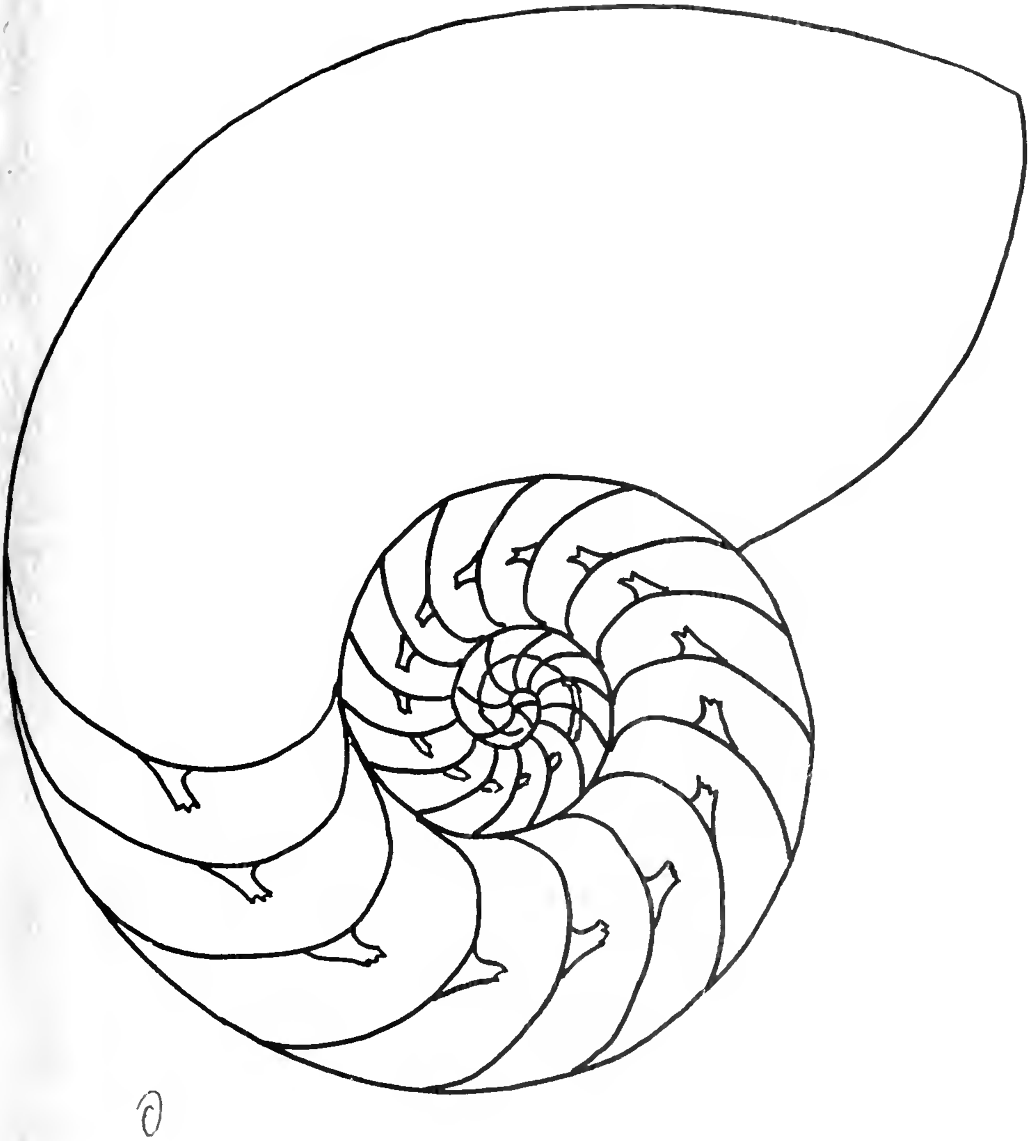

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CONTENTS

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ERRATA

The word Xenoconchia, a fossil ancestor of the scaphopods, is erroneously spelled Xenochonchia in William K. Emerson's article in the last issue of *The Nautilus*, vol. 92, no. 3, p. 117 and 119. The error arose from a translator's misspelling in the title of the English translation listed in the *Literature Cited* on p. 123. Also on page 119, the verb "used" should be inserted after the word "previously" near the end of the second paragraph.

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EFFECTS OF SUBSTRATUM ON GROWTH AND REPRODUCTION OF *MUSCULIUM SECURIS* (BIVALVIA: SPHAERIIDAE)

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ABSTRACT

Laboratory studies show that greater growth and reproduction of Musculium securis *occur on sediments of small particle sizes than on sediments of large particle sizes and, in general, on substrates consisting of soil and leaf litter characteristic of the deciduous forest region than of the coniferous forest region. Soil contributes living food organisms and leaf litter contributes soluble compounds necessary for the maintenance of* M. securis. *The distribution of* M. securis *within and among habitats is in part related to the same factors in the substrate that affect growth and reproduction.*

There is considerable information in the literature showing the effects of various physical and chemical factors in the sediments on the distribution of benthic organisms (e. g. Sanders 1958), especially freshwater oligochaetes (Johnson and Brinkhurst 1971; Brinkhurst 1972), amphipods (Marzolf 1965; Hargrave 1970; Nalepa and Thomas 1976), chironomids (Paterson and Fernando 1970), and bivalves (Gale 1969, 1973; Meier-Brook 1969). However, little is known about the effects of physical, chemical, and biological factors of sediments on the growth and reproduction of benthic organisms, especially Sphaeriidae, one of the most cosmopolitan groups of benthic organisms.

The purpose of the present study is to examine the effects of sediment particle size (texture), different kinds of substrates, and of factors in the substrate on the growth and reproduction of a sphaeriid clam, *Musculium securis*, in the laboratory. Factors which contribute to high growth and reproduction also are examined in relation to the distribution of the species within and among habitats in North America.

MATERIALS AND METHODS

Musculium securis was chosen as the test animal because it is easy to maintain in the laboratory and has a cosmopolitan distribution. After trying several methods we found that rapid rates of growth and reproduction were obtained when clams were reared in "Pyrex" dishes 100 mm in diameter and 50 mm in height containing forest soil, tree foliage, and distilled water. Dishes were topped daily with distilled water and were allowed to sit (i. e. without aeration) with minimum disturbance at 18°C in a constant temperature room. All clams were grown from the newborn stage of development and were obtained either from Britannia Bay of the Ottawa River, near Ottawa, or from Carp Pond near Carp, Ontario. Physical, chemical and biological characteristics of these habitats are described in Mackie (1973) and Mackie and Qadri (1973).

Growth was determined by measuring the increase in length (mm, anterior to posterior) of shell at approximately two week intervals, until death of the clams. A vernier microscope (Precision Tools and Instrument Co. Ltd.) was used to measure length of the shell. Differences in length and growth rates were determined using statistical methods described later.

Reproduction was measured as natality, or the number of young (newborn) produced in each dish, at the end of the experiment. An experiment ended when at least 75% of the parents (usually 100%) were dead. The mean number of newborn produced within replicates was calculated and differences among treatments

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Table 1. Asymptotic growth data for the regression $Y = A + BR^X$ and the natalities of *Musculium securis* adults grown on four different soil textures. Three replicates were made for each soil texture with five clams in each replicate. Means side-scored by the same line are not significantly different at $P = 0.05$.

Texture of soil	Means and standard deviations ( ) of asymptotic regression data for $Y = A + BR^X$						Mean natality and standard deviation ( ) per growth dish	
	A mm		B mm		R			
Fine sand	5.60	(0.22)	-4.38	(0.21)	0.970	(0.0034)	21.3	(3.1)
Silt-clay	4.30	(0.08)	-2.92	(0.09)	0.959	(0.0033)	19.7	(3.5)
Medium-fine sand	4.20	(0.12)	-2.86	(0.11)	0.965	(0.0037)	4.7	(1.5)
Very coarse sand	3.60	(0.13)	-2.22	(0.14)	0.959	(0.0068)	1.0	(1.7)
Sediment only (control)	Little or no growth						0	
Leaves only (control)	Little or no growth						0	

were determined using the statistical methods described later.

The effects of sediment texture on growth and reproduction of *M. securis* were determined by growing newborn in four size fractions of sediments. The sediments were taken from the 2 m depth of Britannia Bay where the sediment particle size ranged from <0.050 mm to >2.00 mm. After air-drying and removing the macroinvertebrates, the sediment was sieved into size fractions of <0.050 mm (silt and clay), 0.050-0.125 mm (fine sand), 0.125-0.50 mm (medium to fine sand), and 0.50-2.00 mm (coarse to very coarse sand). Each size fraction was prepared by putting 50 g air-dried sediment, 2 g air-dried white elm leaves, enough distilled water to fill each dish, and five newborn clams from Britannia Bay into each dish. This procedure was repeated three times for each size fraction. To assess the effects of leaves on growth and reproduction in this experiment, another three dishes were prepared containing only leaves, water, and newborn clams. Adults were removed at approximately two week intervals and growth was determined as described earlier.

To determine the effects of different kinds of substrates, newborn were grown on five soil samples from forest stands of willow-elm, birch-aspen, oak-maple, white spruce, and white cedar. These were prepared in replicates of three with 50 g air-dried soil, 2 g air-dried leaf litter from the soil samples, enough distilled water to fill each dish, and five premeasured newborn from Carp Pond in each dish. Growth in length of clams was determined at approximately two week intervals and reproduction was determined using methods described earlier.

Soils were taken from the upper 15 cm of a forest floor and divided into lots according to the location and time taken. After removing the macroinvertebrates, each lot was air-dried and the pH was determined with a Fisher "Acumet" pH meter on a soil-water paste (1:1 by weight). Exchangeable calcium was extracted from 15 g of soil by washing the soil (from 2 mm mesh sieve) into Buchner funnels with 50 ml of 1N ammonium acetate at pH 7, followed by three additional aliquots of 25 ml each added successively after the previous one passed through the soil.

Calcium concentration of the extracted soil solution was determined on a Jarrell-Ash Atomic Absorption Spectrophotometer, using standards prepared with the extracting solution and 1200 mg/1 La as an interference inhibitor (Pawluk 1967). The coefficient of variation for five replicate samples of Carp Pond soil was 2.2.

The effect of eight different species of leaves were tested to complement the forest soil studies above. Only freshly fallen leaves were used. The leaves tested were white elm (*Ulmus americana*), black willow (*Salix nigra*), trembling aspen (*Populus tremuloides*), white birch (*Betula papyrifera*), red maple (*Acer rubrum*), red oak (*Quercus borealis*), white spruce (*Picea glauca*), and white cedar (*Thuja occidentalis*). The taxonomic keys in White (1957) were used to identify the leaves and trees. Three replicates of each leaf species were tested according to the procedures described above but using only soil from Carp Pond rather than soils from different forests. The methods previously described were used to measure growth (at approximately two-week intervals) and reproduction of *M. securis*.

The calcium content of leaf material was determined on preweighed samples of leaves that were ashed overnight in a muffle furnace at 580°C. Ashed samples were moistened with distilled water, dissolved in 2N HCl, diluted to known volume, and then filtered. Calcium concentration of the filtrate was determined on a Jarrell-Ash Atomic Absorption Spectrophotometer, using standards prepared with 0.25N HCl and 1200 mg/1 of La as an interference inhibitor. The coefficient of variation for five replicate samples of white elm leaves was 0.98.

Table 2. Asymptotic growth data for the regressions $Y = A + BR^x$ and $1/Y = A + BR^x$ and the natalities of <u>Musculium securis</u> adults grown on three replicates of five different soils with seven species of leaf litter. The A and B values of the logistic equation are also transformed to permit tests of significant differences among all groups. Means side-scored by the same line are not significantly different at P = 0.05.

Leaf litter on soil	Growth form	Means and standard deviations ( ) of asymptotic regression data for $Y = A + BR^x$ and $1/Y = A + BR^x$ (or $1/Y' = A' + B'R^x$)					Mean natality and standard deviation ( ) per growth dish	
		A mm		B mm		R		
Black willow on Willow-Elm	1/Y	0.161	(0.018)	0.468	(0.015)	0.985 (0.0021)	42.0	(5.3)
	1/Y'	6.21	(0.68)	-4.73	(0.64)			
White spruce on Birch-Aspen	Y	6.08	(0.20)	-4.54	(0.20)	0.969 (0.0036)	44.0	(2.7)
Red oak on Oak-Maple	1/Y	0.167	(0.028)	0.462	(0.030)	0.967 (0.0038)	35.3	(5.7)
	1/Y'	5.98	(0.92)	-4.51	(0.90)			
Trembling aspen on Birch-Aspen	Y	4.23	(0.88)	-2.80	(0.76)	0.972 (0.0040)	11.0	(3.6)
White cedar on cedar	1/Y	0.243	(0.033)	0.387	(0.031)	0.970 (0.0033)	5.7	(1.5)
	1/Y'	4.12	(0.74)	-2.60	(0.72)			
White birch on Birch-Aspen	1/Y	0.268	(0.013)	0.360	(0.013)	0.994 (0.0032)	7.0	(4.6)
	1/Y'	3.73	(0.20)	-2.27	(0.18)			
Red maple on Oak-Maple	Y	3.62	(0.80)	-2.17	(0.81)	0.958 (0.0066)	7.3	(1.2)
White spruce on spruce		Not described by asymptotic regressions, maximum length attained = 2.41 (0.16)					0	

Table 3. Asymptotic growth data for the regressions $Y = A + BR^X$ and $1/Y = A + BR^X$ and the natalities of *Musculium securis* adults grown on three replicates of eight species of freshly fallen leaf litter. The A and B values of the logistic equation are also transformed to permit tests of significant differences among all groups. Means side-scored by the same line are not significantly different at $P = 0.05$.

Leaf species	Growth form	Means and standard deviations ( ) of asymptotic regression data for $Y = A + BR^X$ and $1/Y = A + BR^X$ (or $1/Y' = A' + B'R^X$)						Mean natality and standard deviation ( ) per growth dish	
		A mm		B mm		R			
White elm	1/Y	0.159	(0.010)	0.469	(0.010)	0.961	(0.0022)	40.3	(6.8)
	1/Y'	6.29	(0.38)	-4.77	(0.36				
White cedar	1/Y	0.162	(0.027)	0.477	(0.025)	0.971	(0.0028)	40.7	(5.0)
	1/Y'	6.18	(0.99)	-4.63	(0.96)				
Black willow	1/Y	0.165	(0.013)	0.416	(0.013)	0.963	(0.0023)	38.3	(4.2)
	1/Y'	6.06	(0.50)	-4.51	(0.49)				
Red oak	1/Y	0.195	(0.059)	0.434	(0.055)	0.975	(0.0048)	34.0	(1.7)
	1/Y'	5.13	(1.58)	-3.64	(1.52)				
White birch	Y	5.20	(0.11)	-3.64	(0.11)	0.969	(0.0024)	31.3	(8.3)
White spruce	Y	5.10	(0.47)	-3.54	(0.45)	0.980	(0.0030)	29.0	(4.4)
Trembling aspen	Y	5.25	(0.13)	-3.64	(0.13)	0.969	(0.0026)	27.3	(4.0)
Red maple	1/Y	0.241	(0.008)	0.388	(0.008)	0.933	(0.0030)	5.3	(2.3)
	1/Y'	4.15	(0.24)	-2.68	(0.23)				
No leaves (control)		Not described by asymptotic regressions, maximum length attained - 2.38 (0.14)						0	

A series of experiments also was carried out to determine if clams were utilizing soluble components or living or dead particulate matter in the growth dishes. Foliar leachate was prepared by allowing 12 g of white elm leaves to decompose for two months in each of four beakers containing 900 ml of distilled water. Two months was chosen as the time interval because it took *M. securis* this period of time to grow and reproduce. After two months had elapsed, the volume in each beaker was brought up to 1200 ml with distilled water. The leachate was then either filtered through No. 1 Watman Filter Paper, autoclaved, or left unaltered. Aliquots of 300 ml of the treated leachates were added to 50 g of either autoclaved or untreated Carp Pond soil in the following manner: (A) autoclaved soil with (1) unaltered leachate and leaves, (2) unaltered leachate less leaves, (3) filtered leachate, and (4) filtered and autoclaved leachate; (B) untreated soil with (1) unaltered leachate and leaves, (2) unaltered leachate less leaves, (3) filtered leachate, and (4) filtered and autoclaved leachate. Three replicates of each combination of leachate and soil were made. Five *M. securis* were added to each dish and their growth was measured at approximately two-week intervals. Water samples from each dish were examined periodically for microorganisms. Some adults were sacrified near the end of the experiment for analyses of intestinal contents.

STATISTICAL PROCEDURES

Since all growth curves of *M. securis* reached an asymptotic value on approximately the 70th day, asymptotic regression formulae were fitted to the growth data. The modified exponential, $Y = A + BR^x$, gave the best fit to hyperbolic growth curves but transgeneration of this regression to the logistic equation, $1/Y = A + BR^x$, gave the best fit to sigmoid growth curves. The coefficient A is the asymptotic value or the maximum length (mm) attained, B is the distance between the asymptotic value and the value of Y when $x = 0$, (i. e. the increment in growth since birth), and R is the ratio of successive differences along the curve.

The logistic regression is merely a modified exponential in terms of the reciprocals of the Y values. That is, A in the logistic expression equals 1/A of the modified exponential (when $x = 0$ and $B = 0$). Also, B of the logistic equation equals $1/Y = 1/A$ of the modified exponential (when $x = 0$). Therefore, to compare coefficients between the two curves, it was necessary to make the appropriate conversions. A Fortran computer program was used to calculate the asymptotic regression of *M. securis* in all growth experiments. The program, described by Dixon (1971: 297-311), is called "BMD 06R".

Results of the growth experiments are reported in figures and tables. There were no significant differences ($P > 0.05$) in the growths of *M. securis* between replicates, as determined by the Student's *t* test (Simpson *et al.*, 1960: 178) on A and B of the regressions. Therefore, the growth curves of *M. securis* are plotted as average observed growth in length within replicated dishes. Significant differences between mean asymptotic values (A) and between growth increments since birth (B) of different growth curves are presented in tables. However, as indicated above, it was necessary to make the appropriate inversion of the coefficient of the logistic expression back to the modified exponential and to express Y and the coefficients in terms of the original units of measurements. Therefore, the A and B values of the logistic expression $1/Y = A + BR^x$, were re-inverted so that $A' = 1/A$ ($X = 0$, $B = 0$) and

Table 4. Asymptotic growth data for the regression $1/Y = A + BR^X$ and the natalities of Musculium securis adults grown on autoclaved and unautoclaved soil and leaf-leachate. Each combination of soil and leaf-leachate shown in the table was replicated three times with five clams in each replicate. Means side-scored by the same lines are not significantly different at P = 0.05.

Combinations of soil and leaf-leachate	Means and standard deviations ( ) of asymptotic regression data for $1/Y = A + BR^X$						Mean natality and standard deviation ( ) per growth dish	
	A mm		B mm		R			
UNAUTOCLAVED SOIL and:								
unaltered leachate plus leaves	0.160	(0.021)	0.469	(0.019)	0.987	(0.0024)	38.4	(3.7)
unaltered leachate less leaves	0.168	(0.015)	0.458	(0.015)	0.980	(0.0025)	33.7	(9.2)
filtered leachate	0.183	(0.018)	0.445	(0.016)	0.976	(0.0051)	27.2	(4.1)
filtered and autoclaved leachate	0.195	(0.024)	0.433	(0.022)	0.970	(0.0060)	21.5	(3.8)
AUTOCLAVED SOIL and:								
unaltered leachate plus leaves	No fit obtained with asymptotic regressions						0	
unaltered leachate less leaves	No fit obtained with asymptotic regressions						0	
filtered leachate	No fit obtained with asymptotic regressions						0	
filtered and autoclaved leachate	No fit obtained with asymptotic regressions						0	

$B' = 1 \quad (1/Y\text{-}A)$. The inversions are indicated in the tables with the expression $1/Y' = A' + B'R^x$.

Also appearing in the tables are the mean natalities of *M. securis* in replicated growth dishes. A student's *t* test was used to test for significant differences between means. Means that are not significantly different at $P = 0.05$ are side-scored by the same line.

RESULTS AND DISCUSSION

Sediment Texture

Table 1 shows that *M. securis* has greater growth and reproduction on fine sediments than on coarse sediments. This is not surprising since texture is related to several other variables (Buckman and Brady 1969) all of which may act independently and synergistically in the natural habitat. Such variables include the sediment particle size and porosity, both of which affect movement of clams through the sediments and the supplies of nutrients to the clams. The results suggest that *M. securis* should be distributed according to sediment particle size in Britannia Bay, with largest populations in fine sand and silt-clay. This generally is not observed; very small densities occur in fine sand although larger densities do occur in silt-clay. However, it is possible that other factors limit the distribution of *M. securis* on fine sand. For example, fine sand is present mainly in the shallow shore zone where summer temperatures often exceed 32°C, a temperature that is lethal to adult *M. securis* (Mackie 1973). Other sphaeriids have similar preferences for fine sediments; *M. transversum* prefers mud instead of sandy-mud and sand (Gale 1969); *Pisidium lilljeborgi* prefers fine grained organic sediments, but *Pisidium nitidum* and *Pisidium hibernicum* prefer coarse organic substrates with large-pored interstitial spaces (Meier-Brook 1969); and small *Sphaerium striatinum* select mud instead of sand and sandy-mud (Gale 1973). These results indicate that the occurrence and abundance of sphaeriids are, in part, dependent upon sediment texture.

Different Substrates

Tables 2 and 3 show that *M. securis* has greater growth and reproduction on soils and leaves of deciduous forests than on soils and leaves of coniferous forests. Of the several factors in leaves and sediments that could affect reproduction of *M. securis*, calcium would be among the most important since it is used in shell formation. The importance of calcium is indicated in Fig. 1 which shows a correlation between the calcium content of leaves and the natality of *M. securis*; no correlation occurred with the calcium content of soil. Comparable calcium contents were found for the same leaf species by Chandler (1939, 1941), Bard (1945), Lutz and Chandler (1946), Scott (1955), and Coile (1937). Slack (1961) has discussed the effects of tree leaves on water quality.

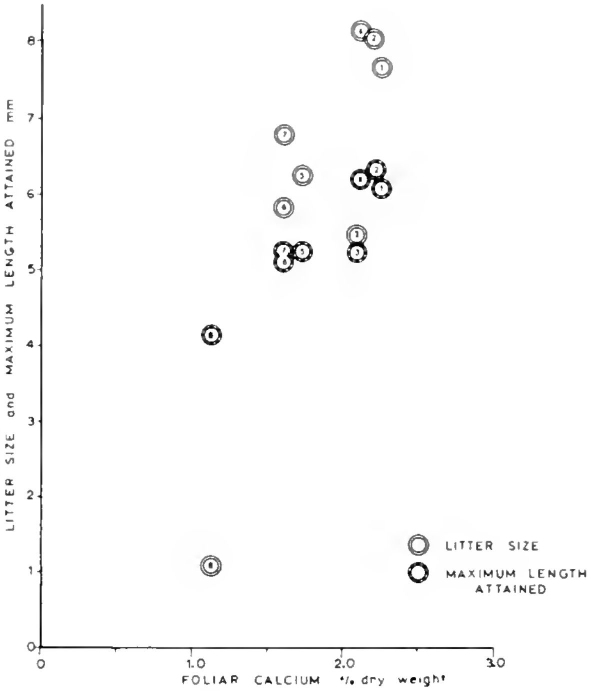

FIG. 1. *The average litter sizes and maximum shell lengths attained by* M. securis *in relation to the calcium content (% of dry weights) of eight species of tree foliage.* (1) *black willow,* (2) *white elm,*(3) *trembling aspen,* (4) *white cedar,* (5) *white birch,* (6) *white spruce,* (7) *red oak, and* (8) *red maple. Correlation coefficient (r) for litter size = 0.79 and for maximum length attained = 0.90*

The laboratory studies show that there are factors in both soil and leaves that are important to the growth and reproduction of *M. securis* (Table 4). Autoclaving of soils and leaf-leachate kills all organisms. Therefore, the lack of growth in dishes containing autoclaved soils and autoclaved, filtered leachate indicates that living organisms are necessary for growth and that nutrients in elemental or detritus form are not sufficient to sustain *M. securis*. Since more growth occurs in dishes containing unaltered soil and autoclaved, filtered leachate, than in dishes containing autoclaved soil and autoclaved, filtered leaf-leachate, most of the food organisms must be in the soil. Also, *M. securis* must derive some nourishment (although apparently little) from leaf tissue since more growth occurs in dishes containing leaves (and unautoclaved soil, unaltered leachate). Several unsuccessful attempts have been made to grow *M. securis* in dishes with only soil and distilled water. The fact that *M. securis* can grow in dishes with unautoclaved soil and autoclaved, filtered leachate but not in dishes with unautoclaved soil and only distilled water indicates that leaves contribute nutrients in elemental form. However, it was shown above that living organisms are necessary for growth of *M. securis*. Therefore, it is implied that the nutrients in elemental form are taken up by microorganisms which in turn are devoured by *M. securis*.

Table 5. The presence (P) and absence (A) of organisms in the intestine of Musculium securis during twelve months of the year in Carp Pond and Britannia Bay. "E" indicates that more than 75% of the intestines examined were empty. "N" denotes that newborns dominated the population and that the intestines were not examined.

INTESTINAL ORGANISMS	CARP POND J F M A M J J A S O N D [illegible]	BRITANNIA BAY J F M A M J J A S O N D [illegible]
Chrysophyta		
Vaucheria[a]	A A A	P P P
Diatoms		
Achnanthes	P P P	A A A
Ampora	P P P	A A A
Cocconeis	P P P	A A A
Cymbella	P P P	A A A
Fragilaria	P P P	P P P
Gomphonema	A P P	A A A
Navicula	P P P	P P P
Rhoicosphenia[b]	P P P	A A A
Synedra[b]	A A A	P P P
Chlorophyta		
Sphaerocystis	P P P	A A A
Stigeoclonium	P P A	A A A
Cyanophyta		
Lyngbya[a]	A A A	P P P
Pyrrophyta		
Glenodinium	P P P	A A A

[a] The phylum is probably represented by the genus indicated.

[b] The genus was not found nor identified by Dr. R. E. S. Lee but it was found and identified by the author.

Apparently, tree foliage is not pertinent to the growth of *M. securis* because the species occurs in Britannia Bay where tree foliage is absent. However, there is a large biomass of algae (primarily *Vaucheria* and *Lyngbya*) in the sediments of Britannia Bay. Analyses of the intestinal contents of *M. securis* from Britannia Bay (Table 5) shows that they feed on cyanophytes and chrysophytes (especially diatoms) which are probably *Lyngbya* and *Vaucheria*, respectively. Further support is seen in the strong correlation (r = 0.79) between the biomass of *Lyngbya-Vaucheria* (the two genera occur together in entangled masses) in the sediment and the densities of *M. securis* in various depths of Britannia Bay (Fig. 2a, b); each plot in the figure represents the average dry weight of algae and the respective densities of *M. securis* in four samples, each sample being composed of four pooled Ekman grab samples (i. e. total of 16 samples per plot). Fig. 2c shows a strong correlation between the calcium content of the algae and the abundance of *M. securis* in various depths of Britannia Bay. The calcium contents were determined in the same manner as for the tree foliage (see Materials and Methods).

The laboratory studies also suggest that, in general, leaves from deciduous trees, especially willows and white elms, are more conducive to the growth and reproduction of *M. securis* than are leaves from conifers, although the soil is also a major factor. This implies a correlation in distributions between *M. securis* and deciduous trees in North America. Fig. 3 shows a striking similarity in the distribution patterns of *M. securis* and deciduous forests in North America and supports the results of laboratory growth studies. White birch and trembling aspen are common deciduous trees in the coniferous forest region (Hosie 1969) and may explain the occurence of *M. securis* in western Canada and United States. However, there are several factors to be considered in assessing the importance of

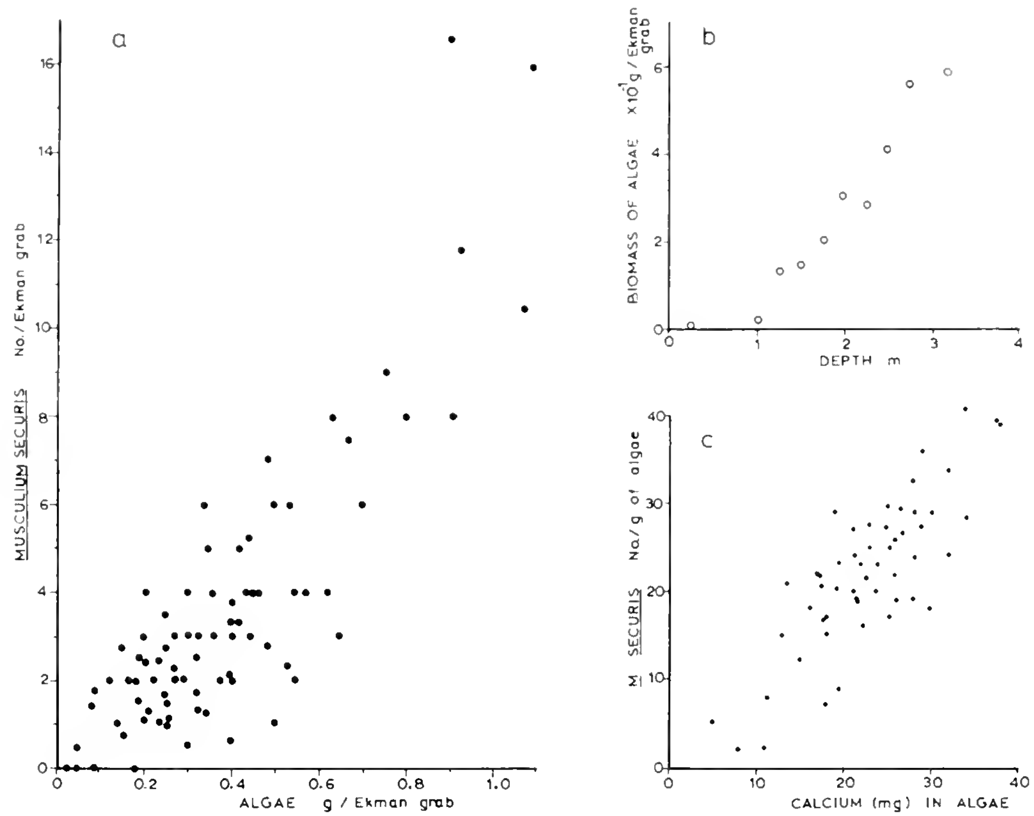

FIG. 2. *Relation between the abundance of* M. securis *and the biomass of* Lynbgya-Vaucheria *algae.* (a) *The abundance of* M. securis *per gram of* Lyngbya-Vaucheria *algae in several standard Ekman grab (15 cm × 15 cm with screen on top) samples of Britannia Bay sediments. Correlation coefficient (r) = 0.79.* (b) *The biomass (g Ekman grab) of* Lyngbya-Vaucheria *algae in various depths of water in Britannia Bay.* (c) *Relation between the abundance of* M. securis *(No. g of algae) and the calcium content (mg) of* Lyngbya-Vaucheria *algae. Correlation coefficient (r) = 0.81.*

tree foliage and different sediments as limiting factors in the distribution of *M. securis*. First, a high water table must be present and the soil should have properties which are conducive to the formation of a body of water for a least a part of the year (the life history studies by Mackie, Qadri and Clarke (1975, 1976) indicate the necessity of water from November to July). Second, only certain forest tree species can tolerate wet environments, e. g. white elm, some willows, red maple, cedars, and some oaks (Hosie 1969). Third, leaves of some tree species are more conducive to the growth and reproduction of *M. securis* than are others; therefore, the abundance of one tree species relative to another often may be important. Fourth, the importance of tree foliage and different soils as limiting factors probably decreases with increasing size (volume) of the body of water. Finally, the species must be easily distributed by an effective dispersal agent.

Considerably more work is needed to show what other edaphic factors limit the distribution of mollusks, especially sphaeriids. Some investigators (Shimek 1930) have related the distribution of land mollusks to the distribution of certain tree species but none have studied this relation with freshwater mollusks. However, Krull (1936) has found that oak leaves are important in raising *M. partumeium* in the laboratory. Boycott (1936) described several factors that limit the distribution of mollusks, including sphaeriids, in

Britain. Kaushik and Hynes (1971) have examined factors that affect rates of decomposition of several species of leaves and leaf preferences of some benthic crustaceans.

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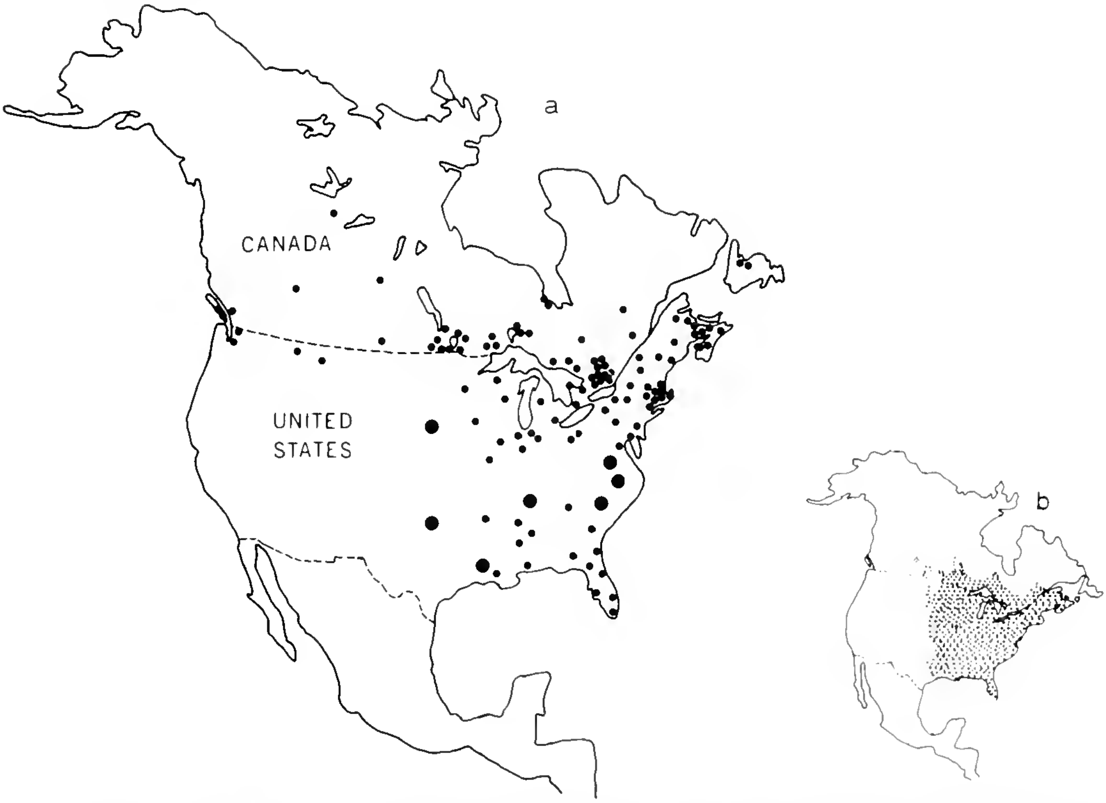

FIG. 3. (a) *Distribution of* Musculium securis *in North America. The small black dots represent locations of* M. securis *that were identified by H. B. Herrington or reported in the literature (Heard, 1962, 1963) or confirmed by the author. The large black dots refer to states in which* M. securis *has been found but the specific localities were not reported* (b)*General distribution of the deciduous forest in North America. (Adapted from Hosie, 1969 and Fowells, 1965)*

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ARE SPHAERIID CLAMS OVOVIVIPAROUS OR VIVIPAROUS?

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ABSTRACT

Several different definitions for the same word has resulted in the indiscriminant use of ovoviviparous and viviparous for Sphaeriidae reproduction. After a re-examination of some of the definitions and of sphaeriid embryology and development it is concluded that, of the two terms, ovoviviparous is most applicable.

There has been and still remains considerable confusion among investigators of sphaeriids concerning the method of bringing forth young in fingernail and pill clams. Most early investigators, for example, Gilmore (1917), Monk (1928), and Okada (1935b), and more recently, Thomas (1959) and Avolizi (1976), refer to sphaeriids as viviparous clams. Others, for example, Clarke (1973), Heard (1977) and Mackie (1978) refer to them as ovoviviparous animals. Still others, including Wilbur and Yonge (1964), Purchon (1977), and Meier-Brook (1977), refer to development in sphaeriids simply as incubation or brooding without designating them as either ovoviviparous or viviparous.

Much of this confusion appears, in part at least, to have resulted from the several different definitions of each term. There are at least four definitions for ovoviviparous that differ either on the basis of site of larval development (i.e. in the reproductive tract or elsewhere) in the maternal organisms or on the source of nutrients for the embryo. Gardiner (1972) defines ovoviviparous as development of young in some part of the reproductive tract and the embryo derives nutriment solely from the yolk of the egg. Balinsky (1975) defines it as, "bearing of young developed from eggs which have been retained in the body of the mother but without the maternal organism providing additional nourishment for the embryo." However, an example of a dogfish is given where some nourishment is derived from substances dissolved in the uterine fluid and therefore implies that not all nourishment comes from the egg alone. Martin (1976) makes no references to the importance of the yolk or dissolved material in the uterine fluid as nutriment and defines ovoviviparity as "a type of animal reproduction in which the embryos develop within the maternal organism but makes no apparent contact with maternal tissues for the purposes of nutrition." Finally, Abercrombie, Hickman and Johnson (1977) add one other criterion, the presence of egg membranes, and define ovoviviparous as "having embryos which develop within the maternal organism, from which they may derive nutriment, though they are separated from it by the persistence, through most or all of development, of egg membranes." Of these four definitions, only Gardiner stipulates that the embryo must develop in some part of the reproductive system. If it develops elsewhere in brood pouches, it is a brooding species. In the other three definitions no site for larval development is described and brooding species are presumably included in ovoviviparity, although this is not made explicit in the definitions. There are several other definitions for ovoviviparity but all are variations of the four given above.

Definitions for viviparity are equally as diverse. Gardiner (1972) uses viviparity when young develop in some part of the reproductive tract and nutriment is derived directly from the tissues of the mother by some special anatomical arrangement. A similar definition is given by Balinsky (1975) as the "embryo establishes a direct connection with the maternal body, so that the nutrition can pass from the mother to the embryo without the intermediate state of being dissolved in the uterine fluid," but no reference is made to the reproductive tract as the site for development. Martin's (1976) definition (i.e. a type of reproduction in animals in which the embryos develop within and derive nourishment from the maternal organism") does not clearly separate ovoviviparity from viviparity and differs from Balinsky's definition in that a direct connection between the embryo and maternal organism is not required, although the lack of this attachment is his definition of ovoviviparity implies presence of attachment in viviparity. Hagan (1951) divides viviparity into adenotrophic, haemocoelous, and pseudoplacental viviparity for insects and the definitions for these differ on the basis of the site of larval development (i.e. in the haemocoele or in parts of the reproductive tract) and whether larval nourishment is acquired from specialized maternal organs or tissues. There are many other definitions in the literature but all seem to be variations of those given above.

Depending on which definition is used, sphaeriid clams may be called either ovoviviparous or viviparous. Eggs of sphaeriids have a vitelline membrane (Woods 1932), are poor in yolk (Raven 1958) and not sufficient to nourish the embryo until maternal deposition of offspring. The larvae develop in brood sacs on the anterior part of outer descending filaments of inner demibranchs and are supplied with nutriment (contained in the marsupial fluid) derived from the inner layer of the brood sacs and the nutriment layer of the inner branchial chamber (Okada 1935a). The larvae of species of *Musculium* are attached to the parent by a byssal thread which serves merely as a holdfast and not as an organ for larval nourishment (Mackie, Qadri, and Clarke 1974). With these facts, sphaeriids are clearly ovoviviparous according to the definitions of this term by Abercrombie, Hickman and Johnson (1977), Hagan (1951) and Martin (1976). They contain brooding or ovoviviparous and viviparous characters according to the definitions of Gardiner (1972), Balinsky (1975) and Martin (1976). None of the definitions describe sphaeriids clearly as viviparous, mainly because the young lack a direct connection with the parent for nutritional purposes. Therefore it seems ovoviviparous is most applicable to Sphaeriidae, as, indeed, it is to other mollusks that brood their young within their bodies.

A quick survey of the literature will show that all possible gradations may be expected among (A) such forms in which the embryo depends solely on the food supplied in the egg after it is laid (i.e. oviparity), or when it is retained (i.e. true ovoviviparity), (B) such forms in which the embryo depends chiefly on food supplied by the mother in uterine or marsupial fluid, and (C) such forms in which the embryo depends solely on food supplied by the mother through anatomical connections (i.e. true viviparity as found in mammals). The next most obvious question seems to be, what do you call organisms in the intermediate phase, B, ovoviviparous or viviparous? Since ovoviviparity is generally considered to be a transitional phase in the evolution of viviparity (Balinsky 1975), it seems obvious (to the author at least) that organisms in the intermediate phase (B) be called ovoviviparous. This includes sphaeriid clams.

ACKNOWLEDGMENTS

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REVIEW OF THE GENUS *BURSA* IN THE WESTERN ATLANTIC

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ABSTRACT

Bursa (Bursa) pacamoni *Matthews and Coelho of Brazil is reported from the Florida Keys, Cuba, Puerto Rico and Curaçao.* Bursa ranelloides *Reeve, of Japanese and Indo-Pacific waters, is now found to occur in deep water off Puerto Rico and Bermuda. The remaining species of the family* Bursidae *in the Western Atlantic are reviewed.*

Bursa (Bursa) pacamoni Matthews and Coelho, 1971, was originally collected on Brazil's east coast, from off the City of Bahia, north to Atol das Rocas, and were taken from the digestive tract of the toadfish, commonly known in Brazil as "Pacamon" (*Amphichthys cryptocentrus* (Cuvier and Valenciennes, 1837)) in depths varying from 23 to 93 meters. The type series of 12 shells cited by the authors had an average length of 24 mm and average width of 16 mm. A revised English description of one of the types of this species follows:

Shell compressed dorso-ventrally, measuring 28 mm in length and 20 mm in width; protoconch consisting of 3½ whorls, well-marked suture, elevated smooth nucleus, becoming immediately cancellate, the axial ornamentation stronger than the spiral one, both weaker, after the second whorl, and the rest almost smooth. Color dirty yellowish white with irregular light-yellow spots. Protoconch in adult shells usually quite eroded. Teleoconch yellowish brown, with small spots of dark-brown and rarely with yellow spots. Ornamented with nodulose spiral cords. Body whorl with 3 more strongly pronounced cords, the one on the periphery of the shoulder with 4 knobs, 3 very strong and 1 weaker, the latter, always proximal to the most recent varix. This cord is also present in the whorls of the spire. All nodulose cords and knobs continue over the varices, producing a slightly irregular profile, more pronounced on the body whorl. In each whorl, immediately after the suture, there is a spiral line of axially elongated nodules. Each whorl with 2 opposite, lateral and continuous varices. Aperture sub-oval, the outside coloration visible on the inside; outer lip reflected, forming a milk-white callus, with 9 elongate teeth of the same color; inner lip with narrow columellar callus, milk-white, thick and adnate anteriorly; thin, adherent and transparent posteriorly; with several long columellar folds, which penetrate into the aperture. Posterior siphonal canal long, set about 40 degrees in relation to the columella axis, almost closed, adhering to the outer lip varix, over which it is bent and reaching the varix of the previous whorl; anterior siphonal canal almost closed, bent toward the apertural side. Operculum corneous, thin, transparent with sub-apical nucleus.

In a brief review of the Western Atlantic *Bursa* by Thomas L. McGinty (1962), the existence of a supposed white-mouthed variant of *Bursa corrugata* Perry, 1811, from Florida and Cuban waters was cited. From a perusal of the Brazilian paper, the examples examined earlier by McGinty are now apparently referable to *B. pacamoni*. From the type locality of the 12 Brazilian specimens, it is interesting to note that the largest example measured 34 mm × 22 mm. New locality records and measurements of specimens taken outside of Brazilian waters, are as follows:

Florida: Dry Rocks, off Key Largo, south end, exposed reef, purportedly live-collected in 1948 by Walter Banka; 55 mm × 35 mm (Finlay collection). Figs. 1 and 2; Sombrero reef, off Marathon; under slab of coral rubble in 20 feet (ocean side); live-taken by Theodore Kalafut, July 7, 1977; 47 mm × 29 mm (Kalafut collection).

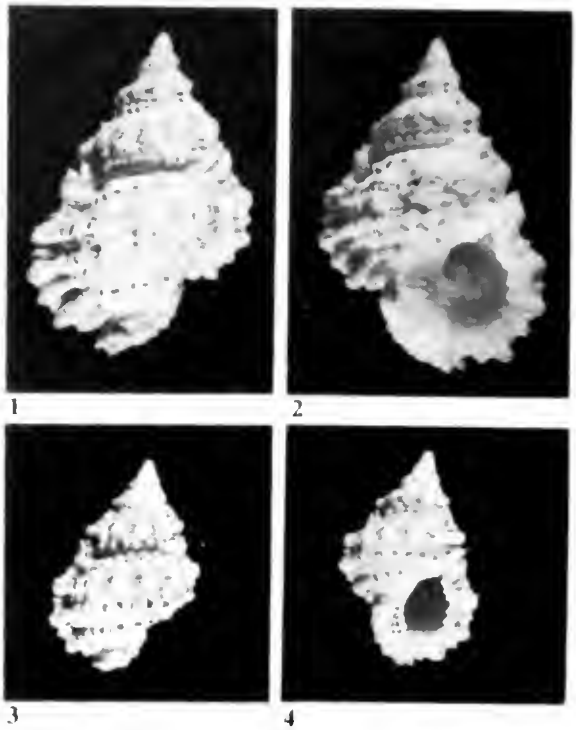
Cuba: Varadero Beach, Matanzas, 1 mile west of north entrance to Paso Malo lagoon. Fresh beach specimen; 38 mm × 25 mm (collection of Mrs. William L. Cosby, Jr.) Figs. 3 and 4.

Puerto Rico: Piñones beach, 4 miles east of Boca de Cangrejos, north coast, dead specimen; 39 mm × 31 mm (collection of Mrs. David Humphrey); Ponce, dredge spoil, south coast, July 1964, collected by Harry G. Lee (Hawaiian Shell News, March 1978).

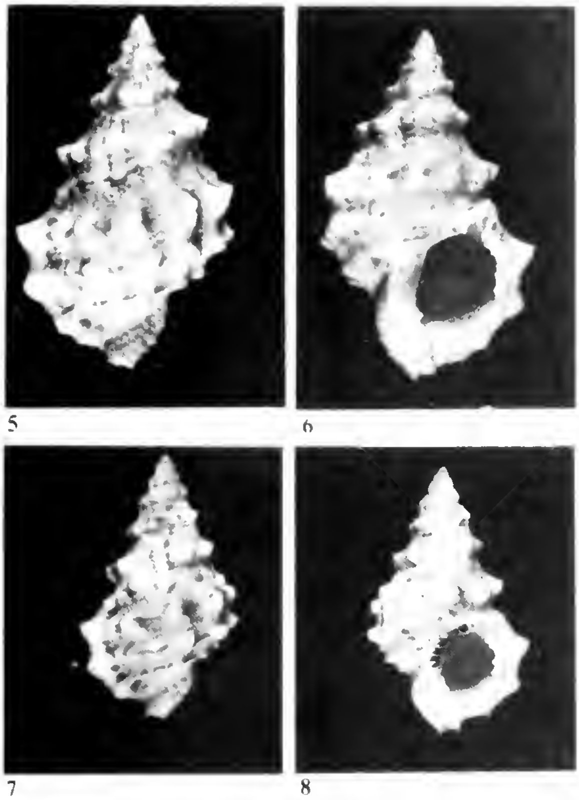
Curaçao: Playa Mansaliña, under slab of broken coral in 2 meters; 44 mm in length; live-taken in April 1973 by Danker Vink and in his collection (Hawaiian Shell News, November 1977).

A careful scrutiny of Western Atlantic and Caribbean collections, will no doubt bring to light more examples of this rare species, quite likely incorrectly identified as *Bursa thomae* which it superficially resembles.

Bursa ranelloides Reeve, 1844, a common Indo-Pacific species, is hereby recorded from the tropical Western Atlantic region. From a series of *Bursa finlayi* McGinty, 1962, acquired in 1973 from deep-water fishermen on the west coast of Puerto Rico, one specimen proved to be this species. Messrs. Jack Lightbourn and Arthur Guest, of Bermuda, have taken a fine series of



FIGS. **1** *and* **2.** Bursa pacamoni *Matthews and Coelho, 1971. Dry Rocks, off Key Largo, Florida. 55 mm.* **3,** *and* **4,** *Varadero Beach, Matanzas, Cuba. 38 mm.*



FIGS. 5 *and* 6. Bursa ranelloides *Reeve, 1844. Off Bahia de Añasco, Puerto Rico. 66 mm. Figs.* 7 *and* 8. *Off Northeast Breakers, Bermuda. 50 mm.*

this taxon in their deep water trapping operations off the south shore of Tuckers Town and Northeast Breakers.

Locality records — **Puerto Rico:** In fish trap, 100 fathoms off Bahia de Añasco, west coast of Puerto Rico. 66 mm × 39 mm. (in Finlay collection). Figs. 5 and 6 **Bermuda:** In fish pot, 60-80 fathoms, off N.E. Breakers, Spring of 1973; 50 mm × 29 mm (in Finlay collection). From Lightbourn and Guest traps. Figs. 7 and 8.

A brief review of the remaining known members of the Western Atlantic *Bursa* group follows:

Bursa finlayi McGinty, 1962. This species is closest to *B. tenuisculpta* (Dautzenberg and Fischer, 1906), but differs in its larger size (a specimen in the writer's collection measures 90 mm), more slender shape, and the possession (in most examples) of small sharp nodules on the spiral sculpture. Color light to dark-brown. The shell is known from deep water (70 to 120 fathoms) in the Florida Keys, the Greater and Lesser Antilles, south to Brazil, where it has been recently reported by Dr. E. de Carvalho Rios (1975). From recent issues of *Hawaiian Shell News,* it is of interest to note that this species has now turned up in the deep water off Hawaii, and in 60 fathoms, near Cape Moreton, Queensland, Australia.

Bursa tenuisculpta (Dautzenberg and Fischer, 1906). This species, while close to *B. finlayi,* differs in being relatively wider, with a finer nodular sculpture, and with a somewhat heavier structure of the teleoconch. Color a dull, ash-gray. While the depth reported by McGinty (1962) for this species is approximately the same as for *B. finlayi,* the writer has never encountered specimens from deep water trappings in the Greater and Lesser Antilles. This species is reported from the Eastern Atlantic region. A taller-spired subspecies was described from Natal, Brazil, *B. natalensis* Coelho and Matthews, 1970 (Bol. Mus. Nacional, n.s. Zoologia, No. 279).

Bursa thomae (Orbigny, 1842). Shell 12 to 25 mm in length, dirty-white, with short axial streaks of reddish brown. Varices situated axially one below the other, as in *B. pacamoni* (which it somewhat resembles). Posterior canal prominent. Mouth lavendar-colored and flaring, with 8 or 9 white teeth. Moderately common in shallow water under rocks and to depths of 40 fathoms.

Bursa corrugata (Perry, 1811). Shell reaching 95 mm in length, laterally depressed; two prominent, knobbed varices on each whorl. While there are usually 1 or 2 rows of blunt nodules on the body whorl, specimens dredged from San Juan Harbor, Puerto Rico, have up to 6 rows. Spire of adult specimens are invariably decollated. Color normally a reddish brown but orange colored specimens are occasionally found.

Bursa granularis cubaniana (Orbigny, 1842). Shell reaching 50 mm in length, flattened laterally. Varices axially arranged, one below the other. Color orange-brown. Three light-colored bands appear on the varices. Spiral sculpture consists of several rows of small beads. Aperture teeth white. This species is commonly collected in Caribbean reef areas, and not infrequently taken in pairs. Occasionally a female may be found resting on top of the round cup-shaped egg case.

Abbott (1958) considers this merely a subspecies of the common Indo-Pacific *granularis* Röding.

Bursa bufo (Bruguière, 1792). This is the most flattened *Bursa* species of the western Atlantic, reaching 50 mm in length; with strong rounded varices, 2 on each whorl and arranged axially one under the other. Surface sculpture consisting of spiral rows of numerous small beads. Color yellowish with diffused markings of orange-brown. Ranges from Florida (rare) to Brazil. Dredged in 28 to 50 fathoms. Alias *B. crassa* Dillwyn, 1817, and *B. spadicea* (Montfort, 1810).

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MATING, SPAWNING, DEVELOPMENT AND FEEDING HABITS OF *CONUS GEOGRAPHUS* IN CAPTIVITY

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ABSTRACT

The feeding behavior, mating, spawning and early development of Conus geographus *Linnaeus, 1758 was observed in captivity. It was found that copulation lasted for approximately 25 minutes, and spawning of a cluster of capsules took two to three days. The extrusion of a capsule is described in detail. Free-swimming veligers appeared within 20 days after egg deposition.*

The egg capsules and larval development of a number of species of *Conus* have been described by Nybakken (1967) and by Kohn (1961), based on field studies in Hawaii, the Indian Ocean and in Sonora, Mexico. An alternative to field observations in studying mating, spawning and development is to induce specimens to mate and spawn in aquaria. This was done inadvertently in our laboratory when we maintained a colony of 20 *Conus geographus* Linnaeus, 1758, specimens in a 10-gallon aquarium in order to study the biochemical properties of the venoms (Cruz *et al.*, 1976). Mating was observed once. Many observations of egg laying were made, especially in the month of April in 3 successive years (1975-1977). We also observed three cases of egg laying by *Conus textile* Linnaeus, 1758, including one case after a year in captivity.

The specimens of *Conus geographus* were obtained from the Island of Marinduque in the Philippines, and after collection were flown by air into our laboratory in Manila and maintained in an aquarium. The *Conus geographus* were initially a problem to feed since fish caught in Manila (*Ambassis* sp. and *Therapon* sp.) did not elicit any interest from the molluscs. For the first few weeks, the *Conus geographus* were individually transferred into basins and fish were forcibly stuck into their funnel-shaped mouths (rostrum or rhynchodaeum). On several occasions, the molluscs would refuse the fish by constricting the base of the rostrum. However, it was found that certain types of fish caused the *Conus geographus* to begin to extend the funnel-shaped dilated rostrum (Johnson and Stablum, 1970). When a group of fish including a puffer fish (*Tetraodon* sp.) and two small eels from Manila Bay were placed in the tank, the *Conus geographus* specimens became extremely active, and eventually captured all the fish. The *Conus geographus* attempted to swallow even the inflated puffer fish; the puffer was able to fight back and injure the cone; however, another *Conus* specimen was later able to kill and ingest the fish. In general, feeding and digestion proceeded as described by Johnson and Stablum (1970); this species was always observed to capture prey with its rostrum and not by stinging the fish first. This is in contrast to *Conus magus*, which harpoons and immobilizes the fish before engulfing it with its rostrum. After digestion in the rostrum, the molluscs would regurgitate fish bones, and other insoluble material along with a very large number of the hollow harpoon teeth. It may be that in this species, stinging serves primarily as a defensive and a digestive adaptation. The only time we observed a specimen possibly attempting to actively sting was when one mollusc was accidentally dropped and the shell broken; the mollusc seemed to be attempting to sting anything close by.

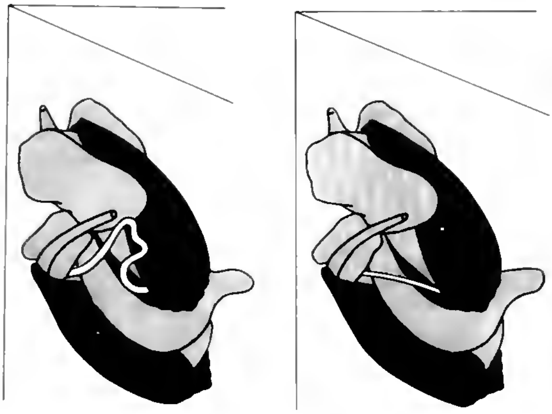
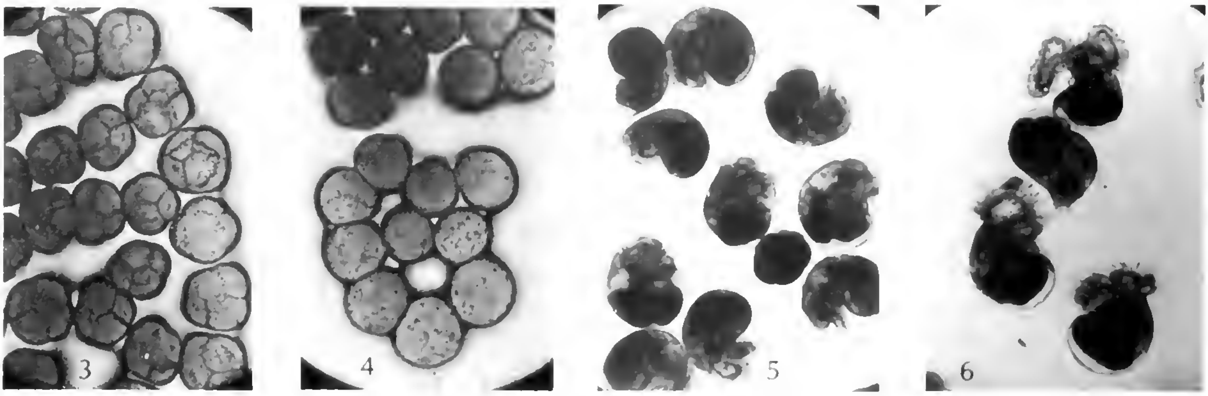


FIG. 1 *The diagram on the left shows the insertion of the verge of the male (ribbon-like white organ) as it was being inserted into the female The specimens are at one corner of the aquarium. The male is the lower specimen and the female is the upper specimen, with its foot partly against the two perpendicular glass walls of the aquarium. The shells are drawn black, while the soft parts (except verge) are shown speckled The figure on the right shows the verge fully inserted. This position was maintained for approximately 25 minutes. The verge was constricted to approximately ⅓ of its orginal width. The verge was then retracted into the side of the male into an opening normally hidden by the shell The two specimens remained in the orientation drawn for at least 15 minutes more after mating*

FIG. 2. Conus geographus *spawning on an aquarium wall The foot of the mollusc is visible, as well as the newly extruded egg clusters.*



FIGS. 3-6 *Development of* Conus geographus. **3,** *Micrograph of eggs in capsules after one day;* **4,** *4 days. The microscope used was an AO Spencer Microstar Series 10 microscope, with an Asahi Pentax Camera. The microscope objective was 10×, and the enlargement from negative to print was 15.3 fold;* **5,** *Larval forms found in capsules after 15 days.* **6,** *20 days. The larval shell and velum of the veligers are clearly visible in some of the specimens. Photography was as in Fig 4, except that the enlargement from negative to print was 10.8 fold.*

There was no evidence that *Conus geographus* attacked other *Conus* specimens; this is in contrast to *Conus textile*, which will attack *Conus striatus* specimens, and if food were withheld for long periods of time would practice cannibalism. We found that after some time in the aquarium, the *Conus geographus* would feed on frozen and thawed anchovies (*Stolephores* sp.) which were placed close to the mollusc.

After one month in the aquarium, two snails were apparently mating. A diagram of what was observed is shown in Fig. 1. Insertion of the long ribbon-like verge was observed and copulation lasted for about 25 minutes. No other examples of mating were seen.

Spawning was observed on 3 occasions, and in one case, the mollusc oviposited on the aquarium wall. It was, therefore, possible to photograph in detail the extrusion of the egg capsules (Fig. 2). The spawning process took approximately two to three days; each cluster consisted of about 40 egg capsules. The *Conus geographus* would first excrete a transparent substance which was stuck on the side of the aquarium glass wall; this transparent fluid (which became the base of a capsule) apparently hardened immediately and became opaque. The mollusc would then remain relatively motionless for 10 to 15 minutes. The mollusc's foot would then curl up and a capsule would be extruded; the capsule was attached to the previously secreted base. The mollusc would then move on, rest for a period of time and repeat the process. The appearance of the capsules and approximate dimensions were essentially as described by Kohn (1961).

The contents of capsules were examined after one day (Fig. 3), after four days (Fig. 4) and then after fifteen (Fig. 5) and twenty days (Fig. 6). The one-day old eggs appeared to be an early cleavage. After fifteen or twenty days, larvae were present in the unhatched capsules; however, the twenty-day capsules were partially open and some of the veligers were swimming around the aquarium.

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A SURVEY OF THE FRESHWATER MUSSELS (BIVALVIA: UNIONIDAE) OF THE KANAWHA RIVER OF WEST VIRGINIA

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ABSTRACT

During the summer of 1976 a survey of the upper Kanawha River produced thirteen species of unionid clams. Although suitable habitat was found throughout the drainage, clams were found in only the upper reaches of the river. Possible explanations for the absence of clams downstream are industrial and urban pollution and habitat modification for navigational purposes.

The richest unionid fauna in the world is found in North America and has been the subject of much research (Burch, 1973). Although much has been done on the distribution of freshwater mussels, little has been done in West Virginia, and no literature records were found of survey work on the Kanawha River. The presence of the species reported herein is of particular significance because they occur in a stream which has had no molluscan fauna for many years.

SITE OF STUDY

The Kanawha River flows for 97 miles in a generally northwesterly direction. It begins at the junction of the Gauley and New River near Gauley Bridge in central West Virginia and terminates at Point Pleasant, W. Va., where it flows into the Ohio River. With the exception of the upper Kanawha River area, where timbering and surface mining contributes sizable sediment loads, the water is generally classified as clean as regards suspended matter (Corps of Eng., 1975).

For the most part however, the river for decades has been characterized as one of low water quality resulting from industrial, urban organic sewage, and acid mine run-off pollution. The Kanawha River basin encompasses the Greater Charleston area (approx. population 100,000) in addition to a large industrial complex comprised primarily of chemical producing firms. This combination, for many years, produced a nearly sterile stream which has been recently referred to as "an open running sewer." Within the past few years, however, through the efforts of local, state, and national authorities, a great deal has been accomplished in cleaning up the river. Perhaps the presence of a fairly varied unionacean mollusk fauna as presented herein might indicate progress in this area.

MATERIALS AND METHODS

During the summer months (April - September) of 1976 a survey of the unionacean clam fauna of the upper Kanawha River was carried out. Six collecting stations were established and visited on an irregular basis (Fig. 1).

Water temperatures were recorded during each visit to a site using a Taylor Bi-therm thermometer. Standard water quality tests were accomplished using a Hach Water Test Kit Model AL-36 B. All testing was carried out in the field at the sample site immediately prior to collecting. These tests were run to ascertain if suitable habitat for mussels, as determined and reported in the literature by previous investigators, did in fact exist at the study sites.

The primary method of collecting utilized a crows-foot dredge as described by Pennak (1953). Wading in shallow areas as well as scuba and snorkel collecting in deeper water were also effective techniques used in this study.

Live specimens collected were returned to the laboratory in plastic bags and later transferred to oxygenated storage tanks. Positive identification was based upon shell morphology in conjunction with soft part anatomy. A relaxing agent AGL (Stansbery, 1976) was used to facilitate opening of the shells. AGL consists of a mixture of 80% ethyl alcohol, 5% glycerin, and 15% distilled water. Representative shells of all species were cleaned and accessioned to the Marshall University Malacological Collection (Numbers MUMC 804-814).

FIG. 1. *Upper Kanawha River drainage including collecting sites (black dots)*

FIELD STATIONS

Station No. 1 — Located at geographic coordinates 81°12′43″W Longitude, 38°08′12″N Latitude, or 1.1 Kilometers downstream of Kanawha Falls, Fayette Co. W. Va. At this site a rocky spit extends approximately 15 meters into the river. Depth ranges from 1 to 3 meters. Water flow is swift and clarity is usually high. Thirteen species of unionids present.

Station No. 2 — Located at geographic coordinates 81°22′54″W Longitude, 38°12′42″N Latitude, or adjacent to the unincorporated village of Pratt, Kanawha Co. This site consists of a long pebbly beach with water that shoals out gradually. Water movement is slow and clarity varies from good to murky. Numerous community sewage outflows enter the river in this area. Three unionid species present.

Station No. 3 — Located at geographic coordinates 81°34′25″W Longitude, 38°15′40″N Latitude. Adjacent to the W. Va. Turnpike and 1.1 Kilometers downstream from the Marmet Locks. Site consists of 100 meter long stretch of pebbly beach. Water depth varies from .6 to 1 m. Flow rate varies as the Lock gates are opened and closed. Clarity is usually good. *Corbicula* present, but no unionids.

Station No. 4 — Located at geographic coordinates 81°37′22″W Longitude, 38°12′42″N Latitude. Site consists of a pebbly spit produced by an intermittent stream located adjacent to property presently occupied by the Columbia Gas Co. and just downstream from Charleston (Kanawha Co.). Rate of flow is slow and water clarity varies from fair to poor. *Corbicula* present, but no unionids.

Station No. 5 — Located at geographic coordinates 81°50′00″W Longitude, 38°23′28″N Latitude. Site consists of a pebbly beach on the river's south side just downstream from the St. Albans-Nitro bridge (Kanawha Co.). Water flow is usually slow and water clarity always poor. No bivalves present.

Station No. 6 — Located at geographic coordinates 81°50′37″W Longitude, 38°30′03″N

Latitude. A sandy beach located on the river's south bank .7 Kilometer upstream from Bancroft (Putnam Co.). Water flow is slow and clarity is usually good. *Corbicula* present but no unionids.

RESULTS

Thirteen species of unionid clams were found to inhabit the upper Kanawha River. The following species were collected as live specimens:

Amblema costata (Rafinesque)
Fusconaia subrotunda (Lea)
Quadrula pustulosa (Lea)
Cyclonaias tuberculata (Rafinesque)
Elliptio dilatata (Rafinesque)
Lasmigona costata (Rafinesque)
Actinonaias c. carinata (Barnes)
Obovaria subrotunda (Rafinesque)
Potamilus alatus (Say) (formerly *Proptera*)
Lampsilis ovata ventricosa (Barnes)
Ptychobranchus fasciolare (Rafinesque)

Two additional species were collected only as dead shells. They are:

Ligumia recta (Lamarck)
Leptodea fragilis (Rafinesque)

All thirteen species were found at site No. 1. Site No. 2 produced only specimens of *Elliptio dilatata*, *Lasmigona costata*, and *Proptera alata*. No unionid clams were found at stations 3, 4, 5, or 6.

At stations 3, 4, and 6 large populations of the asiatic import *Corbicula manilensis* (Philippi) were found.

No bivalve mollusks were collected at station No. 5.

SUMMARY AND CONCLUSIONS

1. Thirteen species of unionid clams were found to inhabit the upper Kanawha River.
2. Station 1 located above the head of navigation (Corps of Eng., 1975) and essentially uneffected by industrial and organic pollution produced the richest diversity, as all thirteen species were present.
3. At stations 2-6 clams are rare or non-existant even though water quality parameters such as dissolved 0_2, temperature, substrate, flow rate, and clarity are compatible with standards established, by previous investigators, as suitable habitat.
4. Limiting factors that might explain the absence of clams at the downstream sites may include industrial wastes, urban organic enrichment, and habitat destruction resulting from navigational impoundment, and the presence of the introduced clam, *Corbicula*.
5. The Asian Clam *Corbicula manilensis* is well established throughout the study area as populations were found at all stations except #5. This fact may lend credence to the theory that *Corbicula* will thrive in water that has been rendered unsuitable for other bivalves.
6. Future studies of the molluscan fauna of the area could serve as a diagnostic tool in assessing efforts by local authorities and industry to clean up the Kanawha River.

ACKNOWLEDGMENTS

The authors wish to thank Dr. David H. Stansbery of the Ohio State University for confirmation of identifications. We also extend a special thanks to Rusty Morris, Mike Harshbarger, C. D. Duncan, and Bill Morris for their assistance in collecting the specimens.

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HABITATS OF TWO FRESHWATER LIMPETS (*FERRISSIA*: ANCYLIDAE) FROM NEW ENGLAND

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ABSTRACT

In a recent survey of 99 freshwater sites in eastern Connecticut and Massachusetts, 14 localities were found to contain populations of Ferrissia fragilis *and 2 of* F. walkeri. *Geology, ecoregions, altitudes, species associations, substrate preferences, and water chemistry are noted.* F. fragilis *appears to be a relatively common inhabitant of ponds and marshes and is able to tolerate the acidic, very low calcium conditions of southeastern New England's natural waters.* F. walkeri *populations are rare, occurring only in two lakes of exceptionally clear water which are otherwise devoid of snail populations.*

There have been relatively few publications dealing with the freshwater pulmonate gastropods of southern New England (Perkins, 1869; Gould, 1870; Baker, 1910; Johnson, 1915; Jacot, 1923; Knight, 1960a, 1960b; Jacobson and Emerson, 1971). These accounts mention three species of anyclids in New England: *Laevapex fuscus* (Adams), *Ferrissia rivularis* (Say), and *F. parallela* (Haldeman). A 1975-76 survey of 99 temporary and permanent aquatic habitats in eastern Connecticut and southern Massachusetts (70°05′W – 72°33′W, 41°21′N – 42°10′N) uncovered 46 sites with one or more populations of ancylid snails present. In addition to *L. fuscus*, *F. rivularis* and *F. parallela*, the survey located populations of *F. fragilis* (Tryon) at 14 sites and *F. walkeri* (Pilsbry and Harris) at 2 sites.

F. fragilis has been reported from southern Michigan (Basch, 1959; Smith, 1967), Ohio (Walter, 1972), north central Texas (McMahon and Aldridge, 1976), Nebraska (Burch and LoVerde, 1974), Oklahoma (Branson and Peters, 1964), Kansas and North Carolina (Basch, 1963). Basch (1963) cites additional references for California and New York, although Harman and Berg (1971) have not listed the species for central New York. Little is known about the environmental preferences of this tiny ancylid except that it has been found in stagnant, marshy habitats (Basch, 1963).

Almost no information is available on *F. walkeri*. The Museum of Zoology at the University of Michigan has lots from Arkansas, lower Michigan and Baja California, but this snail has never been reported from New England.

The published descriptions of *F. fragilis* and *F. walkeri* present a somewhat confused picture. Basch (1963) placed *F. shimekii* (Pilsbry) as a synonym of *F. fragilis*. However, in Baker (1928), the description for *F. shimekii* is almost identical with Basch's (1963) description of *F. walkeri*, the presence of a strongly eccentric apex being characteristic. Basch (1963) pointed out that there appeared to be a continuous gradient of morphological forms between populations of *F. fragilis* (Fig. 1A) and *F. walkeri* but that the two ends of the series were distinct enough to be considered different species. I am following the format of Basch (1963) and designating those populations whose individuals demonstrate an extremely eccentric apex as belonging to the species *F. walkeri* (Fig. 1B). It should be kept in mind that the two species may be different morphs of one plastic species.

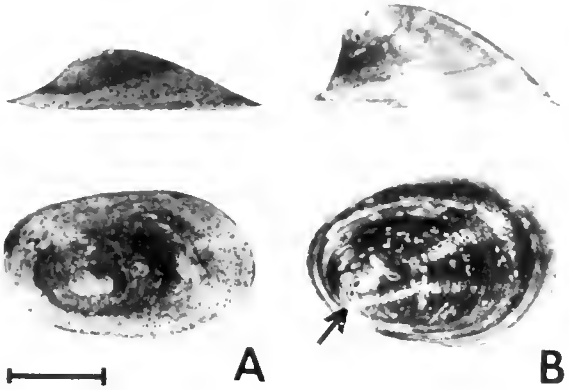

FIG. 1A Ferrissia fragilis *(Tryon). The scale bar is equal to 1 mm for both A and B.* 1B, Ferrissia walkeri *(Pilsbry and Harris). The arrow indicates the extremely eccentric shell apex.*

METHODS AND MATERIALS

Shallow littoral areas of freshwater habitats were examined visually for snails. The snails were relaxed in sodium nembutal (van der Schalie, 1953) and preserved in 70% ethanol. Water samples were taken at each site and analyzed as follows: pH by electrometric analysis with a Corning Model 10 pH meter; CO_2 by the MSA Model 202 Infrared Carbon Analyzer; conductivity by the YSI Model 31 Conductivity Bridge color ($OD_{350\ nm}$) by absorbance in the Beckman Spectrophotometer 70, and cations (Ca^{+2}, Mg^{+2}, Na^{+1}, K^{+1}) by atomic absorption and emission using the Perkin-Elmer Atomic Absorption Spectrophotometer Model 306.

OBSERVATIONS

Ferrissia fragilis

F. fragilis has been noted only once from New England (as *Ancylus (Ferrissia) novangliae* Walker) (Walker, 1908; cotypes at MCZ, Harvard, MCZ 134138, 164776). The type locality was a small pond near Cambridge, Massachusetts. The Department of Mollusks at the Museum of Comparative Zoology has additional New England specimens from the Aroostook River, Caribou, Maine; the Charles River, Cambridge, Massachusetts; and Branford, Connecticut. The present study has located populations of *F. fragilis* on the following substrates at these localities (Fig. 2):

Decaying allochthonous leaves and branches (all localities were scarce in or devoid of emergent vegetation): CONNECTICUT – New London Co., Preston Twp., Avery Pond; Tolland Co., Mansfield Twp., Bicentennial Pond (a newly-impounded former *Typha* marsh); Ashford Twp., a sluggish, small tributary of Bigelow Brook; Middlesex Co., E. Hampton Twp., Lake Pocotopaug; E. Haddam Twp., Peck's Meadow Pond. MASSACHUSETTS – Barnstable Co., Falmouth, Grew's Pond in Gooodwill Park; Truro, Little Pamet River, drainage from a *Typha* marsh; Plymouth Co., Pembroke, Indian Head River Impoundment above Elm Street dam.

Decaying autochthonous vegetation (both locales had few associated trees and, therefore, little allochthonous input): CONNECTICUT – New London Co., Stonington Twp., Barn Island *Typha latifolia* marshes, on decaying *Typha*; Tolland Co., Ellington Twp., Crystal Lake.

Mixed decaying allochthonous and autochthonous material: CONNECTICUT – Tolland Co., Mansfield Twp., "Pipeline Pond" (a pond formed in 1952 when a pipeline access road dammed a *Typha* marsh); Windham Co., Woodstock Twp., Roseland Lake.

Glass bottles: CONNECTICUT – Tolland Co., Stafford Twp., Riverside Pond.

Decomposing paper: MASSACHUSETTS – Plymouth Co., Norwell, Jacob's Pond.

It is apparent from the data that *F. fragilis* has a strong substrate preference for decaying organic matter. In habitats where *Typha* or *Phragmites* existed, the snails were found on the

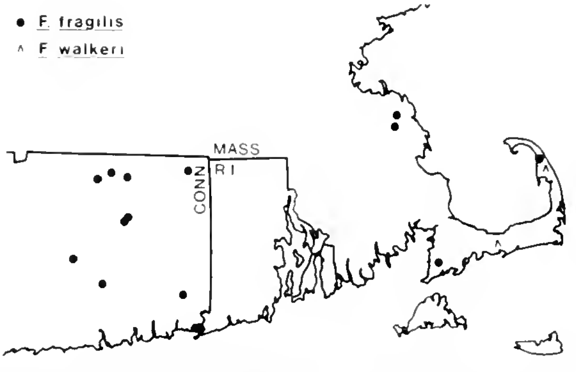

FIG. 2. *Localities in southeastern New England for populations of* F. fragilis *and* F. Walkeri.

decaying leaves or stems. In habitats where these emergents were scarce, the snails existed on decaying terrestrial debris. These observations are in basic accord with those of Basch (1963) and Baker (1928).

The underlying bedrock of eastern Connecticut and Massachusetts is primarily Paleozoic crystalline mica schist, mica gneiss and granite (Brooks and Deevey, 1963; U.S.G.S., 1967a). The surficial deposits are of glacial till (U.S.G.S., 1967b). Barnstable County (Cape Cod) in Massachusetts if formed from glacial moraine and outwash plains (Strahler, 1966). Due to the absence of calcium-bearing rock, the waters of southeastern New England are soft to extremely soft (less than 5 ppm Ca^+) (Deevey, 1940).

Chemical data taken at the collection sites of *F. fragilis* ranged as follows:

pH: 5.1-6.9, rather acidic to neutral. This is within the normal range for southeastern New England.

Conductivity: 37-425 µmhos. New England waters are normally within the range of 50-100 µmhos, a low conductivity indicating a low ionic content. The extreme low value of 37 µmhos was from Peck's Meadow Pond where *F. fragilis* was the only snail present, and the high value of 425 µmhos was from Barn Island marshes where the water is affected by sea spray and *F. fragilis* was moderately abundant along with *Lymnaea columella*. *F. fragilis* apparently has a high tolerance to a wide range of ionic content.

CO_2: measured as 1.3 mg dissolved inorganic C/1-5.1 mg C/1. These low values are within the normal New England range (Brooks and Deevey, 1963) and reflect the soft water.

Ca^{+2}: 1-23 mg/1, a range from very soft to medium hard. Six of the sites were of very soft to soft water.

Mg^{+2}: .6-5 mg/1. These values also reflect the soft water conditions.

Na^{+2}: 1-11 mg/1. The normal mean for hard-water lakes is approximately 4 mg/1 (Wetzel, 1975). Most of the sites had values greater than 6 mg/1, with the coastal lakes being the highest. The high values reflect sea spray influences and indicate that *F. fragilis* is tolerant of high Na^+ values.

K^+: .6-7 mg/1. The K^+ values correlated with the Na^+ with high values reflecting coastal sea spray areas or former salt areas now fresh.

Color: .015-.239 absorbance at OD_{350nm}. This is a range from quite clear to very brown water. Basch (1963) indicated a preference of *F. fragilis* for brown water but this study indicates that although *F. fragilis* is tolerant of extreme conditions, it is not limited to them.

Populations of *F. fragilis* occurred at altitudes from 2 m to 164 m. In Connecticut, these populations were found in the following ecoregions (of Dowhan and Craig, 1976): *northeast uplands* (forest vegetation of hardwoods-hemlock-white pine), *northeast hills* (central hardwoods-hemlock-white pine), *southeast hills* (central hardwoods-hemlock), and *eastern coastal* (coastal hardwoods). These areas have mean annual temperatures of 47.5-51°F and average annual precipitation of 43-46 inches (Dowhan and Craig, 1976). In Massachusetts, Plymouth County is similar to Connecticut's eastern coast but cooler, and Barnstable County is composed of a sand-based scrub-oak and pitch pine community.

In two of the 14 sites, *F. fragilis* was the only gastropod present: Peck's Meadow Pond and Grew's Pond (both with Ca^{+2} of only 1 mg/1). The other 12 sites contained populations of the following species (with the number of sites): *Campeloma decisum* (Say), 3 sites; *Amnicola limosa* (Say), 5; *Lyogyrus* sp., 2; *Lymnaea columella* (Say), 8; *L. obrussa* (Say), 1; *Physa ancillaria* (Say), 3; *P. skinneri* (Taylor), 2; *P. gyrina* (Say), 2; *P. heterostropha* (Say), 2; *Promenetus exacuous* (Say), 3; *Menetus dilatatus* (Gould), 7; *Planorbula armigera* (Say), 1; *Gyraulus parvus* (Say), 1; *G. deflectus* (Say), 5; *Helisoma anceps* (Menke), 5; *H. campanulatum* (Say), 1; *H. trivolvis* (Say), 1; *Laevapex fuscus* (Adams), 3. The most common associates of *F. fragilis* were *Menetus dilatatus* and *Lymnaea columella*, two species commonly found in small, quiet bodies of water. *F. fragilis* was not found to be sympatric with any other species of *Ferrissia*, but apparently co-exists successfully with *Laevapex fuscus*.

Ferrissia walkeri

This study uncovered only two populations of *F. walkeri*. Both were in Massachusetts, Barnstable County: Long Pond, Wellfleet, and Hathaway Pond, Hyannis. Both of these low altitude (2 m and 11 m, respectively), mesotrophic lakes have exceptionally clear (color OD_{350nm} absorbance of .001-.002), low conductivity (99 and 59 µmhos), soft water (both Ca^{+2} and Mg^{+2} of 1-2 mg/l) with high Na^{+1} (12 and 9 mg/l) and moderate K^{+1} (both 1 mg/l). In Long Pond, the snails were on rocks and glass bottles down to a depth of 10 m. In Hathaway Pond, the snails were on sparse decaying allochthonous material on a sand-pebble substrate. Neither lake showed evidence of other gastropod species, and it may be of interest to note that high Na:Ca ratios (over 6), such as occur in both these lakes, have been found to be detrimental to freshwater snails (Nduku and Harrison, 1976).

DISCUSSION

F. fragilis appears to be a common lentic habitat snail in southern New England. It occurs in very soft to medium hard water of variable color. It is tolerant of exceptionally low ionic content, being the only species present in one pond of salt content close to distilled water. On the other hand, it is able to tolerate the relatively high Na values characteristic of coastal lakes. Its distribution is widespread, extending from California (Basch, 1963) to New England (this study), and south to northern Texas (McMahon and Aldridge, 1976). The northern limits are yet to be determined, but Clarke (1973) does not report it from the Canadian Basin. Planned surveys of northern New England may reveal the northeast limit of the distribution range of this ancylid and statistical analysis of the distribution of this species in relation to other New England species (Jokinen, unpublished data) will hopefully elucidate the nature of the communities in which *F. fragilis* exists.

Smith (1967) has implicated *F. fragilis* as an intermediate host for strigeoid and echinostome trematodes. These groups of trematodes parasitize aquatic birds, amphibians, reptiles and mammals which feed on amphibians, fish and aquatic invertebrates (Cheng, 1964). It is of interest that these snails favor a habitat of littoral lentic water, especially among marshy vegetation where they would be most likely to be in contact with aquatic or amphibious vertebrates.

Little can be summarized about the biology of *F. walkeri* except that it is not a common species in southern New England and was located in exceptionally clear water of high Na:Ca ratios in lakes not harboring other visible gastropod populations. Basch (1963) also noted specimens from clean standing water. More observations on this species are necessary.

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NEW SPECIES OF OVULIDAE AND REINSTATEMENT OF *MARGOVULA PYRULINA* (A. ADAMS, 1854) (GASTROPODA)

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ABSTRACT

Eight species of living Ovulidae are described as new, and the species Margovula pyrulina *(A. Adams, 1854) is reinstated.*

Ovulidae Fleming, 1828
Prionovolva Iredale, 1930

Prionovolva castanea Cate, new species

(Figure 1)

Description (holotype): Shell of medium size, pyriformly ovate, thin, light-weight in construction. Terminals are roundly produced, smooth. Dorsum smooth, sub-glossy, without transverse striation at the beaks. Base inflated, smooth, ovate, narrowing to the front as a longitudinally thickened ridge, and constricting on the anterior base to form a broad, bold terminal ridge.

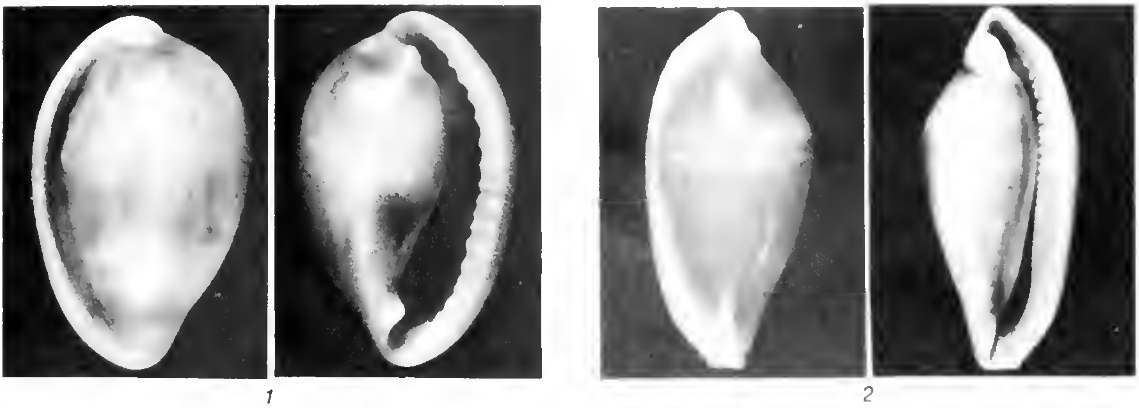

FIG. 1, Prionovolva castanea *Cate, new species. 11.4 mm. Algeria.* 2, Aperiovula testudiana *Cate, new species 14.3 mm. Japan.*

Funiculum somewhat prominent, triangularly thickened at its base. Columella long, curved, flattened, barely depressed. A deepened fossular area is a broadening of the columella in front. Aperture wide, curving, becoming more open abapically. Outer lip edge moderately thickened with callus, and having numerous (approx. 21) large, fairly well developed teeth. Shell color light chestnut brown, with a thinning of color in various dorsal areas; the outer lip, teeth, funiculum, terminal ridge, and terminal beaks are rich ivory.

Measurements: holotype: L-11.4; W-7.3; H-5.8 mm.

Type Locality: Gulf of Oran, Algeria (Mediterranean Sea), N Africa; (35°45'N; 00°38'W).

Holotype: Los Angeles County Museum of Natural History, No. 1789.

Discussion: This new species may be compared with *Prionovolva pudica* (A. Adams, 1854) [cf. Cate, 1973; fig. 15]. The Cate 1973 figure appears rather convincingly similar to *P. castanea* Cate; however, their color and certain morphological differences seem to easily separate them. This new species is less solidly formed, thinner and more fragile in shell construction; the different application of shell color is brown, rather than rosy-lilac; there is no dorsal striation apparent, nor sub-angular, transverse surface ridging; and the outer lip teeth are shorter, not extending to the outer lip's periphery.

Of special interest in *Prionovolva castanea* Cate is the thin brown dorsal stain (almost periostracum-like). It is as if the coloring were applied externally, rather than being an internal part of the shell's nacre. In Cate, 1973: 22; fig. 39, *Globovula tripolia* Cate, 1973, an ovulid species from the Gulf of Oran, a similar application of shell coloring was referred to thus: "Dorsum covered with a semi-smooth, light brown periostracum."

The new name, *castanea*, is derived from the Latin adjective *castaneus*, meaning 'of the color of chestnuts.'

Aperiovula Cate, 1973

Aperiovula testudiana Cate, new species

(Figure 2)

Description (holotype): Shell of medium size, oblong-ovate, narrow, glossy, strongly formed. Terminals produced, solid, narrowing to a fairly pointed adapical beak; narrowing squarely to the front. Dorsum glossy, smooth, except for transversely incised striae emanating restrictedly from both terminal beaks, leaving one half of the dorsal surface without sculpture; with a strong adapical dorsal protuberance at the base of rear terminal beak, and two transverse dorsal flattened bands, one wider than the other, subcentrally. Base almost glossy, convex, somewhat acutely ridged longitudinally; ridge angling downward and away to the right shell margin and to the columellar edge within; base narrows evenly to the front, where it terminates as a longitudinal terminal ridge; the rear base with a large, thick, slightly bumpy-edged funiculum forming the right rear wall of the posterior canal.

Aperture somewhat long, narrow, almost straight, curving gently posteriorly, broadening abapically. Anterior and posterior canals open. Columella broad, concave, with a long, upraised, adaxial carinal ridge within, defines a broad fossular cavity in front. Outer lip sharply angular inward to aperture, with numerous denticles on the inner edge graduating to a smaller size anteriorly. Shell color a rich rosy-mauve with paler transverse bands; base, funiculum, outer lip, side margins and posterior dorsal protuberance ivory colored.

Measurements: holotype: L-14.3; W-6.6; H-5.4 mm.

Type Locality: Mukaishima, Japan.

Holotype: Muséum National d'Histoire Naturelle, Paris, France; without catalogue number. (Bouchet, *in litt.*)

Discussion: This new ovulid species perhaps most closely resembles *Aperiovula takae* Cate, 1973, from which it differs by having a usually larger shell; by having transverse dorsal sculptured banding; by the differently formed outer lip, with more denticles on the inner edge, in a different pattern; the rear funicular callosity is also much more ponderous and larger, with a different relationship to the posterior canal and terminal beak; and the shell color is different, with an absence of dorsal coloring on the base.

This new species is dedicated to Anne-Marie Testud, Laboratoire de Malacologie (MNHN), Paris, who has assisted me immeasurably in many ways.

Primovula Thiele, 1925

Primovula (Primovula) santacarolinensis

Cate, new species

(Figure 3)

Description (holotype): Shell small, somewhat narrow, rhomboidly ovate, centrally humped. Terminals: tapering to a dull point adapically, less sharply anteriorly. Dorsum shiny, with longitudinal incremental growth lines, transversely marked with numerous incised striae, more widely separated over the central part. Base shiny, spindle-shaped, sub-ovate, in some areas striae obscured by a thin nacreous covering. Funiculum curiously sculptured, and denticulate. Aperture long, narrow, curving, broader at the front. Columella long, narrow, concave, with only a vestige of a fossula. Outer lip narrow, posterior

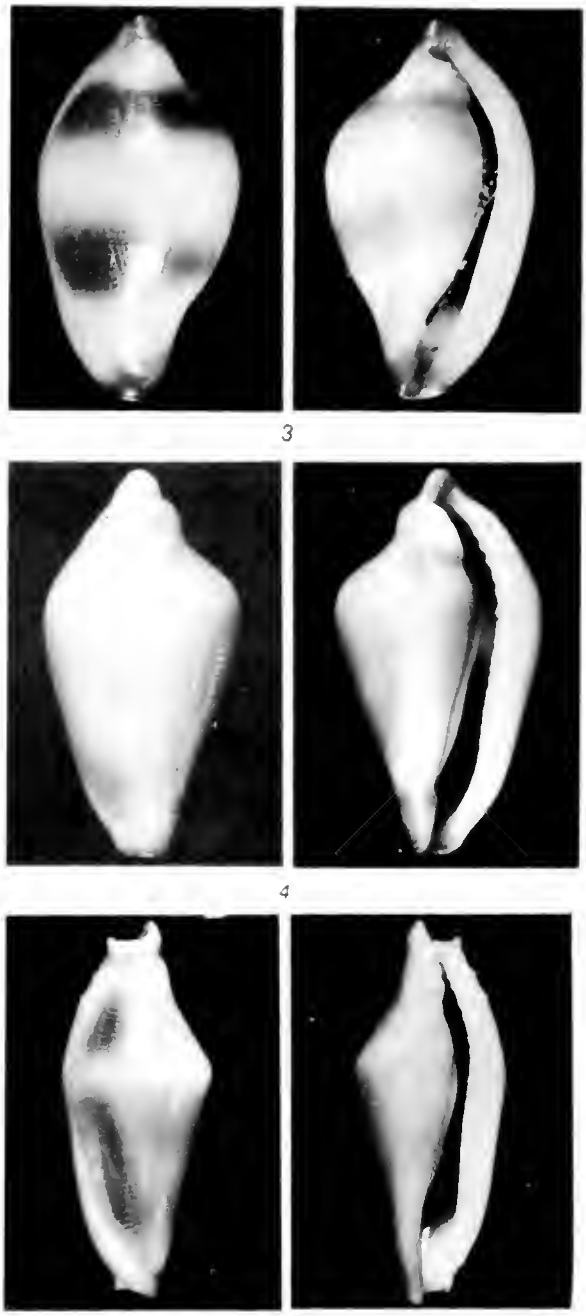

FIG. **3**, Primovula (Primovula) santacarolinensis *Cate, new species, 8.2 mm. Mozambique.* **4**, Primovula (Primovula) uvula *Cate, new species, 7.4 mm. Australia.* **5**, Crenavolva (Crenavolva) periopsis *Cate, new species 10 mm. Indonesia.*

half somewhat convex, anterior half flattened, slanting adaperturally; ventral lip surface minutely crenulate. Shell color basically dark to medium beige, with two broad, transverse bands of dark brown; both canals and terminal beaks dark brown.

Measurements (holotype): L-8.2; W-4.5; H-4.0 mm.

Type Locality: Mozambique, East Africa; 100 yards W of Santa Carolina, dredged in 18 meters of water, from a coral and rock bottom; leg. E. Roscoe, 1 March 1976 (15°03'S;40°12'E).

Holotype: Natal Museum, Pietermaritzburg, South Africa, No. G-7280.

Discussion: Although this new ovulid species seems to be distinct, it may be compared with the more southern East African *Primovula beckeri* (Sowerby III, 1900). *Primovula santacarolinensis* Cate differs by having a slightly larger shell; by lacking the longer, protruding teeth on the posterior outer lip's peripheral edge; by having the striking, broad dorsal bands of dark coloring on the terminal beaks and canals, and transverse dorsal incised striation is less boldly apparent.

The new name is derived from that of the type locality of the species.

Primovula (Primovula) uvula Cate, *n. sp.*

(Figure 4)

Description. (holotype): Shell small, solid, subglossy, rhomboidal in peripheral outline. Terminals produced, bluntly square anteriorly, roundly pointed, twisted adapically. Dorsum roughened, with numerous deeply incised transverse striae over all; dorsum transversely angulate subcentrally with a broad hump. Funiculum a highly elevated, thick, massive callus, forming the left wall of the posterior canal. Base narrowly rhomboid, dorsal striation extending onto base of columella, with a thin layer covering abapical base. Columella consisting of a long, somewhat narrow, fairly deep concave groove, becoming a fossula anteriorly. Aperture fairly evenly broad throughout. Outer lip broad, with a flattened ventral surface; lip surface angling downward, inward to aperture, with about 8 denticles extending from apertural edge to outer periphery of lip, and a noticeable gap between the last tooth and posterior terminal beak; denticles more numerous, but insignificant to crenulate anteriorly. Shell color pale greenish ivory over all, except much lighter on dorsal hump; anterior terminal canal outlet tinted with brown; (C 4147).

Measurements (holotype): L-7.4; W-3.7; H-3.0 mm. Los Angeles Co. Mus. Nat. Hist., No. 1790.

Type Locality: Moreton Bay, Queensland, Australia; dredged from deep water; (27°12'S; 153°12'E); *ex* Miss Elizabeth Grigg coll., Cairns.

Discussion: This Australian ovulid species seems unlike most of its congeners from Japanese deep water, notably from the Kii Channel. The acutely angular shoulders appear to be a major character in their separation. However, it may be compared with a species from the Philippines, *Primovula bellica* Cate, 1973, from which it differs in its more acutely angled shell form; by the brown coloring in the anterior canal; by virtue of the more tortuously twisted adapical terminal beak; its more elevated and massive rear funicular process, in that its base is striate, rather than smooth and glossy; and the columellar sulcus is broader and deeper.

The name of this new species is derived from the Latin noun, *uvula*, meaning pendant.

Crenavolva Cate, 1973

Crenavolva (Crenavolva) periopsis Cate, n. sp.

(Figure 5)

Description (holotype): Shell small, slightly reflexed, narrow, rhomboidly elongate, shell tapering, narrowing evenly at either end. Terminals squarely, cylindrically produced, with thickly rolled exterior edges. Dorsum shiny, divided by sub-central, transversely sharply elevated, angular dorsal ridge; dorsum numerously, incisedly striate over all. Base elongate, narrowly rhomboid, becoming very narrow and somewhat constricted anteriorly. Funiculum multi-knobbed (4), forming left wall of adapical canal. Columella long, narrow, smoothly concave, bordered adaxially by a longitudinal carinal ridge within. Fossula nearly obsolete. Aperture long, narrow, becoming wider anteriorly. Outer lip fairly broad, flatly angled inward, smooth, partly dentate; having three strong, separated teeth anteriorly, with several (11) denticles traversing ventral lip surface from the outer margin to its inner edge, two of which extend beyond peripheral lip-edge. Shell color creamy-white over all, with darker tone visible through a thinned base color; a broad creamy-white band of color on dorsal ridge separating the anterior and posterior rear dorsum; the base and rolled terminal edges a contrasting darker ivory.

Measurements, (holotype): L-10.0; W-4.1; H-3.2 mm.

Type Locality: Soerabaja, Java, Indonesia (07°22′S; 112°40′E).

Holotype: Los Angeles County Museum of Natural History, No. 1791.

Discussion: This new species seems most closely to resemble the Western Indian Ocean species *Crenavolva (Crenavolva) hesperia* Cate, 1973.

Crenavolva (C.) periopsis differs from it, however, by having a slightly larger shell form; by a more elevated, sharply angled dorsal ridge, over which is a broad transverse band of light coloring. In addition, the rear outer lip teeth are larger, stronger, more prominent, and extend beyond the peripheral outer lip edge.

This new name is derived from the Greek prefix, *peri*, and the Latin suffix *opsis*. The combination denotes 'a likeness to'.

Spiculata Cate, 1973
Spiculata advena Cate, *n. sp.*
(Figure 6)

Description, (holotype): Shell of medium size, thin, translucent, long, narrow, tapering from center to either end. Terminals somewhat pointed, more sharply so adapically. Dorsum glossy, smooth, except for a few minute, restricted, incised striae over posterior beak. Base (apertural face) polished, glossy, narrowly ovate (spindle-shaped), curving very narrowly anteriorly. Columella rounded, polished, glossy, without longitudinal groove or carina, but with a minute fossular depression at the front. Aperture wide, open, nearly straight. Funiculum an upraised, massive, spiralling cord. Outer lip smooth, evenly curving, with a thin, cord-like edge callus. Shell color dark ivory over all, except for outer lip edge and terminal ends a contrasting glossy pale ivory.

Measurements, (holotype): L-14.6; W-5.6; H-4.3 mm.

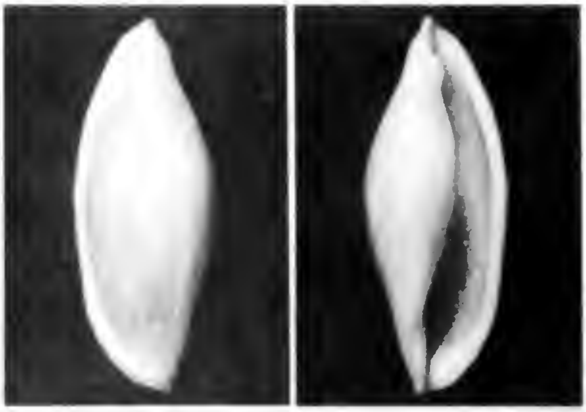

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FIG 6. Spiculata advena *Cate, new species. 14.6 mm. Florida.*

Type Locality: Off Sand Key, Florida; 7 miles SW of Key West (approx. 24°33′N; 81°47′W).

Holotype: Los Angeles County Museum of Natural History, No. 1794.

Discussion: This new species may be compared with the west Gulf of Mexico ovulid species, *Simnialena marferula* Cate, 1973, from which it differs by having a larger shell and by having an open, straight apertural canal posteriorly. The funiculum is differently formed, with much less distortion of the posterior base and terminal area, and the shell colors are entirely different.

The new name for this species is derived from the Latin noun *advena*, meaning newcomer (as this species is to the Western Atlantic Ovulidae).

Cyphoma Röding, 1798
Cyphoma rhomba Cate, *n. sp.*
(Figures 7 and 8)

Description (holotype): Shell relatively small, sub-rhomboid (rectangularly elongate), sub-glossy, less solidly formed than any of its congeners. Terminals broad, beaks squared, calloused, as are the roundly thickened side margins. Dorsum smooth, tapering, barely corded, elevated ridge. Base (apertural face) smooth, elongate, sub-rhomboid, with a low transverse modification of the extended dorsal ridge crossing it. Columella rounded, smooth, curved. Both funicular and fossular sculptural characters absent. Aperture

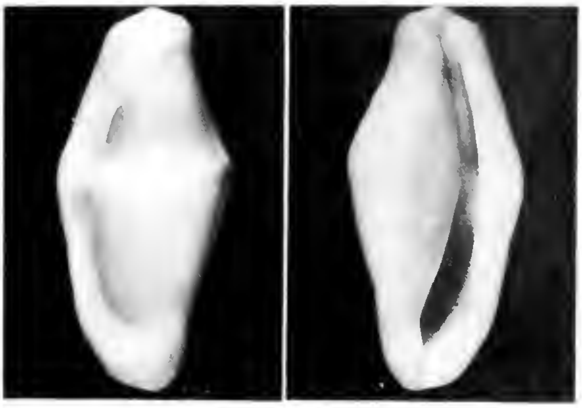

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FIG. 7, Cyphoma rhomba *Cate, new species, holotype 22.7 mm. Florida.* 8, Cyphoma rhomba *Cate, new species, paratype 20.9 mm. Florida.*

long, gently curving, somewhat wide, especially anteriorly. Outer lip smooth, fairly narrow, without dentition. Shell color: dorsum pale mauve, with the terminal tips, side margins, transverse dorsal ridge, and apertural face a contrasting bright white.

Measurements (holotype): L-22.7; W-10.5; H-8.3 mm. Paratype: L-20.9; W-11.1; H-8.9 mm. (Figs. 7 and 8 respectively).

Type Locality: Fort Lauderdale Reef, Florida; in 18 meters of water, living on Sea Whips (approx. 27°00'N; 80°00'W); leg. William Chapman, Fort Lauderdale, Florida, 20 February 1971.

Holotype: Los Angeles County Museum of Natural History, No. 1792; paratype in author's collection (C 3891).

Discussion: This new cyphomid species appears to be distinct and has generally a smaller shell than other species of the genus, with the possible exception of the Eastern Pacific *Cyphoma emarginatum* (Sowerby I, 1830.)

This new species seems most closely to resemble *Cyphoma emarginatum* (Sowerby I, 1830) in many morphological respects, but appears to differ in several important ways: by lacking the distorted adapical terminal beak, being smoothly terminated and less emarginate; by lacking the spiral funicular cord on the posterior columella, and by having a more thickly and heavily applied coat of callus on the terminal ends and side margins.

The basic color of the living animal is lavender over all. The mantle is decorated with fairly large, dark lavender spots (similar in shape to those of *Cyphoma mcgintyi* Pilsbry, 1939; (cf. Cate, 1973; figs. 150-150a); the foot is alternately marked with long and short stripes of dark lavender, and the peripheral edge of the foot is yellow. The animal's siphon is long, pale in color, with a dark lavender tip; the white tipped antennae emerge from a lavender base.

I am indebted to Kirk Anders, Fort Lauderdale, who sent the shells of this new species for study; and to William Chapman and Alfred Calabrese, Fort Lauderdale, Florida, for the pertinent details.

The rhomboid shape of the shell suggests its new name.

Pseudocyphoma Cate, 1973

Pseudocyphoma gibbulum Cate, new species

(Figure 9)

Description (holotype): Shell of medium size, solid, though not thickly formed; spindle-shaped, tapering equally, evenly to either end. Terminals dully pointed. Dorsum smooth (this dead shell may have been glossy when alive), without transverse striation, but having a distinct gibbous, sub-acute, transverse, sub-central angular ridge. Base (apertural face) evenly, narrowly ovate, smooth. Funiculum thick, obliquely corded. Columella smoothly rounded, without depression, with a very long inner carinal ridge on the anterior half. Fossula somewhat long, narrow, enhanced by ridge within. Aperture long, gently curving, of medium width. Outer lip's ventral edge narrowly thickened, edentate, somewhat flattened abapically, and shouldered above. Shell color pale yellow-ivory.

Measurements (holotype): L-16.1; W-6.4; H-5.2 mm.

Type Locality: in 18 meters of water, dredged from a coral rubble bottom, off the Dry Tortugas Islands, SW Florida (24°40′N; 82°55′W).

Holotype: Los Angeles County Museum of Natural History, No. 1793.

Discussion: This new ovulid species is probably best compared with *Pseudocyphoma intermedium* (Sowerby I, 1828), which has a present range in the central West Indies. *Pseudocyphoma gibbulum* Cate differs from it, however, by having a smaller shell form and a more light-weight shell construction; by having less ponderous, more fragile terminal beaks, with the anterior canal opening flatter; and by having a more narrowly thickened outer lip edge. The base is less angularly ovate, with less narrowing and lengthening of the front base.

The new name is a diminutive of the Latin noun *gibbus*, meaning humped.

Margovula Cate, 1973
Margovula pyrulina (A. Adams, 1854)

(Figures 10 and 11)

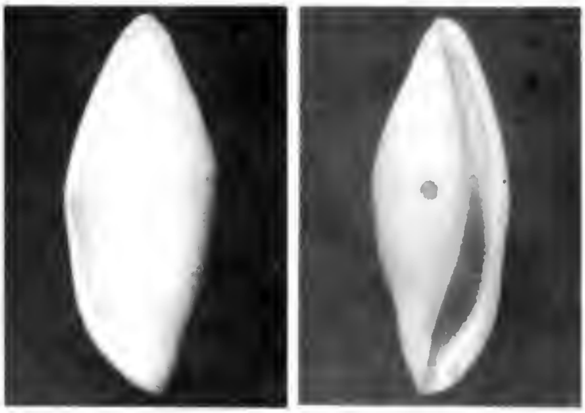
1854 *Amphiperas pyrulina* A. Adams, Proc. Zool. Soc. London **22**: 131.

Description (holotype): "*Amphiperas pyrulina*— A. testa ventricosa pyriformi, albida [pale grey], ad extremitates subproducta et pallide fulva, transversim striata; apertura angustata; labio laevi, in medio tumido, canalibus brevibus vix emarginatis, postice callo simplici instructo, labro intus crenulato." (A. Adams, 1854: 131).

Measurements (lectotype): approx. L-14.8 mm. (Figure 10); paralectotype: approx. 15.0 mm. (BM(NH), Reg. No. 1961145-2); hypotype: L-18.5; W-10.8; H-8.8 mm. (Cate coll. C 4144: Figure 11). [Measurements, *pyriformis*: L-19.7; W-11.3; H-9.4 mm. (C 3874-B: Figure 12)].

Type Locality: New Caledonia.

Locality Records: paralectotype: presumably New Caledonia (?). Hypotype: Nagai, Japan, in 3



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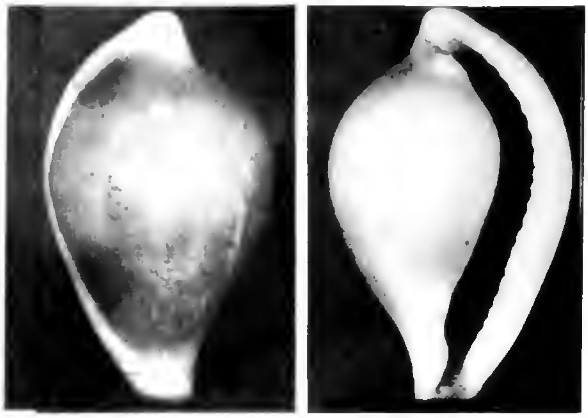

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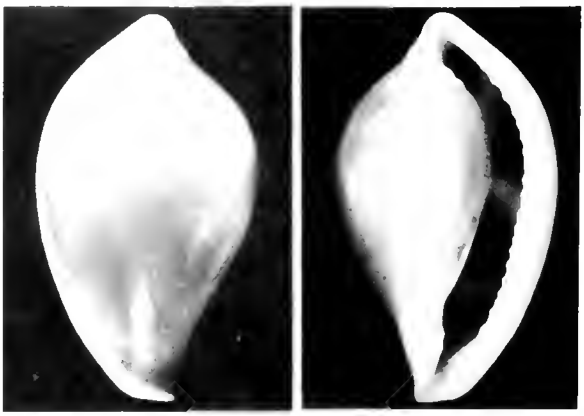

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FIG 9. Pseudocyphoma gibbulum *Cate, new species 16.1 mm. Florida* **10,** Margovula pyrulina *(A. Adams, 1854)* [*lectotype*]. 118 mm **11,** Margovula pyrulina *(A. Adams, 1854)* [*hypotype*] × 3½.

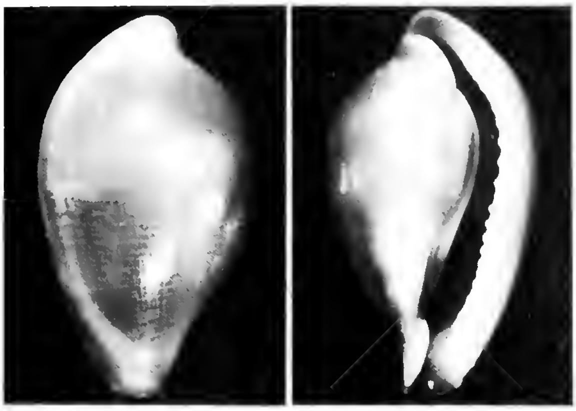

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FIG. 12. Margovula pyriformis *(Sowerby I, 1828)* [*hypotype*]. 19.7 mm.

meters of water; also collected off Jogashima, Sagami Bay, Japan (35°20′N; 139°20′E); dredged, 2-3 meters of water; leg. A. Teramachi, *ex* Elizabeth Grigg coll. Cairns, Qld., Australia. Since this species seems not to have been reported from New Caledonia (in this author's experience) in recent times, there is some question as to the validity of Adams' New Caledonia locality; the Japanese locality is the only confirmed one.

Lectotype: British Museum of Natural History, Reg. No. 1961.145-1; one of two syntypes.

Discussion: It is the purpose of this report to amend this author's earlier record (Cate, 1973: 16, fig. 28), by removing *M. pyrulina* from the synonymy of *Margovula pyriformis* (Sowerby I, 1828) and now recognizing it as a valid species.

Margovula pyrulina (A. Adams, 1854), (Figs. 10 and 11), although distinct, may be compared with *M. pyriformis* (Sowerby I, 1828) (Fig. 12) as follows: it possesses a more evenly ovate base, not acutely constricted sub-centrally at the aperture; the outer lip surface is more convex ventrally, roundly formed, less flattened as it tapers downward and inwardly; the outer lip teeth are smaller, more weakly formed; the dorsal striation is less deeply incised than that in *M. pyriformis*; the adapical canal, terminal beak, and funiculum are not so acutely reflexed to the left; the pale gray coloring of the dorsum, with the contrasting light ivory of the base, side margins, outer lip margin, and terminal beaks, all appear constant in *M. pyrulina*. The shell colors of *M. pyriformis* are many and varied (none of which is gray), ranging from light brown, yellow, deep rose, to pure white, and a pure white with a brown base (all of these color variations of *M. pyriformis* exist in the author's collection); and, finally, the canal endings are ringed with brown.

LITERATURE CITED

Cate, Crawford Neill. 1973. A Systematic Revision of the Recent Cypraeid Family Ovulidae. *The Veliger* **15**, Supplement: 1-116; 51 plates, 4 in color; 1 text fig. (31 January 1973).

LEOPOLD AND RUDOLPH BLASCHKA'S NUDIBRANCH GLASS MODELS

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ABSTRACT

A brief sketch of the life of the European Blaschka family, particularly of Leopold and Rudolph, famous for their glass-blowing skills, is given. A list of their glass models of nudibranchs surviving in the Museum of Comparative Zoology, Harvard University, The Museum of Science, Boston, and the Academy of Natural Sciences of Philadelphia is presented, with a selected bibliography of general works and those that might well have been consulted by the Blaschkas in making their models.

In mid-nineteenth century Germany, two men emerged whose artistic talents in glasswork have yet to be surpassed. By combining a unique set of skills and knowledge, Leopold Blaschka (1822-1895) and his son Rudolph (1857-1939) created a remarkable and lasting collection of biological glass models. The most famous examples are the "Ware Collection of Blaschka Glass Models of Plants" belonging to Harvard University's Botanical Museum. This collection consists of representatives of 780 species and varieties in 164 families. It was presented on April 17, 1893, to Harvard as a gift from Mrs. Elizabeth C. Ware and her daughter, Miss Mary Lee Ware, as a memorial to Dr. Charles Eliot Ware of the Harvard Class of 1834.

Little is known of how the Blaschkas learned and developed their skills. Great secrecy surrounded their studio and techniques. It is known that the family tradition of glass working and ornamentation goes back at least seven generations and is thought to be of Venetian origin. The name "Blaschka" is a Slav/Czech adaptation of the Latin name "Blasius" and is to be found at Prague University in the latter half of the fifteenth century. More recent generations of the family lived in the area of upper Austria.

Leopold Blaschka was born in 1822 in Aicha, a town in Bohemia at the foot of the Jeschken Mountains. His first enterprises centered around goldsmithing and the cutting of precious stones, but his father also instructed him in the family art of glass work and enamelling. He was married in 1846 and was widowed four years later. It was at this time, in semiretirement and seclusion, that his interests turned toward the study and appreciation of nature. With the help of a friend's library, he began collecting and painting plants of his surrounding area.

In his early career, however, Leopold became best known for his models of invertebrates. These encompassed many phyla including the Protozoa, Coelenterata, Platyhelminthes, Aschelminthes, and Annelida. Some of the most beautiful models still in existence are representatives of the Mollusca, especially the Cephalopoda and the Opisthobranchiate Gastropoda. The present study is devoted to the Nudibranchia within the latter group.

Shortly after his father's death in 1852, Leopold embarked on a voyage to America, sailing on a small brig out of Bremerhaven. During the voyage he was becalmed near the Azores for two weeks. He spent the time collecting and sketching marine organisms. Among these was the Portuguese Man-of-War which he later reproduced in glass. The glasslike appearance of these animals interested him, since, like many of his contemporaries, he had previously known them only through illustrations.

Leopold was remarried shortly after his return from America and in June 1857 his son, Rudolph, was born. Around this time, Leopold began producing flowers out of glass for his own pleasure. Using specimens from a nearby greenhouse, he produced over one hundred models of some fifty tropical species, mostly orchids, displayed on two artificial tree trunks. These models went on exhibit in Prague and Dresden; eventually they were sold in part and sent to Liege.

In the early 1860's an Englishman living in Dresden inquired about the making of artificial sea anemones for aquaria. It was arranged that a sample collection be produced, using the illustrations of Phillip Henry Gosse's *Actinologia Britannica* (1860). These proved a great success and were purchased immediately by the natural history museum of Dresden. With the help of his son, Leopold Blaschka began producing marine models, but, due to their low prices, the family was forced to supplement their income by making a variety of products, including prosthetic glass eyes and novelty items decorated with small enamelled flowers.

Edward Sylvester Morse (1838 - 1925), the well-known zoologist of Salem, Massachusetts, paid the Blaschkas a visit on his way home from meetings in Europe in October 1887. In his personal diary, while in Dresden, he wrote:

> "After getting through these museums in a murderous hurry, I got a hasty mutton chop and bottle of beer and started to hunt up Leopold Blaschka, the maker of the famous zoological models in glass. I found him a very pleasant old man, and with his younger son, who has an eye to business, passed a pleasant half hour. They are very fond of music, violin and piano, and the old gentleman showed me with some pride oil paintings hanging on the wall as his productions. . . .

> The father and son make the most perfect and wonderful reproductions of animals that have been conceived of . The most intricate and difficult animals, like *Physalia* [etc.], depicted with the most wonderful accuracy. I asked to see their workroom and found it an ordinary room with a table covered with glass tubes of various sizes, lamps, bellows with treadle below, unfinished acephalids, bits of. . . hydroids, drawings of animals. In another room an alcoholic collection of invertebrate animals. I was shown also some glass models of orchids being made for Dr. Goodale. [Harvard professor of botany and responsible for procuring for Harvard the "glass flowers."] These were exquisite, and it would seem that their art of modeling might compass the most delicate objects. They lived in a large block of buildings . . . . The buildings here and in Berlin are great substantial blocks, people living in flats". (see Dorothy G. Wayman's 1942 biography of *Edward Sylvester Morse*. Harvard University Press, pp. 322 and 324)

Rudolph's formal education began in catholic school where he studied for the priesthood. Later he left the school to work with his father, but continued to study languages, mathematics, history, and science. The Blaschkas, unlike many others of their time, considered themselves "glassworkers" rather than "glassblowers." They did not occupy their time making the usual "blown" objects, but concentrated instead on detailed and realistic sculptural pieces.

In 1879, Rudolph went to Italy and the Adriatic to study marine life. At this time a room in their family home became filled with marine tanks stocked with living animals sent from the Imperial Austrian Zoological Station of Trieste and from England. Their work improved, and many orders were received from museums in Germany, America, England, India, Australia, New Zealand, and Japan. After 1878 all models sold in the United States were sold through H. A. Ward's Natural Science Establishment. These orders continued up to and after the time that Harvard requested samples of plant models for their newly created Botanical Museum. In 1886 an exclusive contract was signed with the university which ended their work on invertebrates. The glass models were probably created between 1865 and 1886. Leopold Blaschka died in 1895 at the age of 73, but his son carried on the family work until his death in 1939. They are both buried in Hosterwitz, East Germany.

TABLE 1 *Glass models surviving at the Museum of Comparative Zoology, Boston Museum of Science (marked BMS) and Academy of Natural Sciences of Philadelphia (marked ANSP) Names and authors of models are taken from model labels. Differing names which appear on the underside of the model bases are indented*

Actinodoris australis Angas
Aeolis papillosa L. BMS only
Ancula cristata Loven BMS
Angasiella cristata Bergh BMS
    (Trevelyana cristata Bergh)
Angasiella nigerrima Bergh
    (Trevelyana nigerrima Bergh)
Archidoris tuberculata
    (*Doris diademata* Agassiz)
Argus ellioti A. & H.
    (*Doris ellioti* Alder & Hancock)
Argus formosa A. & H.
    (*Doris formosa* A. & H.)
Beccaria tricolor Trinchese
Bornella arborescens Pease BMS
Bornella digitata Adams & Reeve [listed as Ald. & Hanc.] BMS
Bornella hermanni Angas
Cadlina obvelata Müller (Doris) BMS only
Caccinella luctuosa Bergh BMS, ANSP
Casella philippinensis Bergh
Ceratosoma gracillimum Bergh BMS
Chromodoris albomaculata Pease BMS
    (*Goniobranchus albomaculata* Pease)
Chromodoris bennetti Angas (Goniodoris)
Chromodoris citrina Bergh BMS
Chromodoris crossei Angas (*Goniodoris*)
Chromodoris erinaceus BMS
    (*Goniodoris erinaceus* Crosse)
Chromodoris lentiginosa Pease BMS
Chromodoris maculosa Pease BMS
Chromodoris tryoni Garrett (*Goniodoris*)
Chromodoris varians Pease BMS
Chromodoris variegata Pease BMS
Chromodoris verrucosa
    (*Goniodoris verrucosa* Crosse)
Coryphella diversa
    (*Aeolis diversa* Couthouy) BMS
Coryphella foulisi
    (*Aeolis foulisi* Angas) BMS
Coryphella rufribranchialis Johnston (Eolis) BMS only
Coryphella salmonacea Couthouy (Eolis) BMS
Cratena gymnota
    (*Aeolis gymnota* Couthouy) BMS
Cratena longibursa Bergh BMS
Dendronotus arborescens (? Van Branneus, M.) BMS
    [*Doris arborescens* Müller]
Discodoris fragilis A. & H.
    (*Doris fragilis* A. & H.)
Doriopsis atromaculata A. & H. (*Doridopsis*)
Doriopsis clavulata A. & H. (*Doridopsis*) ANSP
Doriopsis debilis
    (*Doris debilis* Pease)

Doriopsis denisoni
(*Doris denisoni* Angas) BMS
Doriopsis gemmacea A. & H. *(Doridopsis)* BMS
Doriopsis herpatica (Bergh)
(Doris compta Pease)
Doriopsis nigra Stimpson (Doris)
Doriopsis nodulosa
(Doris nodulosa Angas)
Doriopsis rubra Kelaart (Doris) BMS only
Doriopsis rubrilineata
(*Doris rubralineata* Pease) BMS
Doriopsis scabra Pease BMS
Doriopsis tuberculosa Quoy & Gaimard (Doris) BMS only
Doris arbutus Angas BMS
Doris bilamellata L.
Doris coccinea Forbes (listed on model as Ald. & Hanc.)
Doris debilis Pease ANSP only
Doris funebris Kelaart BMS
Doris muricata Müller BMS
Doris pantherina Angas
Doris pilosa Abildgaard BMS only
Doris repanda A. & H.
Doris variabilis Angas ANSP
Doris villosa Pease
Doto coronata A. & H. [no record of this species except type species for genus: *Doris coronata* Gmelin] ANSP
Embletonia fuscata Gould BMS
Embletonia pallida A. & H. BMS
Embletonia remigata Gould BMS
Eolis alba A. & H.
Eolis exigua A. & H
Eolis rufibranchialis Johnston
Eubranchus exigua A. & H. *(Eolis)* BMS only
Eubranchus pallidus A. & H *(Eolis pallida* A. & H?) BMS only
Facelina bostoniensis Couthouy (*Eolis*)
(Coryphella bostoniensis Couthouy)
Facelina coronata Forbes (& Goodsir) (*Eolida*)
Facelina drummondi Thompson, Wm. (*Eolis*)
Facelina militaris A. & H.
(Aeolis militaris A. & H.)
Facelina rubrovittata costa (Aeolis) BMS only
Favorinus albus A. & H [? Eolis alba A. & H. - type species for genus]
Flabellina ianthina Angas
Flabellina newcombi Angas
Flabellina ornata Angas
Glaucilla briareus Bergh (author listed as Reinh.?) BMS only
Glaucilla marginata Bergh (author listed as Reinhardt?)
Glaucus atlanticus Forster [? this name is not recorded] BMS only
Glaucus lineatus Bergh (author listed as Reinhardt?)
Glaucus longicirrhus Bergh (author listed as Reinhardt?)
Goniobranchus albomaculatus Pease ANSP only
Goniodoris citrina A. & H.
Goniodoris modesta A. & H.
Goniodoris verrucosa Crosse (also on model as *Chromodoris*) BMS only
Idalia coronata or *Doto coronata* A. & H. [neither are recorded] BMS only
Janus sanguineus Angas BMS only
Kalinga ornata A. & H BMS
Kentrodoris rubescens Bergh BMS
Lamellidoris aspera (*Doris* A. & H.)
(*Doris pallida* Agassiz)
Lamellidoris grisea
(*Doris grisea* Stimpson) [neither name is recorded]
Lomanotus marmoratus A. & H. [author recorded as Gray, J. E.]
Melibe australis Angas (*Melibaea*) BMS, ANSP
Melibe fimbriata A. & H
Miamira nobilis Bergh BMS
Onchidoris aspera A. & H. (Doris) BMS only
Onchidoris fusca Müller (Doris) BMS only
Pleurobranchaea delicatus Pease ANSP
Pleurobranchus grandis Pease
Pleurophyllidia pallida Bergh BMS
Pleurophyllidia semperi Bergh BMS
Plocamophorus ceylonica Kelaart (*Polycera* or *Trevelyana?*)
Plocamophorus imperialis Angas
Polycera lessoni D'Orbigny
Polycera lineata Risso BMS only
Polycera ocellata A. & H. BMS
Polycera quadrilineata Bergh ANSP only
Scyllaea marmorata A. & H
Taures (?) *sanguineus* Angas
(Janus sanguineus Angas)
Tergipes despectus Johnston (? *Eolidia despecta* Johnston) BMS only
Tethys leporina L. [name rejected, new authority: Bahadsch 1761] BMS only
Thordisa villosa A. & H. (*Doris*) BMS only
Trevelyana nigerrima Bergh BMS only
Triopa clavigera Müller (*Doris*)
Triopa yatesi Angas BMS only
Trippa areolata A. & H.
(Doris areolata A. & H.)

There are eight unidentified models at the Museum of Science, Boston and one unidentified model at the Academy of Natural Sciences, Philadelphia.

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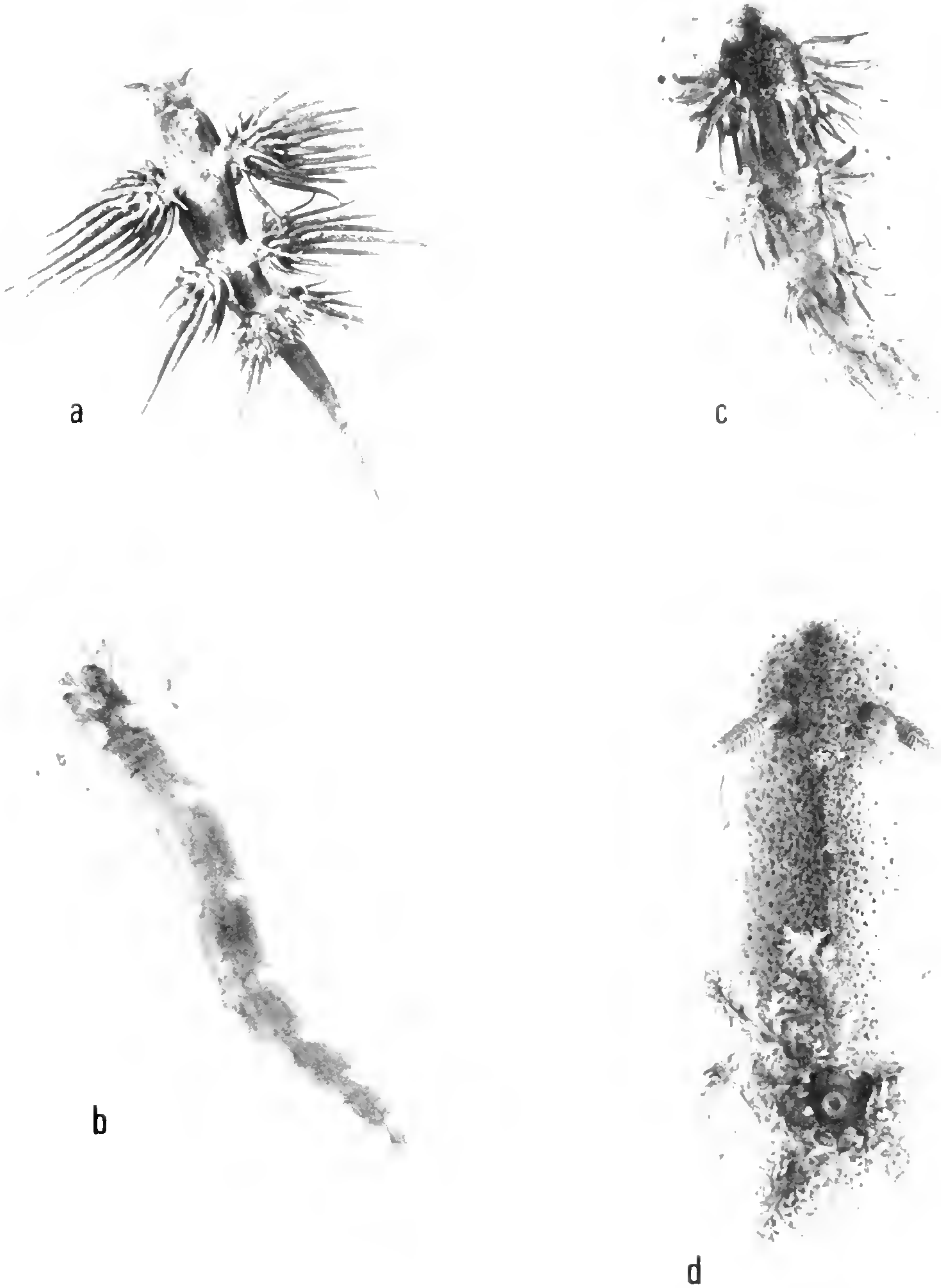

FIG. 1. *Glass model of* **a.** Glaucus longicirrhus *Bergh, 1860 62 mm.* **b.** Bornella arborescens *Pease 1871 85 mm.* **c.** Facelina coronata *Forbes and Goodsir 1839 80 mm.* **d.** Miamira nobilis *Bergh 1874 97 mm*

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