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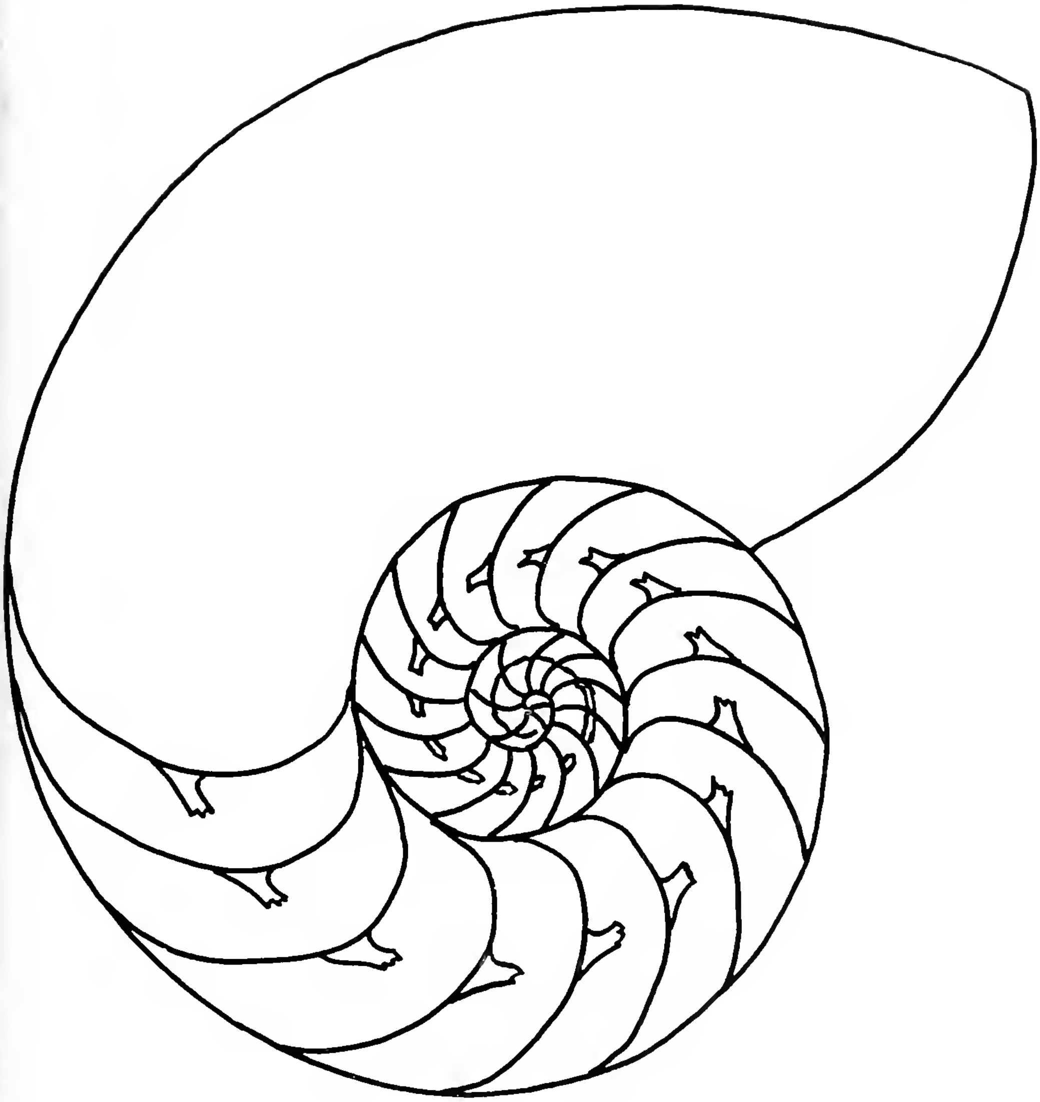

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I certify that the statements made by me above are correct and complete.
(signed) R Tucker Abbott, Editor

EDITORIAL

Rapid publication of research papers is now possible, usually within two or three months of submission of the manuscript, providing the author pays page charges ($30.00 per page). This priority does not in any way delay the papers of other authors, since articles with paid page charges merely increase the normal size of an issue.

AMU 1976 ANNUAL MEETING IN COLUMBUS

The annual meeting of the American Malacological Union will be held Monday, August 2 (registration) through Friday (field trip) the 6th on the campus of the Ohio State University, Columbus, Ohio. Inexpensive but excellent lodgings. More details in the April issue.

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Humm, Harold J. and Charles E. Lane, editors. 1974. *Bioactive Compounds from the Sea.* Marcel Dekker, Inc., N. Y. xiii + 251 pp. $18.75. Among the 13 chapters resulting from a 1971 symposium on this subject, some relate to toxins carried by marine mollusks, especially those of dinoflagellates.

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Kay, E. Alison and William J. Clench. 1975. A Biobibliography of William Harper Pease, Malacologist of Polynesia. *Nemouria,* no. 16, 50 pp. Gives Pease's life and lists about 660 of his new names, with references. $2.00 from the Delaware Museum of Natural History, P.O. Box 3937, Greenville, Delaware 19807.

ONTOGENY OF PREDATORY BEHAVIOR IN MARINE SNAILS (PROSOBRANCHIA: NATICIDAE)

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ABSTRACT

Naticid gastropods (Natica gualtieriana) *were reared through metamorphosis and presented with gastropod prey. The first prey were bored by a single well-formed hole in a stereotyped position. As the animals matured and gained experience at boring there was no change in the circular distribution of the boreholes in each whorl but whorl preference changed and the animals became seemingly less proficient borers.*

INTRODUCTION

Marine gastropods of the family Naticidae are noteworthy because of their predatory habit of capturing bivalves or snails, boring a hole through the hard calcareous shell, and consuming the soft parts within. There have been numerous reviews of the controversy concerning the mechanisms involved in boring (Ziegelmeier, 1954; Carriker, 1961; Fretter and Graham, 1962; Hyman, 1967; Bernard, 1967) and the position of the borehole (Ansell, 1960; Reyment, 1966).

While it has been suggested that experiential factors play some role in prey selection of gastropods (Fischer-Piette, 1935; Carriker, 1957; Wood, 1968; Morgan, 1972) there are no studies of the ontogenetic development of predatory behavior. Such studies are of particular interest with those species of naticids whose development includes a planktonic veliger stage, during which they use ciliated velar lobes to filter-feed on phytoplankton. These snails possess neither a radula nor a proboscis until after metamorphosis. Veligers are therefore incapable of boring and have no experience as predators. I have found the complete behavior patterns involved in prey manipulation and boring to be present upon first experience with a prey. I have also described how the position and the quality of the borehole change as the predators mature.

METHODS

Fourteen veligers of *Natica gualtieriana* were collected from the plankton in Kaneohe Bay, Hawaii, and reared separately in small (55mm × 15mm) plastic petri dishes containing 20ml of sea water. The animals metamorphosed within 24 hours and were provided with a new dish containing water, sand, and one prey-snail every second day. Morphologically similar *Bittium* and *Rissoella* species were offered as prey. At each change of dish, the shells of the previous prey were removed and taped to index cards in sequential order for each predator. As the *N. gualtieriana* grew, larger prey were provided, up to a maximum of 20 prey per predator. The position of the borehole was examined with respect to the longitudinal axis of the shell and to the plane of the aperture by determining the whorl in which the hole was bored, the distance from the tip of the siphonal canal to the center of the hole, and its circular distribution. The pooled data were analysed using standard statistical tests and tests for circular distribution patterns (Snedecor and Cochran, 1967; Batschelet, 1965).

The shells from each predator were coated with gold and examined under a Cambridge Stereoscan (S4) scanning electron microscope. Qualitative changes in the shape of the hole and the amount of radular scraping were noted for each series of shells.

Young specimens of *Natica gualtieriana* Recluz used in these observations are deposited in the Delaware Museum of Natural History, no. 103100.

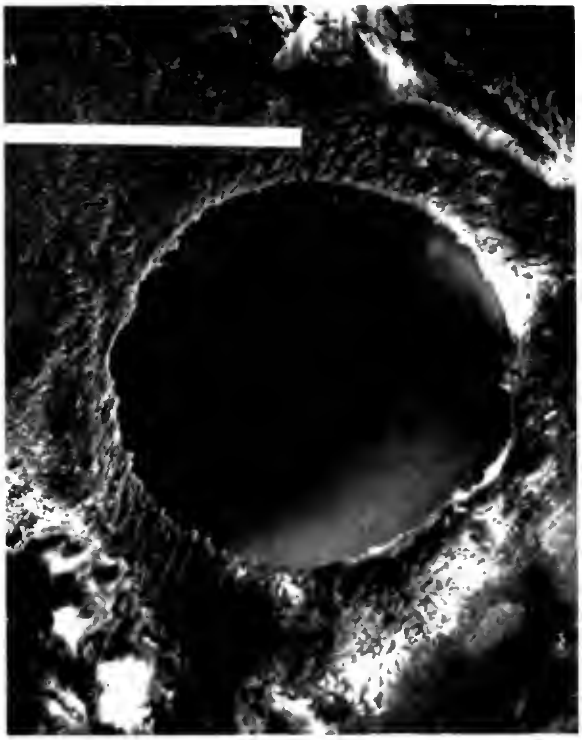

FIG. 1. *Scanning electron photomicrograph of the first borehole made by a newly metamorphosed* Natica gualtieriana. *Bar represents 0.1 mm.*

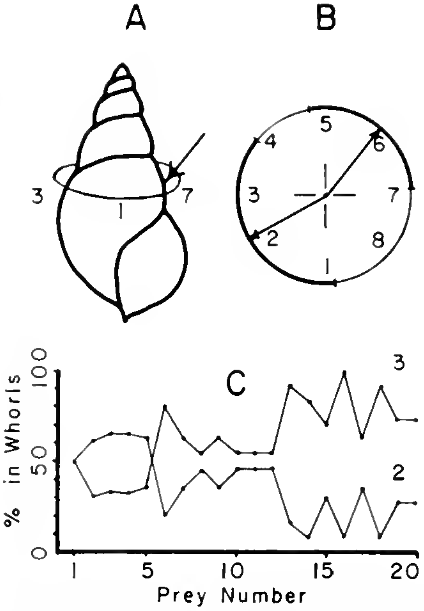

FIG. 2. *Distribution of boreholes in prey of* N. gualtieriana. *A. Shell of prey, indicating sectors used to designate circular distribution of boreholes around the shell. Arrow indicates position of mean angle of first borehole in whorl no. 2. B. Distribution of the total sample of boreholes in whorls no. 2 and no. 3. Arrows indicate mean values (Whorl No. 2 at sector 6; whorl no. 3 at sector 2). Broad lines represent 2 angular deviation units. C. Percentage of holes in each whorl for successive prey. Holes midway between whorls counted for both whorls.*

RESULTS

Upon first presentation of prey, all newly metamorphosed *N. gualtieriana* bored a single well-formed hole (Figure 1). There was no evidence of incomplete boreholes or misplaced rasping. The first holes were distributed with mean values of either 273.3° to the right of the aperture in whorl 2 (Figure 2A) or 114° in whorl 3 (Table 1). There was no overlap in the range of distribution for each whorl. The centers of the holes were located 1.31 mm (Md_{50} value) from the tip of the siphonal canal, which represents 65% (Md_{50} value) of the distance between the tip of the siphonal canal and the top of the fourth whorl (Figure 3A). Measurements were not made with respect to total shell length because the prey were often missing the initial smallest whorls.

If the total sample of boreholes drilled by the 14 predators is analyzed, distinct patterns become evident. The holes drilled into the first 20 prey by each of the *N. gualtieriana* were not uniformly distributed around the circumference of the shell ($p < .05$). Holes drilled in whorl 2 were located at a mean of 217° to the right of the aperture, but holes in whorl 3 were only

TABLE 1. *Distribution of* Natica gualtieriana *boreholes in gastropod prey*

	Whorl Number	*N*	*Mean angle*	*Angular deviation*	*Rayleigh z test for uniform distribution*	*Watson & Williams F test for no difference in mean values*
First Prey	2	7	273.3°	10.3°	$p < .05$	$p < .05$
No. 1	3	7	114°	20.3°	$p < .01$	
Total Prey	2	95	217°	17.9°	$p < .01$	$p < .001$
No. 1-20	3	146	60.8°	67.6°	$p < .01$	

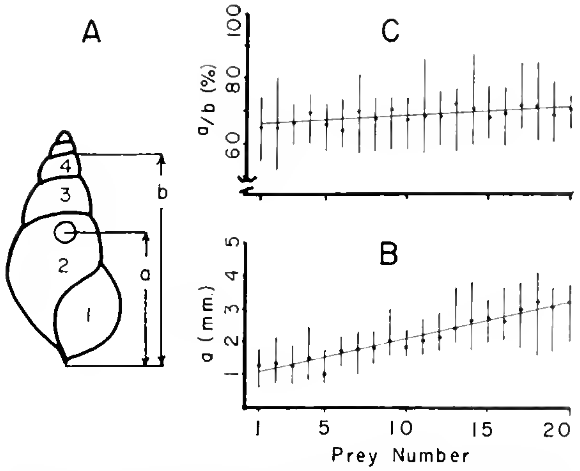

FIG. 3. *Distribution of boreholes along the longitudinal axis of prey of* N. gualtieriana. *A Shell of prey, indicating distance from tip of siphonal canal to center of borehole (a) and to the top of the fourth whorl (b). Numbers indicate whorl number, starting from the tip of the siphonal canal. B Change in distance of borehole from the tip of the siphonal canal (b) with successive borings. Dots indicate median values, vertical lines the range of values,* $Y = 1.06 + 0.105X$, $r = 0.80$. *C. Change of ratio (a/b) with successive borings. Dots indicate median values, vertical lines the range of values,* $Y = 65.63 + 0.295X$, $r = 0.29$

60.8° to the right (Table 1 and Figure 2B). Although the range of distribution for each whorl did overlap slightly, the difference in mean values was significant ($p < .001$).

There was no significant change in the circular distribution of boreholes in each whorl with increased experience or boring. However, a dramatic change in whorl preference occurred between the fifth and sixth prey bored (Figure 2C). Five animals switched from boring into whorl 2 to boring into whorl 3, but only one animal made the opposite switch. From the sixth prey on, there was a significantly increased preference for boring into whorl 3, with $p < .01$ for the difference from even distribution in both whorls for prey number 17, 18, 19, and 20 combined.

The increased percentage of holes bored in the more distant third whorl and the large size of prey may explain the increase in the distance between the center of the borehole and the tip of the siphonal canal (Figure 3B). However, the ratio of the distance between the tip of the siphonal canal and the center of the borehole and the distance from the tip to the fourth whorl varied only slightly with experience (Figure 3C).

DISCUSSION

The quality of the borehole and the proficiency of boring seemed to decrease with repeated boring. The boreholes became less round in appearance, indicating that the holes were not bored perpendicular to the plane of the shell surface, the walls of the holes were rasped in a more random fashion, and the holes were not bored completely through the shell although the prey was eaten. There was one case of two holes being drilled in the same prey and cases of boreholes left incomplete and new holes formed. In general, it seemed that the predators became less proficient at boring during early post-metamorphic development. This may reflect changes in the sensory systems being used in determining the suitability of prey and the position of boring. Such changes would adapt the animals for preying upon a greater variety of prey species as they get older.

The position of the borehole is determined by the way the prey is manipulated and positioned for boring (Böettger, 1930; Ziegelmeier, 1954). The behavior appears stereotyped in naticids. Tactile characteristics of the aperture and chemicals emanating from it are probably used as cues by the predators. When shells of greatly varying shape were given to *N. gualtieriana*, they were bored directly above the aperture, regardless of the length or width of the new prey shell. This preferred position lies over the mantle cavity of the prey snail in its withdrawn condition. This drilling position probably confers on the predator certain selective advantages which have led to its becoming fixed during evolution. One might explain the advantages of the preferred site by a combination of factors: 1) By boring on the same plane as the aperture, the naticid's foot covers this opening, blocking escape by the prey. 2) By boring approximately midway along the longitudinal axis of the shell, the extensible proboscis, which enters the shell through the borehole, has a greater probability of reaching both ends of the shell and removing all of the meat. Therefore, it probably makes little difference which part of the prey's body is con-

FIG. 1. *Young* Natica gualtieriana *(4 mm. in length) from Kaneohe Bay, Hawaii, raised in the laboratory from the veliger stage, and used in shell boring observations.*

sumed first, as Pieron (1933) and Verlaine (1936) contended.

Since the position of the borehole is the result of a complex series of behavior patterns involving prey capture, prey manipulation, and the actual process of boring, the stereotyped position of the borehole reflects a stereotypy of behavior. The stereotyped boring behavior of naticid gastropods is present upon metamorphosis; no experience is necessary. There is an increase in the variability of borehole position and a decrease in the quality of the borehole during early post-metamorphic development. These observations contradict Verlaine's (1936) earlier conclusions based upon boreholes in shells found on the beach. He suggested that the naticids learn, by successive drillings, the position of the gonads under the shells of bivalves and therefore become more restricted in their place of boring. This idea has not been substantiated by my work or that of Bernard (1967).

The gastropod mollusc *N. gualtieriana* and the cephalopod molluscs *Sepia officinalis* and *Octopus cyanea* (Wells, 1962; Wells and Wells, 1970) are competent predators upon metamorphosis and, in fact, their behavior becomes more variable with increasing age. This appears distinctly different from the fact that experience is necessary for most vertebrate predators and for the analogous behavior of nut opening by squirrels (Eibl-Eibesfeldt, 1951).

ACKNOWLEDGEMENTS

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FOSSIL EGGS OF THE LAND SNAIL GENUS *VALLONIA* (PULMONATA:VALLONIIDAE)

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ABSTRACT

Pleistocene fossil eggs of the land pulmonate genus Vallonia *have been identified on the basis of ultrastructure, mineralogy and size. The eggs are remarkably well preserved and show a great deal of surface detail with respect to their calcite crystals. Similar comparisons of the ultrastructure of extant snail eggs with fossils should allow the identification of many more fossil species.*

INTRODUCTION

During the course of my studies on the mineralogy and ultrastructure of calcareous land snail eggs, Dr. Claude Hibbard of the Division of Paleontology, Museum of Zoology at the University of Michigan, kindly provided me with some fossil eggs that he had collected. These eggs had been identified by F. C. Baker as probably belonging to land snails (unpublished). However, their mineralogy and ultrastructure had not been investigated. Since the fossil shell fauna of this locality (Miller, 1968) includes many extant species and genera whose eggs were recently investigated (Tompa, 1974a), an attempt was made to identify them.

MATERIALS AND METHODS

The eggs came from: 1) the Cudahy Fauna, Meade County, Kansas, collected just below the Pearlette ash (restricted), type 0, 600,000 BP years, Loc. 10 (KU) S½NW¼ Sec. 2, T. 31S., R. 28 W, Meade County, 2) Meade County, Loc. UM-K1-51-Sangamon NW½ SW¼, Sec. 33, T. 34S., R. 29W., and 3) McPherson County, Kansas, Loc. #29, SW¼ T18S., R4W, = Loc. UM-K1-62, Sandahl Local Fauna, Illinoian. The eggs were untreated or briefly rinsed in distilled water, then coated with gold and examined with a JEOL JSM-U3 model scanning electron microscope. Several eggs were crushed into a fine powder, packed into Glaskapillaren of 0.5 mm diameter, and examined with x-ray diffraction using CuKa radiation with a Ni filter, at 35 kV, 15 mA, for 4 hours, with an 11.5 cm camera.

RESULTS

X-ray diffraction analysis of the recent eggs of *Vallonia pulchella* (Müller) and *V. costata* (Müller) shows that they are made of calcite; the fossil eggs examined are also made of calcite. Table 1 shows the results of measurements taken of fossil eggs compared with that of recent eggs of *V. pulchella*.

Figure 1 is a low magnification of a fossil egg, showing that it is extremely well preserved, intact. Figure 2 is a higher magnification of another fossil egg, while figures 3 and 4 are of the egg of extant *V. pulchella*. It should be noted that the ultrastructural study of the egg of *V. pulchella* and *V. costata* shows no difference; in fact, it seems that they are not distinguishable on any basis. A comparison of figure 2 with figure 3 shows that the two eggs are identical on the basis of crystal size, shape and pattern of distribution.

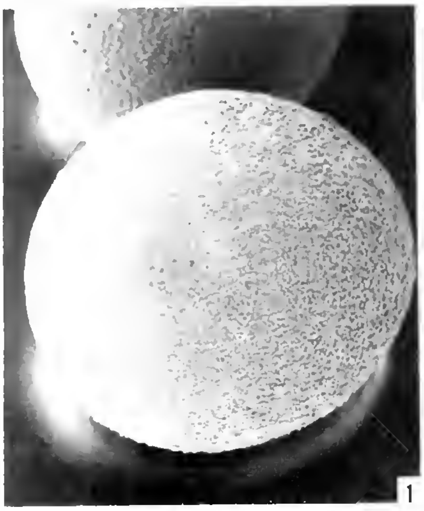
TABLE 1

egg type	N	length (mm)	width (mm)	height (mm)
Fossil egg	(10)	0.67±0.03	0.66±0.04	0.52±0.03
Vallonia pulchella egg	(10)	0.66±0.01	0.62±0.09	0.53±0.02

DISCUSSION

Miller (1968) found 3 species of the genus *Vallonia*, *V. cyclophorella* Sterki, *V. gracilicosa* Reinhart, and *V. pulchella* in the Cudahy fauna, Meade County, Kansas. Tompa (1974a; 1975) found that the genus *Vallonia* has eggs which are distinguishable from all other land snail eggs examined on the basis of egg size and ultrastructure, but the two species examined, *V. pulchella* and *V. costata* were indistinguishable from each other. On the basis of the information presented here, it is concluded that this fossil egg definitely belongs to the genus *Vallonia*, and possibly to *V. pulchella*.

Pilsbry (1948) states that this genus, consisting of about 25 species, is found in North America above Mexico, Europe, North and Central Asia and Japan. As fossils, vallonias are known from the Paleocene, Eocene, Miocene and Pliocene of Europe and Pleistocene of Europe and America. It is an old group which apparently evolved in Mesozoic time and has changed very little since the Eocene.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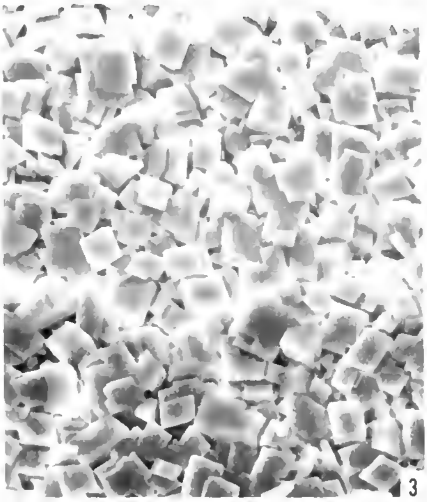
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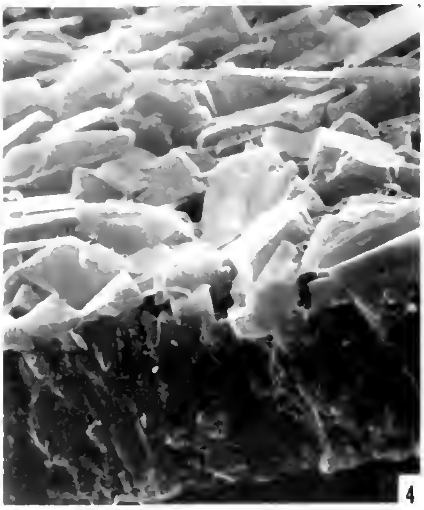
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FIG. 1. *SEM of a fossil egg, showing remarkable preservation of structure.* ×100 FIG. 2. *View of the surface of another fossil egg, untreated. Note crystal shape and distribution.* ×1260 FIG. 3. *Surface view of the egg of* Vallonia pulchella, ×1260. *Note similarity of shape, size and distribution of crystals with those of figure 2.* FIG. 4. *Cross section of* V. pulchella *egg, showing that the large crystals are only on the surface layer.* ×3150

The fact that such delicate and fragile objects as calcified snail eggs should be preserved intact is amazing. Hibbard (1949) describes the method for their collection. It should be noted that these snails, *V. pulchella* and *V. costata* generally deposit a single egg every 24 hours (Whitney, 1938; Tompa, unpublished). Whitney (*op. cit.*) also examined the effect of environmental changes on their rate of reproduction.

Fossil eggs much larger than these have also been reported. Cox (1960) mentioned that large oval bodies up to 30 mm in length, believed to be fossil eggs of *Filholia elliptica* (J. Sowerby) are found in the Oligocene of England, and that similar bodies, probably eggs of *Limicolaria*, occur in the Miocene deposits of Koru, Uganda. Hubricht (1952, 1964, 1965) reported eggs up to 3.6 mm in diameter and attributed the several types found to the genera *Discus* and *Anguispira* and/or *Haplotrema*. Since then, Tompa (1974a, 1975) has documented over 35 genera in 17 families of Stylommatophora as having calcareous eggs. Actually, land snail eggs can be divided into three categories on the basis of the degree of calcification of the egg (Tompa, 1974b): 1) uncalcified, 2) partly calcified, with discrete crystals dispersed throughout the jelly, and 3) heavily calcified, or "shelled," made of fused crystals. Many more fossil eggs of this third group should be found after a more careful examination of collections (I have seen small fossil snail eggs in collections of fossil ostracods). A check-list of genera known to form heavily calcified eggs has been made (Tompa, 1974a) and should be useful in locating additional fossil eggs. Moreover, many of these eggs have already been examined with the scanning electron microscope (*op. cit.;* Tompa, 1975) which should aid greatly in the identification of fossils.

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ASPECTS OF THE FEEDING HABITS OF *VIVIPARUS GEORGIANUS*

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ABSTRACT

Study has been made on the feeding habits of Viviparus georgianus *(Lea) which were collected from a lentic zone of the Sawkill Tributary of the Hudson River.* Viviparus *feed on diatoms but cannot break down all diatoms. The results imply some orientation to diatom clusters, possibly related to a silt-mud substratum. Aggregation behavior of* Viviparus *is described.*

Viviparus georgianus (Lea, 1884) is a freshwater prosobranch found generally in eutrophic lakes, ponds, and slow-moving streams. The specimens in this study were collected in the Fall from a lentic zone of the Sawkill Tributary of the Hudson River at Annandale-on-Hudson, New York. Vegetative decay was prevalent in the area, as well as an abundant brown and green scum covering the surface of a silt-mud substratum which, according to Fritch (1965), represents the diatoms in cluster. It was on this scum that the animals apeared to graze.

The habitat of this study differs slightly from that described by Cook (1949). In Cook's study, *Viviparus* was confined to areas dominated by rocks and only a small portion of mud while *Viviparus* in this study was generally confined to areas dominated by thick silt bottom and few rocks.

This report describes aspects of the feeding habits of *Viviparus georgianus*. After general observations in the field and laboratory during a period of two years investigations were limited to: (1) an examination of gut contents; (2) an examination of a possible substrate preference; and (3) an investigation of a possible relationship between feeding behavior and substrate composition.

MATERIALS AND METHODS

The following methods and materials were utilized for each of the behavioral investigations: (1) all experimental animals were acclimated for at least one day before use in an experiment; (2) the temperature was maintained at between 20° and 25° C; (3) sterile, filtered water from the Sawkill was used in all experiments; (4) all apparatus were horizontally leveled to limit the possible influence of a geotaxic response; (5) all apparatus were shielded with black paper to limit the influence of reflected light; (6) and all experiments were done separately with and without aeration in both the Fall and Spring.

Fifty animals were placed in a mild solution of magnesium sulfate which facilitated dissection and removal of the gut. After removal of the gut its contents were flushed with water and collected for examination. The gut effluent was preserved and examined by the method of Williams (1964).

The sizeable aggregations of *Viviparus* in areas characterized by silt-mud and the decreased concentrations of *Viviparus* in other areas of the Sawkill suggested a possible substrate association. This was investigated by optically dividing a twenty gallon aquarium into two sections. One section of the aquarium contained sterile washed rock and gravel from the natural habitat. The other section contained sterile washed silt-mud from the same general habitat. Twenty adult animals which had been starved for ten days were then randomly placed into the aquarium. The animals were then allowed to acclimate for one day. The number of animals in each section were then counted each hour for a period of seven days. No data was collected between 12:00 p.m. and 7:00 a.m. In addition, a second group of 20 immature animals measuring 3-5 mm in diameter were also used in the experiment.

Observations in the field and in the laboratory also suggest that *Viviparus* may "seek out" clusters of diatoms associated with the silt-mud substratum. To confirm this supposition, the following experiment was performed. A mixed culture of diatoms consisting primarily of the order Pennales was placed in random areas on a substratum consisting of only washed sterile silt. Twenty adult animals which had been previously starved for a period of one week were then added to the aquarium. After an acclimation period of six hours observations were made of the animal's behavior. During this time feces were removed to insure that the animals would not feed on them. In addition, the distance from diatom clusters was measured from each animal. Distance measurements were made at half hour intervals for a period of twelve hours. At the termination of the experiment gut analyses were done on each animal. Two modifications of the preceeding experiment were done as follows: (1) washed sterile gravel was substituted for the silt and (2) the diatom clusters were placed directly on the slate bottom of an aquaria.

RESULTS AND DISCUSSION

Observations in the field indicate that

Viviparus in this study tend to aggregate in silt-mud areas which are dominated by attached filamentous algae and large clusters of diatoms. Additional observations lead this observer to believe that *Viviparus* may tend to avoid, or cannot tolerate, conditions where blue-green algae predominate.

Gut analyses of the animals from the field showed that *Viviparus* do ingest and at least partially break down diatoms and other algae. Of the diatoms ingested, *Merdion*, *Fragellaria* and especially large naviculoid cells were conspicuously fragmented, but no specific fragmentation pattern was observed. Other diatoms such as *Gomphonema* and *Diatoma* were not conspicuously fragmented. The fragmentation of only specific groups of diatoms may be related to the structural features of the diatom fustrule and the structure of the radular apparatus. This should be further investigated. Blue-green algae were absent in a vast majority of the gut samples, but sparsely present in some samples. Fragments of filamentous green algae were found in all samples. In addition, in all of the above gut samples, a conspicuous amount of a fine grit was found. The importance of fine particles of grit in the gut of at least some gastropods has been demonstrated by Colton (1908). He noted that in the absence of grit, food was able to pass through the gut unmolested. This may also be the case with *Viviparus*.

In the laboratory experiments 80% of the animals congregated and grazed upon the spread diatoms in the silt sections of the aquaria. A less intense congregation behavior was observed when diatoms were provided over gravel or slate substrata. All animals in the silt section went through a burrowing behavior after most of the diatoms were removed. This observation is not in direct agreement with Cook (1949) who stated that *Viviparus* is not an active burrower. This behavior culminated in each animal burrowing to at least half the depth of its shell. After burrowing, the animals did not move for a minimum of a half hour. Eleven of the burrowed animals did not show locomotion for two days. Gut analyses of the animals which grazed on diatoms in the silt-aquarium showed diatom fragmentation which was consistent with the samples from the field. No or little diatom fragmentation was found in the guts of animals which were in the exposed slate aquarium. This would tend to demonstrate that diatom breakdown is at least in part related to the presence of grit in the gut of *Viviparus*.

In the substrate preference experiments with no algae present, all animals initially showed a random behavior and moved about with their snouts moving from side to side. Six hours after the beginning of the experiment all of the adult animals had either moved to the silt side of the aquaria or remained in the silt-mud side of the aquaria. Why adults of *Viviparus* will be aggregated to sterile silt in the absence of diatoms was not ascertained. The immature animals did not show this behavior.

No immediate directed orientation movement to diatom clusters was observed. Instead, the animals moved randomly but continuously, until they came within an average of 10 centimeters of a diatom cluster. Thereafter, their rate of movement intensified in the general direction of the diatom cluster. Kohn (1961) pointed out that *Viviparus* will respond to organic compounds, and some herbivorous gastropod species are attracted to stimuli emanating from food. In addition, Hyman (1967) also reiterated that chemoreception is well-developed in prosobranchs. Therefore, it is possible that the previously mentioned intensified movement may be related to chemoreception. That is to say, that the initial feeding behavior is undirected and upon reaching the immediate area of the diatom cluster the animal's behavior becomes directed. Possibly the diatom mass provides a threshold concentration of some organic stimulus in its immediate area. Even if this is correct, it can only be one of the stimuli to which *Viviparus* responds when searching for food. The aggregation response to a predominately silt-mud substratum with a grit make-up in the absence of organic matter also may be significant in locating areas associated with food. This may then suggest that a possible tactile response or possibly tactile memory may be involved in locating an area where food may be present. Tactile memory is well known in marine limpets and chitons although it has not been reported with *Viviparus*.

It may be noteworthy to point out that the aggregation behavior described in this paper does not seem to be confined to *Viviparus*. Bovbjerg (1965) has shown that *Stagnicola reflexa* tends to aggregate on patches of *Spirogyra*, and Calow (1970) has demonstrated that *Lymnaea pereger* tends to select green filamentous algae.

In summary, this study tends to show the following: (1) that *Viviparus* will feed on diatoms but cannot breakdown all diatoms; (2) there is at least some orientation to diatom masses; and (3) that the orientation may in some way be related to a silt-mud substratum.

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THE OCCURRENCE IN FLORIDA OF THE WEST INDIAN LAND SNAIL *BULIMULUS GUADALUPENSIS*

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Bulimulus guadalupensis (Bruguière, 1789) is widespread in the West Indies where it is found on most of the Lesser Antilles, all of the Greater Antilles and many of their satellite islands. No doubt, its distribution prior to man's arrival was much more restricted. The snail adapts to a wide variety of environmental conditions at low elevations within its present range. It occurs near human habitation and is easily disseminated to new areas on live agricultural plants. Thus, it is not surprising that it has become introduced into southern Florida.

Recently *Bulimulus guadalupensis* was collected in Florida at three localities by field inspectors of the Florida State Division of Plant Industries: (1) Snead Island, Palmetto, Manatee Co., October 1969; (2) Eustis, Volusia Co., August 1975; (3) 1500 block, W. 7 Avenue, Hialeah, Dade Co., July-August, 1975. Specimens from each of these localities are deposited in the Florida State Museum. The first two records involve specimens found at nurseries on ornamental plants recently imported from Puerto Rico. Established colonies at these two places have not been confirmed. The third locality, in Hialeah, has an established population where the snail is abundant in a residential area in lawns and among ornamental vegetation. The geographic extent of this population has not been determined. Most likely the species soon will be found throughout the greater Miami area.

VARIATION IN THE NEW ENGLAND PYRAMIDELLID GASTROPOD, *TURBONILLA NIVEA* (STIMPSON)

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ABSTRACT

Based on the study of a large population of a highly variable species of Turbonilla, *and examination of type specimens of* T. nivea *and* T. stricta, *it is the author's opinion that* Turbonilla (Turbonilla) stricta *Verrill, 1873, is a synonym of* T. (T.) nivea *(Stimpson, 1851). The syntype of* T. nivea *located at the Academy of Natural Sciences of Philadelphia is not a typical example of the species, but is well within the variation observed in a population from Connecticut.*

INTRODUCTION

Recent studies on Northwestern Atlantic species of the genus *Turbonilla* revealed that the characters originally used to separate two of the species, *T. (Turbonilla) nivea* (Stimpson, 1851) and *T. (Turbonilla) stricta* Verrill, 1873, are insufficient. As Robertson (1968) noted, the systematics of the Pyramidellidae is based solely on shell characteristics. For example, Verrill (1873), in his original description of *T. stricta*, stated that it differed from *T. nivea* in the form of the aperture and lip, and in being smaller though having the same number of whorls. Bartsch (1909) separated the two on the basis of the number of axial ribs on the last whorl (eighteen on *T. stricta* and twenty-two on *T. nivea)*, and by a slight difference in the shape of the aperture. A large population of *Turbonilla* from Connecticut exhibited a high degree of variability in these and other characters, making the existence of two distinct species questionable. An examination of types on deposit at the Academy of Natural Sciences, Philadelphia *(T. nivea* syntype, ANSP #20013; *T. stricta* probable syntype or paratype, ANSP #78205), confirmed the suspicion that the two species should be synonymized. The Academy's single specimen of *T. nivea* was obviously collected dead, as the shell is quite worn and even has a drill hole in it. From the variation shown by the population from Connecticut, and the poor condition of the *T. nivea* syntype, it is easy to see how two species were described.

Over six hundred specimens were collected from a population located subtidally in eel grass beds off Noank, Connecticut, during 1970 and 1971. Most of the snails burrowed beneath the sediment throughout the year, and were seldom seen on the surface. This may have been due to a lack of surface materials, since a nearby population lived beneath dead scallop shells which littered the surface. Spawning occurred in late summer, and the young snails grew to a length of about 2 mm before winter. No growth was added during the winter, and the shells became thickened and opaque. Some of the adult snails also survived the winter. Growth resumed the following May and June. Approximately 2 mm of translucent shell material was added by August. Spawning adults averaged nearly 4 mm and had 8 to 9 whorls. Snails dredged offshore from a depth of 30m were somewhat larger, with more whorls. *Lunatia triseriata* (Say) appeared to be the chief predator of *T. nivea* at Noank, although it preferred the less common *T. verrilli* Bartsch.

Sanders (1958) has suggested that at least one species of *Turbonilla* is a deposit feeder rather than an ectoparasite. Because of their burrowing habits and the scarcity of suitable prey, feeding by *T. nivea* was not actually observed at Noank. Thus the question remains unresolved, and much more work on this aspect is needed. There is a well-defined series of ciliary currents present on the foot, mentum, and tentacles. These serve to transport substrate particles over and around the head while

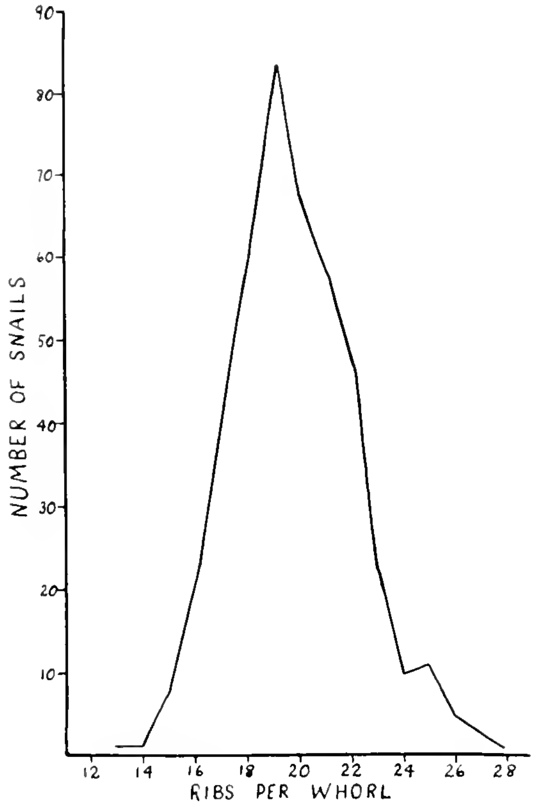

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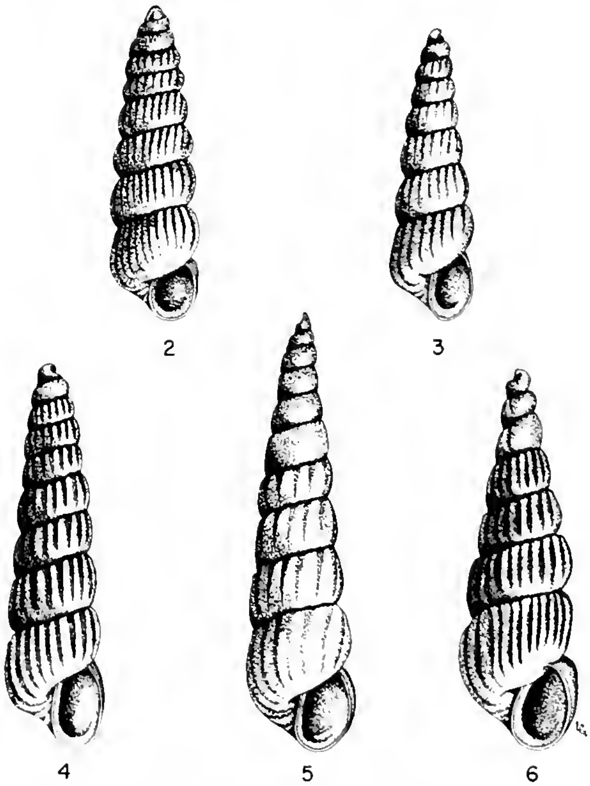
FIG. 1. *Graph showing the number of ribs per whorl in a sample of 436 snails.*

burrowing, and might also be used in feeding if the animal is a selective deposit feeder.

VARIATION

About five hundred snails were examined, and the number of ribs on the youngest whorl was counted. Figure 1 shows the result. The continuous curve shows that this character should not be used to separate species of the subgenus *Turbonilla*. Such variation was due to differences in both the width of the whorls and the width of the ribs themselves. Variation in length and number of whorls per shell did not affect the variation in number of ribs per whorl. Shells of the same size also varied in the number of whorls they possessed. Similarly, shells with the same number of whorls varied by as much as one millimeter. The shape of the ribs was also somewhat variable — even from whorl to whorl in some specimens. Most were slender and slightly curved. However, many specimens had ribs that were straight. The size of the aperture was measured and found to be quite variable in this population: from narrowly elliptical to squarish — though most commonly broadly oval. Figures 2-6 illustrate some of the variation in this species. A representative series, showing the highly variable nature of this species, was deposited at the Academy of Natural Sciences of Philadelphia.

Shell characteristics alone are generally unacceptable for a clear understanding of specific differences between species of the subgenus *Turbonilla*, especially since population studies have not been undertaken to determine variability within a species. And until more complete studies have been done, precise definitions of the species will be impossible. Lopes (1958) and Bartsch (1909) have also studied variation in the shell characteristics (especially spiral incisions) of *Turbonilla*. However, they were dealing with other subgenera; and the



FIGS. 2-6. *Five specimens of* Turbonilla nivea *collected from the same locality showing variation within the species*

taxonomic problems resulting from such variation were less severe because of the presence of other useful shell characters.

Other possible characters useful for describing species of *Turbonilla* are the operculum, which is elaborately sculptured in some species; the color of the hypobranchial gland (Robertson, 1968), yellow-green in *T. nivea;* feeding habits or host preference; presence (or possible absence) and form of the stylet; and the presence or absence of denticles. Such denticles, for example, are present in *T. (Pyrgiscus) verrilli* but absent in *T. (T.) nivea.* They are quite similar to the penial denticles figured by Maas (1964). It is also quite probable that further studies will reveal that the differences between at least some species of *T. (Pyrgiscus)* and *T. (Turbonilla)* are generic rather than subgeneric.

The Pyramidellidae as a whole, and the genus *Turbonilla* in particular, need a great deal of study before even some of the basic taxonomic problems can be cleared up. Other species of *Turbonilla* (e.g. *T. verrilli* and *T. vinae)* should be examined for similar synonymies. Populations should be studied to determine variability, and a combination of other characters should be used in conjunction with shell morphology to redefine species.

ACKNOWLEDGEMENTS

I wish to express my deepest appreciation to Dr. Robert Robertson for his assistance on many aspects of this study. I also wish to thank Miss Lauren Green for illustrating the snails; and the faculty and staff of the University of Connecticut Marine Research Laboratory, Noank, who provided much assistance during the project. This research was supported in part by an NSF Graduate Fellowship from the University of Connecticut.

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ALVAR NÚÑEZ AND THE SNAIL *RABDOTUS* IN TEXAS

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In a recent article in *The Nautilus,* Hester and Hill (1975 : 38) discussed the possible ethnohistoric account of Alvar Núñez Cabeza de Vaca referring to the eating of snails in the Gulf Coastal Plain. In an earlier article, also in *The Nautilus* (Clark 1973 : 24) I lamented the lack of ethnohistoric accounts referring to this practice among the Texas Indians. Unfortunately, this situation must remain lamented.

Hester and Hill depend on two sources: Bishop (1933 : 95) and Krieger (1956 : 53). The Krieger article on the food habits of the Texas coastal Indians unfortunately indicates no sources other than Cabeza de Vaca and that somewhat vaguely. The problem of the Bishop book is that there appears to be considerable differences between it and more standard translations. Unfortunately, neither of these sources agrees with the Bandelier (1906) translation, the Covey (1963) translation or the original Spanish (Núñez 1906 ed.).

There are two passages of the Cabeza de

Vaca Relación pertinent to the discussion:

1) "Algunas vezes matan algunos venados, y a tiempos toman algun pescado; mas esto es tan poco y su hambre tan grande que comen arañas e huevos de hormigas y gasanos e lagartijas e salamanquesas e culebras y biuoras que matan los hombres que muerden, y comen tierra y madera e todo lo que pueden auer, y estiercol de venados y otras coasa que dexo de contar, y creo aueriguadamente que si en aquella tierra ouiesse piedras, las comerian (Núñez 1906 : 70)."

2) "En todo el tiempo que comiamos las tunas teniamos sed y para remedio desto beuiamos el çumo de las tunas y sacauamoslo en vn hoyo que en la tierra haziamos, y desque estaua lleno beuiamos del hasta que nos hartauamos (Núñez 1906 : 75)."

Covey (1963) translates these passages following the Spanish closely:

1) "Occasionally, these Indians kill deer and take fish; but the quantity is so small and famine so prevalent that they eat spiders and ant eggs, worms, lizards, salamanders, snakes and poisonous vipers; also earth and wood — anything, including deer dung and other matter I omit. I honestly believe that if there were stones in that land they would eat them (Covey 1963 : 79)."

2) "The thirst we had all the while we ate the pears, we quenched with their juice. We caught it in a hole we hollowed out in the ground. When the hole was full, we drank until slaked (Covey 1963 : 83)."

The Bandelier translation is similar to that of Covey.

Obviously, the Spanish word for snail, "caracol" does not appear in these passages nor does the word appear in any of the Spanish language passages dealing with the Mareames Mariames).

Thus, by examining the original Spanish text one can see that, although Alvar Núñez provides much information on the subsistance of the Mariames and the central Texas coastal Indians, he does not mention snails. T. C. Hill's experiment (Hester and Hill 1975 : 38) indicates that the Indians could have eaten *Rabdotus* sp. snails. Likewise, their presence in vast numbers in certain archeological sites is suggestive. As I suggested in my 1973 article (Clark 1973 : 24) the presence of radulae of these snails in human coprolites would be the best indication as to whether these animals were eaten. Unfortunately, none have yet been found in human coprolites from Texas sites or any other North American archeological sites.

Dr. Vaughn Bryant of the Anthropological Research Laboratories at Texas A&M University (May 1975: personal communication) has specifically searched for snail radulae during the processing of coprolites but has failed to find any. This may be due in part to the procedure of sampling the coprolites, the selection of coprolites for analysis or the possibility that the Indians did not eat snails. I believe that at present it is a sampling problem in that coprolites have not been analyzed which were associated with snail shell deposits in dry rockshelters.

In summary, the Bishop (1933) monograph apparently is in error, possibly leading Krieger (1956) into error. The original Spanish text (Núñez 1906) does not mention snails nor do two of the major translations, thus, there is still no ethnohistorical evidence from Cabeza de Vaca and Bryant has yet to find hard empirical evidence for the eating of snails. As of the moment, all theories are inferential.

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SPECIES CRITERIA IN *ANGUISPIRA (ANGUISPIRA)* (PULMONATA: DISCIDAE)

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ABSTRACT

The functioning surface of the penis in Anguispira (Anguispira) *shows consistent differences in pilaster pattern among* A. alternata *(Say, 1816),* A. cumberlandiana *(Lea, 1840), and* A. picta *(Clapp, 1920), although the gross appearance of their genitalia is nearly identical. Investigation of the conchologically divergent morphs lumped as* A. alternata *probably will result in recognizing several species. The genital difference reported here corresponds with major shell shape and sculpture differences. Radular structure in the Discidae, as represented by* Anguispira, *is generalized and differs from the basic patterns found in the Charopidae, Endodontidae, and Helicodiscidae.*

INTRODUCTION

The ribbed and unicolored to flammulated shells grouped as *Anguispira* and *Discus* have been monographed by MacMillan (1940) and Pilsbry (1948). Comparison of these papers shows considerable disagreement as to species limits and affinities, although the generic limits are the same. MacMillan (1940) relied strictly on the shell for taxonomic decisions and Pilsbry (1948: 566) indicated that "... fundamental inaccuracies are involved" in MacMillan's phylogenies. Preliminary work by H. B. Baker on the anatomy of various species of *Discus* was included by Pilsbry (1948: 599-600) in the form of a key, together with some anatomical details on both *Anguispira (A.) alternata* (Say, 1816) and *A. (Zonodiscus) kochi kochi* (Pfeiffer, 1845) (Pilsbry, 1948: 568, fig. 304), and, additionally, *Discus (D.) patulus* (Deshayes, 1830) (Pilsbry, 1948: 599, fig. 327). Subsequently Forcart (1957) commented on the subgeneric divisions of *Discus;* Umiński (1962) revised the Palearctic species of *Discus* and summarized the widely scattered European literature; and Umiński (1963) reported on the anatomy of *Discus marmorensis* H. B. Baker, 1932.

Various discrepancies and contradictions in these accounts will be discussed elsewhere (Solem, *in preparation*). Here, it is sufficient to point out that the species of *Discus* have several longitudinal pilasters within the penis (Pilsbry, 1948: 599, fig. 327a; Umiński, 1963: 84, figs. 5-8) and in *Anguispira* there are only two pilasters, one very large and the other small (Pilsbry, 1948: 568, figs. 304C, 304F). There has not been any detailed study of the anatomy in different species of *Anguispira* previously, and unpublished observations by Hubricht, Grimm and myself had failed to identify species level identification features from the external aspects of the genitalia.

During a survey of rare and potentially endangered land snail species of Eastern North America for the Office of Endangered Species, it was necessary to investigate the status of the taxa grouped as *Anguispira (A.) cumberlandiana* (Lea, 1840). MacMillan (1940: 392-394) and Pilsbry (1948: 586-589) recognized four subspecies, *A. c. cumberlandiana* (Lea, 1840) from Northeastern Alabama and Tennessee; *A. c. alabama* (Clapp, 1920) from Northeastern Alabama; *A. c. columba* (Clapp, 1920) from Marion Co., Tennessee; and *A. c. picta* (Clapp, 1920) from near Anderson, Franklin Co., Tennessee. Clapp (1920) described *Anguispira picta* as a full species, and Hubricht (unpublished) agreed with this opinion on the basis of shell features.

This paper reports on species level differences in the terminal genitalia of *Anguispira*

(Anguispira) alternata, A. cumberlandiana, and *A. picta*, and thus suggests features that can be investigated to determine the status of the many forms that have been lumped as *A. (A.) alternata* by earlier authors and Pilsbry (1948), but split into several species by Hubricht (1952, 1965, 1968, 1970, 1974) on the basis of field observations and shell features. Radular teeth of the same three species are illustrated to show the basic structures and inter-row support mechanisms of the central and lateral teeth in the Discidae.

The field work by Mr. Glenn Goodfriend was supported by Office of Endangered Species Contract 14-16-0008-764, which also provided for the excellent anatomical illustrations by Elizabeth A. Liebman. OES Contract 14-16-0008-965 supported the page and illustration charges for publication. The scanning electron microscope photographs were taken with a Cambridge S4-10 Stereoscan provided to the Field Museum of Natural History by NSF Grant BMS72-02149. The SEM prints were prepared by Fred Huysmans. The help of Sharon Bacoyanis and Elizabeth Liebman in manuscript preparation is gratefully acknowledged as is the support and help given this project by the Office of Endangered Species staff, particularly Marc Imlay.

MATERIAL STUDIED

The data on the illustrated material are as follows:

Anguispira (A.) alternata (Say, 1816). Northwest side of Route 272, 0.4 miles southwest of Route 270 junction, north side Rich Mountain, Polk Co., Arkansas. Glenn Goodfriend! September 13, 1973. Field Museum of Natural History 176186.

Anguispira (A.) cumberlandiana cumberlandiana (Lea, 1840). Near Martin Springs Road, 8 miles south of Monteagle, Marion Co., Tennessee at 960 feet elevation. Glenn Goodfriend! September 4, 1974. FMNH 171433.

Anguispira (A.) picta (Clapp, 1920). Southwest side of Buck Creek Cove, 4 miles south of Sherwood, Franklin Co., Tennessee at 750 feet elevation. Glenn Goodfriend! September 6, 1974. FMNH 171138.

Several additional sets of typical *A. alternata* were dissected, but are not illustrated, since they agreed with the structures seen in the figured material. What appears to be seasonal variation in the prostate-uterus and development of the main pilaster was discovered. Material collected at the same time of year was selected for illustration, despite the geographic incongruence of the *A. alternata* set.

FIG. 1. *Genitalia of* Anguispira: **a,** Anguispira alternata alternata *(Say, 1816) FMNH 176186. North side of Rich Mt., Polk Co., Arkansas;* **b,** Anguispira picta *(Clapp, 1920). FMNH 171138. Buck Creek Cove, south of Sherwood, Franklin Co., Tennessee;* **c,** Anguispira cumberlandiana cumberlandiana *(Lea, 1840) FMNH 171433. About 8 miles south of Monteagle, Marion Co., Tennessee. Scale lines equal 5 mm.*

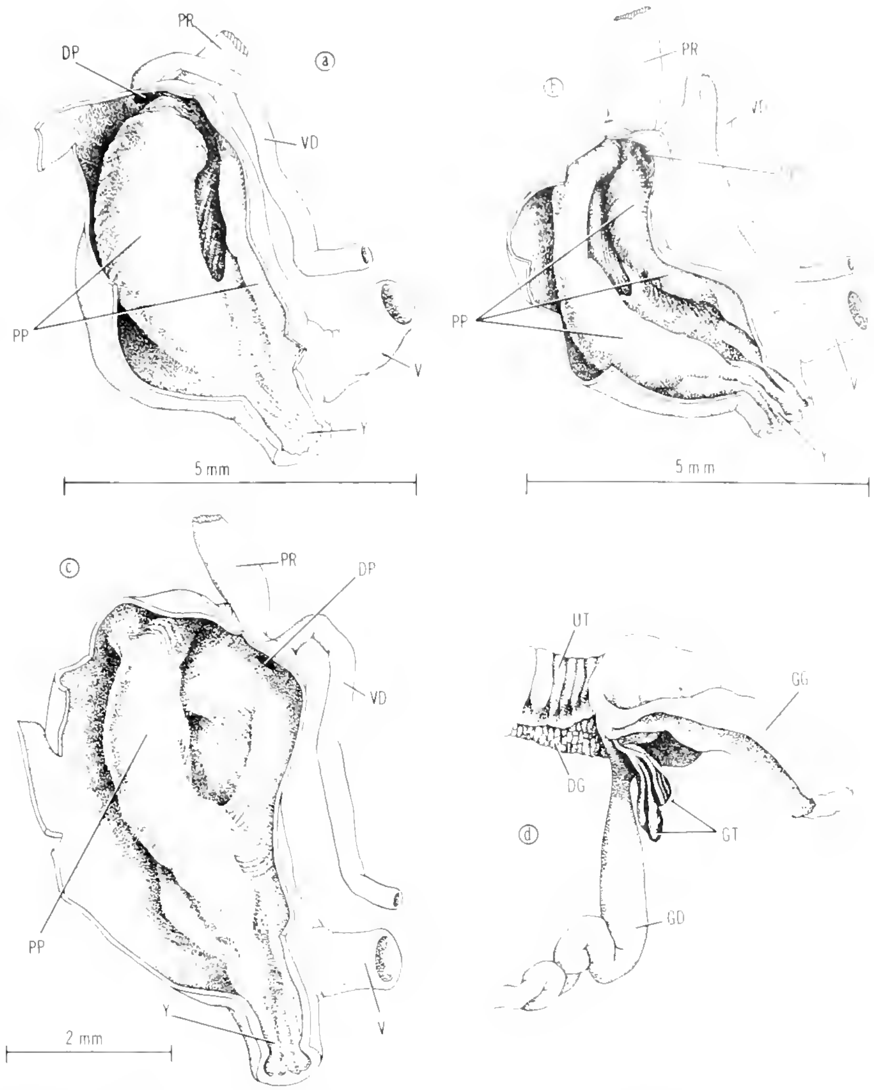


FIG 2 *Penis internal structure and talon in* Anguispira **a,** Anguispira alternata alternata *(Say, 1816).* **b, d,** Anguispira picta *(Clapp, 1920);* **c,** Anguispira cumberlandiana cumberlandiana *(Lea, 1840). Scale lines as marked.* **d** *greatly enlarged*

TERMINAL GENITALIA

The apical genitalia of *A. alternata* and *A. picta* are not illustrated, since the ovotestis (G) and hermaphroditic duct (GD) showed no differences from the structures seen in *A. cumberlandiana* (fig. 1 *c*). All three species have the tri-lobed talon (fig. 2 *d*, GT) first reported by Pilsbry (1948: 568, fig. 304D). *A. picta* (fig. 1 *b*) does have a slightly longer prostate (DG) and uterus (UT), but this may be a facet of individual population variation. The very long spermatheca (S) and slender, fingerlike albumen gland (GG) also are typical of the Discidae. *A. alternata* (fig. 1 *a*) does have a shorter free oviduct (UV) than either *A. picta* (fig. 1 *b*) or *A. cumberlandiana* (fig. 1 *c*). There is a slight variation in the length of the vagina (V), but because of the angle at which the spermatheca joins the free oviduct to form the vagina, measuring the exact length of the latter is very difficult.

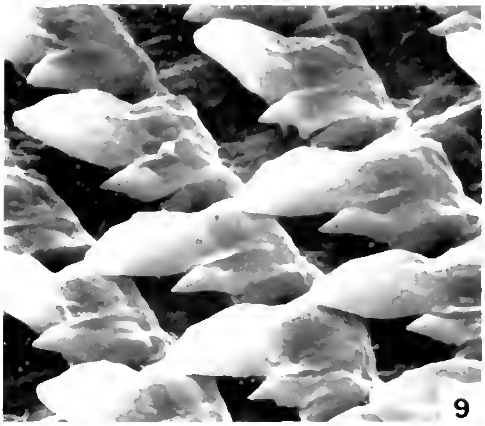
In all *Anguispira (Anguispira)* examined so far, the vas deferens (VD) emerges abruptly from the acini bundles of the prostate, narrows slightly and lies free of the adjacent tubes in its passage to the peni-oviducal angle, then reflects apicad to enter the penis (P) through a simple pore (fig. 2 *c*, DP). The vas deferens entrance is lateral to insertion of the penial retractor muscle (PR), which, contrary to previous literature statements, arises from the diaphragm, not the columellar muscle. In all cases the insertion of the penial retractor muscle is on the apex of the penis. The illustration of *A. cumberlandiana* (fig. 1 *c*) suggests that the insertion is slightly lateral instead, but this is an artifact of preservation. The illustrated specimen was partly retracted into the shell. As part of the retraction process, the penis is shifted apicad relative to the origin of the penial retractor muscle. At full shift the apex of the penis is bent slightly to the left and the retractor muscle extends diagonally anteriorly, rather than in its normal apical orientation. When fixed in the preservative, this slight distortion can be misinterpreted as part of the basic structure unless it is compared with the condition found in fully expanded materials.

There is a definite difference in the shape of the penis, which is caused by the quite divergent internal pilaster structures (figs. 2 *a-c*). In *A. cumberlandiana* (fig. 1 *c*) the penis tapers almost evenly from apex to atrial junction (Y). In *A. picta* (fig. 1 *b*) the penis has an almost uniform diameter on its upper two-thirds, then rapidly narrows toward the atrium on its lower third. *A. alternata* (fig. 1 *a*) has a more bulbous penis that narrows slightly apically, but tapers toward the atrium on its lower two-fifths. Typically these differences can be detected, but flattening during dissection or in the initial preservation process can distort individual specimens and mislead the observer.

Only by slitting the penis from atrium (Y) to penis pore (DP) and studying the major pilasters, can the differences (fig. 2) be seen clearly and the species differentiated without question. In *A. alternata* (fig. 2 *a*) the major pilaster (PP on left) expands to great size, tapers very slightly at the apex, and sharply near the atrium. The second pilaster (PP on right) is a narrow, much lower, raised ridge that varies at most slightly in height over its entire length. In *A. picta* (fig. 2 *b*) the major pilaster (PP) expands much less, even on its lower third, then narrows greatly toward the middle, and is a relatively narrow ridge in its upper half. The second pilaster is lower, wider on its lower half, then broadens into a semicircular pilaster on its upper half. The second pilaster itself is composed of less dense tissue. In *A. cumberlandiana* (fig. 2 *c*) the main pilaster is rather high and narrow, without major size change from near the apex to near the atrium. The second pilaster is greatly reduced in height, becoming a wide, nearly flat patch of fibrous tissue. Near the middle of the penis in each species, a "pocket" is formed by a flap of tissue running between the two pilasters. This is vaguely similar to a structure found in many Charopidae, but apparently formed quite differently (Solem, unpublished). All *Anguispira* have vague longitudinal fold ridges extending from the atrium into the penis base (figs. 2 *a-c*). One or two of these may extend up alongside the major pilaster, but I have not dissected enough individuals to determine if the longer ridge shown for *A. cumberlandiana* (fig. 2 *c*) is an individual variation or represents another species difference. The different shapes found in the two large pilasters are characteristic within quite narrow limits and thus represent species differences.

The above observations are based on studying five individuals from each population, and on sampling ten populations from the Middle West and Eastern United States of *A. alternata*. The differences in pilaster structure are constant and I conclude that they are valid species differences. Thus *A. picta* is distinct from *A. cumberlandiana*, as originally proposed by Clapp (1920), and both are distinct from *A. alternata*. Restudy of dissections that I had made many years ago of *A. fergusoni* (Bland, 1861) from Cambridge, Maryland, (specimens courtesy of Ralph Jackson), *A. macneili* Walker, 1928 from Alabama (specimens courtesy of Leslie Hubricht), and new dissections of *A. mordax* (Shuttleworth, 1852) from Well Spring, Campbell Co., Tennessee (FMNH 137820, L. Hubricht! June 5, 1964) show equally different

FIG 3-8. *Central and lateral radular teeth* Figs. **3-5, 8.** Anguispira picta *(Clapp, 1920) FMNH 171138* Fig **3.** *Newly formed central (upper center) and 1st lateral teeth 1,135×.* Fig. **4.** *Lateral teeth from mid section of radula showing functioning of support ridge and anterior flare 1,260×.* Fig. **5.** *Central (upper right) and lateral teeth viewed from anterior angle, erected position 650×* Fig **8.** *Late lateral tooth viewed from low outside angle to show extent of free anterior margin 1,315×* Figs **6-7.** Anguispira cumberlandiana cumberlandiana *(Lea, 1840)* Fig. **6.** *Central (left) and 1st lateral near posterior end of radula showing dual support ridges on central, single support ridge on lateral, marked anterior flare of lateral 1,250×* Fig **7.** *Central and early lateral teeth viewed from a high posterior angle 650×*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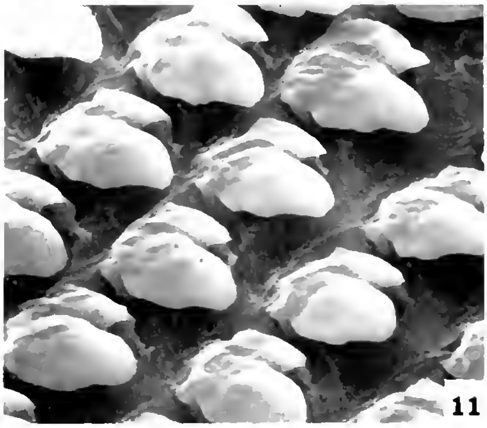
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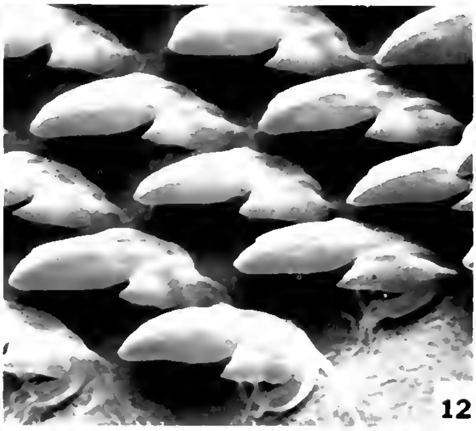
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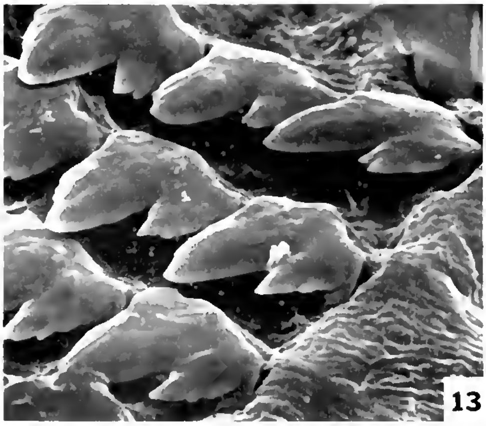
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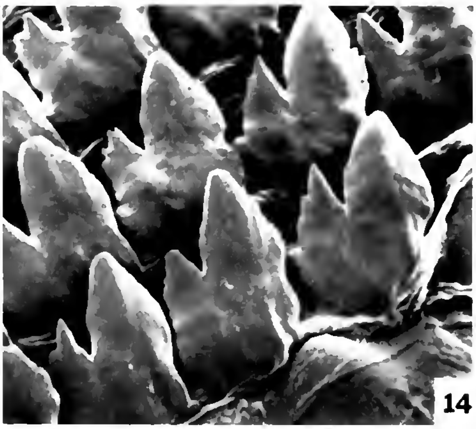
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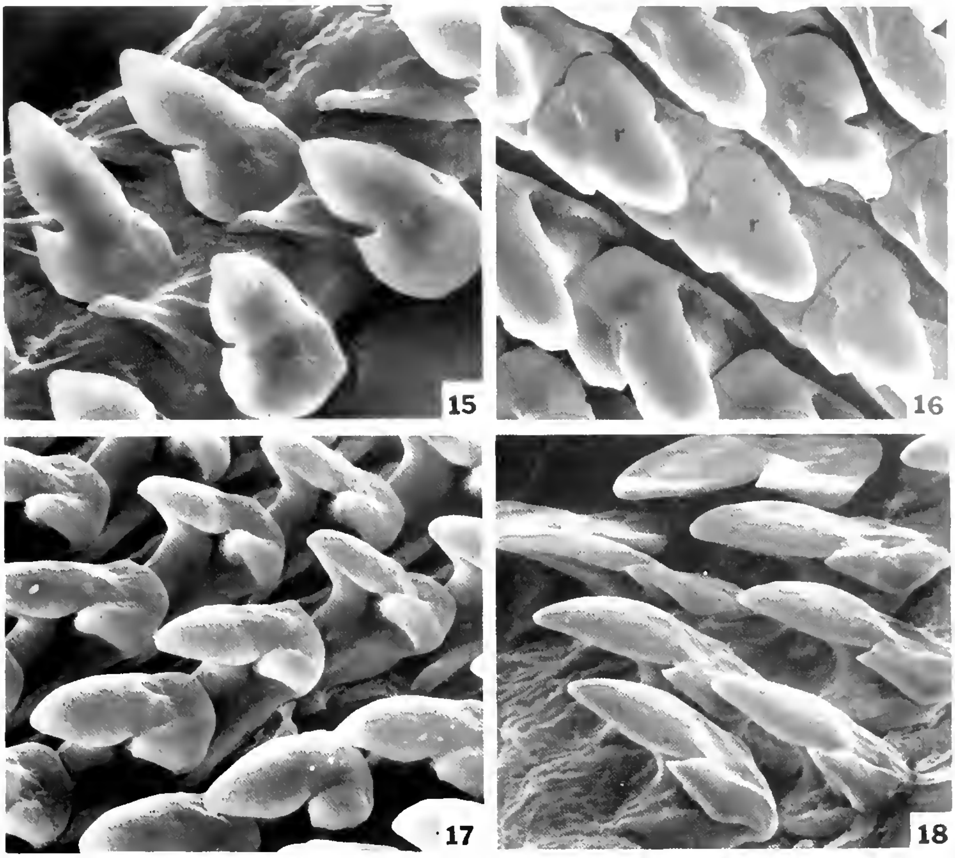
FIGS. 9-14. *Marginal radular teeth.* Figs. **9-10.** Anguispira alternata alternata *(Say, 1816).* Fig. **9.** *Outer marginals from high posterior angle. 1,300×.* Fig. **10.** *Outer marginals on a creased area to show shape and angle of elevation. 1,300×.* Fig. **11.** Anguispira cumberlandiana cumberlandiana *(Lea, 1840) FMNH 171733. Midmarginal teeth from a high central angle. 625×.* Figs. **12-14.** Anguispira picta *(Clapp, 1920) FMNH 171138.* Fig. **12.** *Transition from lateral to marginal teeth. 1,000×.* Fig. **13.** *Outermost marginals showing splitting of side cusps. 1,250×.* Fig. **14.** *Outermost marginals from a high anterior angle. 1,115×.*



FIGS. 15-18. *Radular teeth.* Figs. **15-17.** Anguispira alternata alternata *(Say, 1816). FMNH 176186.* Fig. **15.** *Newly formed early lateral teeth showing function of basal support ridge.* 1,050×. Fig. **16.** *Worn central and early lateral teeth from anterior end of radula.* 1,000×. Fig. **17.** *Lateral teeth.* 1,160×. Fig. **18.** Anguispira picta *(Clapp, 1920) FMNH 171138. Transition from lateral to marginal teeth showing shortening of basal plate and reduction of anterior flare.* 1,110×.

pilaster patterns in these taxa. Revision of the *Anguispira alternata* group is beyond the scope of this study, but the existence of distinctive pilaster patterns in some of its more strongly characterized "races" indicates that several species are represented, as Hubricht has suggested previously on the basis of his collecting experiences. An investigation of penis pilaster structure in this complex can be expected to yield significant data, despite the lack of obvious differences in the gross genitalia.

RADULAR STRUCTURE IN *ANGUISPIRA*

The radulae were prepared using the techniques outlined in Solem (1972). Published illustrations have been chosen to demonstrate the functioning and structure of the inter-row support system in the Discidae, to illustrate the pattern of change from lateral to marginal teeth, and to demonstrate the form of the marginal teeth. Differences between the three species are trivial, with *A. cumberlandiana* (fig. 7) having a smaller central tooth in relation to the 1st laterals than either *A. picta* (fig. 3) or *A. alternata* (fig. 16) and *A. alternata* (figs. 15-17) having a more prominent ectocone on the lateral teeth than either of the other species.

The rachidian or central tooth of the radula, marked "r" in figs. 3-7 and 16, has very weak to weak ectocones, a variably (fig. 7) indented and sinuated anterior margin, no anterior flare, and two prominent lateral buttresses on the basal plate (figs. 3, 6, 7). The first lateral teeth are immediately recognizable in that they lack an endocone (fig. 7) and in having the basal plate buttress only on the outer side of the basal plate (fig. 6). In addition, there is a distinct anterior support flare on the early laterals that is lacking in the rachidian tooth (fig. 5). When a tear in the basal membrane partly separates two rows of teeth (figs. 5-7), then the basal plate structures and anterior flares can be observed quite easily. After the first few lateral teeth, the basal flare becomes accentuated and somewhat elongated (fig. 8), with the anterior two-fifths of the tooth free of the basal membrane. This is the generalized "helicoid" pattern for inter-row support of the laterals (see Solem, 1972; pl. 5, figs. 22-23). Figs. 3, 4, and 7 show the stress support system in various phases of operation. For the rachidian tooth, the anterior margin is pressed back against the basal plate and fits right in between the lateral buttresses. Fig. 7 shows two stages in the process: at far left, the anterior flare is tilted down, but not in contact with the basal plate, while at far right the flare is in contact. Fig. 16 shows the interlock system in full operation even more clearly. The first lateral teeth differ only in the stronger anterior flare being pressed partly against the shaft of the cusp and partly against the outside buttress (lower left of fig. 4 and center of fig. 15).

This is a highly generalized buttress system that is widely distributed in the Pulmonata and yields no information as to the phylogeny of the group.

Transition from lateral to marginal teeth occurs fairly abruptly (figs. 17-18) and involves changes in basal plate, anterior flare, cusp length, and angle at which the cusp is pointed. Fig. 17, top to bottom, shows the shortening of the anterior flare, while the different angle in fig. 18 demonstrates the further progression in this loss and the then very rapid change in the length of the posterior section of the basal plate. The shift is completed with the teeth at the bottom of fig. 18, where the anterior margin is simply rounded, the cusp is at a lower angle, the posterior section of the basal plate is greatly shortened, and the lateral buttress on the basal plate is lost. The shift in angle of the cusp continues to the point shown in fig. 12, where the cusp is elevated a comparatively few degrees from horizontal. At this point, a weak endocone may appear on some of the marginals, although most (fig. 11) will have only a small knob-like protrusion. Newly formed marginals (figs. 9, 10) in *A. alternata* show no special features, but fig. 10, which was taken at a curve in the radula, effectively demonstrates the cusp angle. Outermost marginal teeth (figs. 13, 14) show irregular splitting of the ectocone with teeth in successive rows showing different ectoconal splitting features. In some individual outer marginal teeth there is a weak endocone (upper right of fig. 14).

In maintaining a basically bicuspid condition, the lateral and marginal teeth of the Discidae differ from those of the Charopidae (Solem, 1974: 167) or Helicodiscidae (Solem, 1975: figs. 6-8) which are essentially tricuspid with often extreme cusp splitting. The Endodontidae (Solem, 1973: figs. 6-9, 13-14) also have bicuspid lateral teeth with bicuspid to tricuspid marginals, but the inter-row support system (*loc. cit.*, figs. 6, 14) is very different. The anterior margin of the lateral teeth is rounded and totally lacks an anterior flare, the cusps are narrower and curved, and support comes by pressing against the raised posterior tip of the basal plate ridge. When viewed with optical equipment, the endodontid and the discid radulae would look essentially identical, but the functioning patterns in the two groups are very different.

SHELL FORM AND GROSS SCULPTURE

Differences in shell form and sculpture between the nominate taxa of the three species have been covered quite adequately by MacMillan (1940) and Pilsbry (1948). *Anguispira alternata* (Say) has a rounded to angulated periphery on the body whorl and weak to very strong radial ribs that continue across the periphery and into the umbilicus. *A. cumberlandiana* (Lea) has a protruded, thread-like peripheral keel with prominent radial ribs that continue across the keel. *A. picta* (Clapp) has the radial ribs present on the upper spire, but absent from the body whorl and with the protruded peripheral keel smooth and without any trace of radial ribbing.

Because races of *A. alternata* and *A. cumberlandiana* vary greatly in the prominence of their sculpture, considerable uncertainty continues to exist concerning the limits to be assigned sculptural variation within a species. Thus the decisions by MacMillan (1940) and Pilsbry (1948) to combine *A. picta* with *A. cumberlandiana* were based on the latitude of sculptural variation in the morphs lumped as *A. alternata*. The demonstration here of differences in the penial pilaster patterns between *A. picta* and *A. cumberlandiana* suggests that investigation of the named forms of *A. alternata* that show widely divergent sculpture may lead to a splitting of that taxon into several discrete units.

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RANGE EXTENSION OF *CORALLIOPHILA MARRATI* KNUDSEN (GASTROPODA: MAGILIDAE)

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ABSTRACT

Coralliophila marrati *Knudsen, 1956 originally described from off Liberia is here reported from Congo and Angola.*

In his report on the molluscs collected during the *Atlantide* Expedition to the coasts of tropical West Africa, Knudsen (1956) described three new species of the family Magilidae: *Coralliophila jarli*, *C. kraemmeri* and *C. marrati*. Although all were based on one or two specimens, no doubt seems to exist concerning the specific status of these species.

Coralliophila marrati was based on a single specimen dredged from a depth of 78 m at 5° 06′ N, 9° 34′ W off Liberia. Since Knudsen's description no additional data have been added to the distribution of *C. marrati*.

The Zoological Museum of Amsterdam acquired the second known specimen from Mr. W. Bergmans. This specimen was collected in 1969 by J. Moret near Pointe Noire, Congo. It agrees in full detail with the original description of Knudsen (1956: 29, pl. 2, fig. 14). It is only slightly larger: height 26.7 mm; width 17.1

mm (respectively 21.9 and 14.7 mm in the holotype).

The Hebrew University of Jerusalem received recently a third specimen from Mr. J. Bruynseels. This specimen was trawled at a depth of 73 m on a coral bottom off Moita Seca, Angola, in 1973. The measurements of this specimen are: height 22.4 mm and width 14.1 mm. Another specimen from the same locality is still in Mr. Bruynseel's collection.

These two additional records of *C. marrati* mean an important range extension in a southern direction. It is, however, clear from the known data that systematic dredging along the coast of tropical West Africa may yield additional specimens and localities of this rare *Coralliophila*.

I wish to thank Dr. H. E. Coomans and Mr. R. Moolenbeek for their kind hospitality during my visit to the Zoological Museum of Amsterdam. Thanks are also due to Mr. J. Bruynseels (Belgium) for presenting the Hebrew University of Jerusalem with one of the discussed specimens.

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CITTARIUM PICA (TROCHIDAE) IN FLORIDA

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Recent reports of living specimens of the West Indian trochid, *Cittarium pica* (Linné), at various localities along the shores of Marathon and Molasses Keys seem to substantiate the fact that this species has become established, at least temporarily, along the Florida Keys. Whether they were introduced by man from the West Indies purposefully or accidentally, or whether they arrived as floating larvae will probably never be ascertained. Among the earliest collectors were Mrs. Carol Brunner of Miami (live, 30 mm., Molasses Keys, October, 1973), Mrs. Betty Greene of Long Island, N. Y. (live, 51 mm., oceanside of Ohio-Missouri Key, March 9, 1974), Gary Magnote of Miami (live, 80 mm., East Sister Rock, Marathon, May 1975), and Robert J. L. Wagner of Marathon (live, several, 100 mm., yacht basin at Marathon, July 1975).

Clench and Abbott (1943) recorded only dead shells from the Florida Keys, with the comment that the species probably died out within comparatively recent times, perhaps due to low temperatures. Verrill (1900) reported a similar extinction of the species in Bermuda. On the basis of Helen Randall's (1964) studies on the growth rate of *Cittarium*, the 1973 specimens from Molasses Keys may be assumed to be about a year and a half old. Wagner's specimens are about three years old. It is possible therefore, that Wagner's specimens came from a natural larval invasion sometime during 1971 or 1972. Until other young specimens, say under 10 mm in diameter, are discovered it will remain a mystery whether or not these are breeding populations. It will also be interesting to see if an unduly cold winter in the future will kill them.

Wagner (*in litt.*) reported the nearby presence of "numerous" adult *Purpura patula* (Linné), a common Caribbean species usually thought to be somewhat uncommon in the Florida Keys. H. Randall (1964) reported that this snail is a predator of *Cittarium*.

There have been sporadic records of large adults found at various Florida localities, but these may have been brought in from the West Indies by fishing boats. A large live specimen was collected in July 1948 at Dry Tortugas by R. O. Smith and was donated to the U. S. National Museum.

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COMMENTS ON EASTERN NORTH AMERICAN POLYGYRIDAE

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ABSTRACT

The genitalia and radular structure of several Mesodon *and* Triodopsis *from Arkansas, Oklahoma and West Virginia are illustrated and discussed in relation to their potential significance in phylogenetic studies. The structure of the verge, penial pilaster details, penial sheath muscle attachment, and details of radular cusping are emphasized.*

INTRODUCTION

During a survey of rare and potentially endangered land snail species of Eastern North America, numerous polygyrid land snails were collected. Some of these previously had not been dissected, others were studied in order to check their affinities and compare their structures with those of sympatric taxa. Although the emphasis here is on species from Arkansas and Oklahoma, the opportunity is taken to include information on the West Virginia *Triodopsis (T.) platysayoides* (Brooks, 1933), since its structures differ from those found in *Triodopsis (Neohelix) albolabris alleni* (Wetherby, 1883) and *T. (N.) divesta* (Gould, 1851). The main purpose of this report is to review shell, genital, and radular structures that can be confused on the basis of shell structures and distributional overlap. It is hoped that further work on their ecology and relationships will be stimulated.

The field work by Mr. Glenn Goodfriend was supported by Office of Endangered Species contract 14-16-0008-764, which also paid for the excellent anatomical illustrations by Elizabeth A. Liebman. OES contract 14-16-0008-965 provided the page charges for publication. The scanning electron microscope photographs of radulae and jaws were taken by the author with a Cambridge S4-10 Stereoscan provided to the Field Museum of Natural History by NSF Grant BMS72-02149 A01. The SEM prints were prepared by Fred Huysmans. I am indebted also to Leslie Hubricht for loaning material of *Triodopsis platysayoides*, to Katy Baker for help with literature compilations, and to Jayne Freshour for aid with manuscript preparation. The OES staff, particularly Marc Imlay, has been most helpful and encouraging in these efforts.

STATUS OF KNOWLEDGE

Explorations for land snails in Missouri, Arkansas and what is now Oklahoma were carried out by James Ferriss in 1900 and 1901, and then by Henry A. Pilsbry and Ferriss in 1903. The papers by Pilsbry (1903) and Pilsbry and Ferriss (1907) contain data that is still essential for any field work in this region, although their major findings were summarized by Pilsbry (1940) in his monograph of the Polygyridae. This work, which synthesizes the efforts of a century, remains the basic reference for work on the family. Subsequent faunistic and descriptive papers by Leslie Hubricht, B. Branson, L. Lutz and others have provided additional distributional records. The conchological review of *Triodopsis* by Vagvolgyi (1968), and the review of the *T. fallax* group by Wayne Grimm (1975) contain much useful information.

Potentially the most significant studies are those of Glenn R. Webb (1952, 1954a, 1954b, 1959, 1961, 1974) on mating behavior and anatomy. Unfortunately these papers are difficult to use. Webb's supraspecific taxa were ignored by Vagvolgyi (1968) and Grimm (1975). The subgeneric and sectional names *Wilcoxorbis* (Webb, 1952), *Aphalogona* and *Ragsdaleorbis* (Webb, 1954b), *Haroldorbis* and *Shelfordorbis* (Webb, 1959), and the subfamily Ashmunellinae (Webb, 1954a) are validly proposed taxa and must be included in any revision of polygyrid classification.

The characters that have been used to define supraspecific categories are few in number. Mostly they involve alternative states, such as: penis sheath and retentor muscle (present or absent); epiphallus (present, absent or vestigial); duct of spermatheca (slender or swollen); verge (present or absent); number of major pilasters inside the penis (one or two); and the size of

FIG. 1. *Shells of Ozarkian Polygyridae.* **a-b,** Triodopsis albolabris alleni *(Wetherby) FMNH 176127, Tenkiller State Park, Sequoyah Co., Oklahoma;* **c-d,** Mesodon binneyanus *(Pilsbry) FMNH 176008, Rich Mt., Polk Co., Arkansas;* **e-f,** Mesodon clausus *(Say) FMNH 176220, Calico Rock, Izard Co., Arkansas;* **g-h,** Mesodon clenchi *(Rehder) FMNH 176059, Mt. Nebo State Park, Yell Co., Arkansas. Scale lines equal 10 mm.*

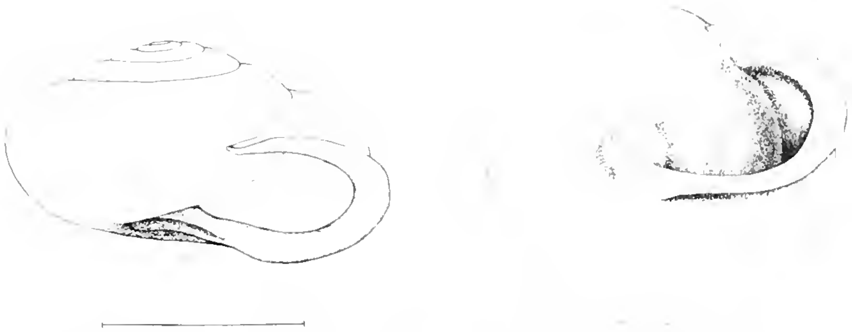


FIG. 2. *Shell of* Triodopsis divesta *(Gould) FMNH 176082, Magazine Mt., Logan Co., Arkansas. Scale line equals 10 mm*

the papillae in the upper chamber of the penis. Although Pilsbry (1940: 703) had pointed out that the finer structure inside the penis should be investigated, subsequent workers have ignored this suggestion.

Triodopsis platysayoides and *Mesodon elenchi* (Rehder, 1932) had not been dissected previously, and only fragmentary data had been published concerning the structures of *Triodopsis divesta* and *Mesodon clausus* (Say, 1821). New details on the structures of *Mesodon binneyanus* (Pilsbry, 1899) and *Triodopsis albolabris alleni* are presented.

SHELL CHARACTERS

The absence of any major shell differences between species of *Mesodon*, *Triodopsis*, and *Allogona* that lack apertural barriers has confused students and collectors of the group for more than a century. Particularly in the Ozarkian region, several *Mesodon* and *Triodopsis* are conchologically quite similar. They have differences in the lip and umbilical region, but most previous illustrations fail to show these features. New line drawings are presented here to demonstrate such distinguishing characters.

Triodopsis (Neohelix) albolabris alleni (Wetherby) is highly variable in size and color, ranging as adults from 17-32 mm. in diameter. The relatively depressed spire, fairly sharp descension of the body whorl just before the aperture (fig. 1 *a*), presence of a thickened ridge on the basal lip (figs. 1 *a*, *b*), and sharply defined union of the columellar region to the umbilical covering (fig. 1 *b*) present a distinct contrast to the *Mesodon* (figs. 1 *c-h*). *Triodopsis (Neohelix) divesta* (Gould) generally is much smaller in size, mostly 17-21 mm. in diameter, has a distinctly weaker ridge on the basal lip (fig. 2 left), shows only slight descension of the body whorl near the lip, and has a very gradual merging of the columellar lip into the umbilical covering (fig. 2 right). Small specimens of *T. a. alleni* can be confused with normal *T. divesta*, but the differences outlined above are sufficient to enable identification.

Mesodon binneyanus (figs. 1 *c-d*) and *M. elenchi* (figs. 1 *g-h*) differ from each other most obviously in umbilical size, degree of lip reflection, and body whorl thickness, while *M. clausus* (figs. 1 *e-f*) has a higher spire, narrow lip, and a more angular insertion of the columellar lip (fig. 1 *f*). There is partial size overlap among these species. *M. clausus* (10-20 mm. in diameter) normally is smaller than *M. binneyanus* (16-28 mm.) and *M. elenchi* (19-23 mm.).

In many places three or more of the above species are sympatric, at least to the extent of living on the same slope or in the same ravine. A compilation of recorded localities in Arkansas, Oklahoma and Missouri for *T. divesta*, *T. a. alleni*, and *M. binneyanus*, for example, showed that for the 35 *T. divesta* localities, *T. a. alleni* also was recorded from 16 of these. Of the 23 localities known for *M. binneyanus*, *T. a. alleni* also has been taken at five, *T. divesta* at two, and at an additional two localities, all three species have been collected. The exact ecological relationships between these species are unknown, and a comparative ecological survey would be well worthwhile.

TERMINAL GENITALIA

The degree to which the terminal genitalia function in "species recognition" and the extent to which major differences in structures of this region make hybridization difficult or unlikely vary greatly from group to group of land snails. Webb (1952, 1954a, 1954b, 1959, 1961, 1974) has published voluminously on mating behavior and anatomies of polygyrid snails, with the cited references only serving as a locator for his studies. Grimm (1975) reported evidence of hybridization in the field and many laboratory crossings among *Triodopsis, s. s.* The situation in polygyrids is quite complex. All this report can do is to focus on some structural features for future investigation and to report on some previously undissected species.

Rather than present formal descriptions, comments are restricted to comparisons between structures in order to emphasize features with potential phylogenetic significance and of use in classification.

The classic key difference between *Mesodon* and *Triodopsis* involves the presence in the latter of a penis sheath (PS) and a continuation of the penial retractor muscle (PR) from its insertion on the vas deferens (VD) or penis (P) apex to the penis sheath. This continuation sometimes is called the "penis retentor muscle". The length of the sheath varies greatly, being long in *T. platysayoides* (fig. 3 *b*), short in *T. divesta* (fig. 4 *b*), and intermediate in *T. a. alleni* (fig. 5 *a*). These differences were constant in the materials examined. The sheath in *T. platysayoides* (fig. 3 *b*) also has a very unusual muscle attachment, in that it essentially spreads completely around the penis and onto the inside of the sheath, whereas in the other species it fastens to one portion of the sheath wall (fig. 4 *b*). All *Triodopsis* dissected to date agree in having two sections to the penis. The upper chamber has one very large pilaster plus a large microsculpture of papillae, while the lower chamber, the area below the apex of the penis sheath, has a series of simple longitudinal pilasters (PP) that continue into the atrium (Y). The relative length of the two chambers varies from species to species (compare figs. 3, 4, 5) and the lower chamber sometimes shows a distinct difference in pilaster size below the penis sheath when compared with the area of the penis sheath (compare figs. 3 *b*, 4 *b*).

There are obvious and major differences in the size and spacing of the papillae in the upper penis chamber (see figs. 3, 4 and 5). What has not been recorded previously, is the variation in apical penis structures. Although *Xolotrema* and *Neohelix* were reported to have verges (Webb, 1952), any differences in verge size and form were not recorded or illustrated. In *T. platysayoides* (fig. 3 *b*) there is no trace of a verge, while in *T. a. alleni* (fig. 5 *a*) the verge

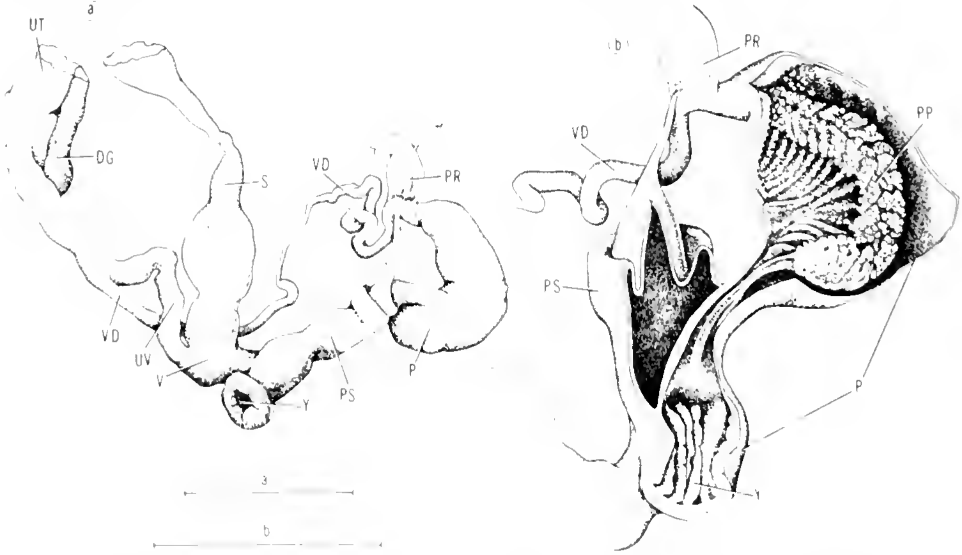


FIG. 3. *Genitalia of* Triodopsis (T.) platysayoides *(Brooks) Cooper's Rock, Monogalia Co., West Virginia. Leslie Hubricht 11860.* **a,** *terminal genitalia,* **b,** *interior of penis and penis sheath. Scale lines equal 5 mm.*

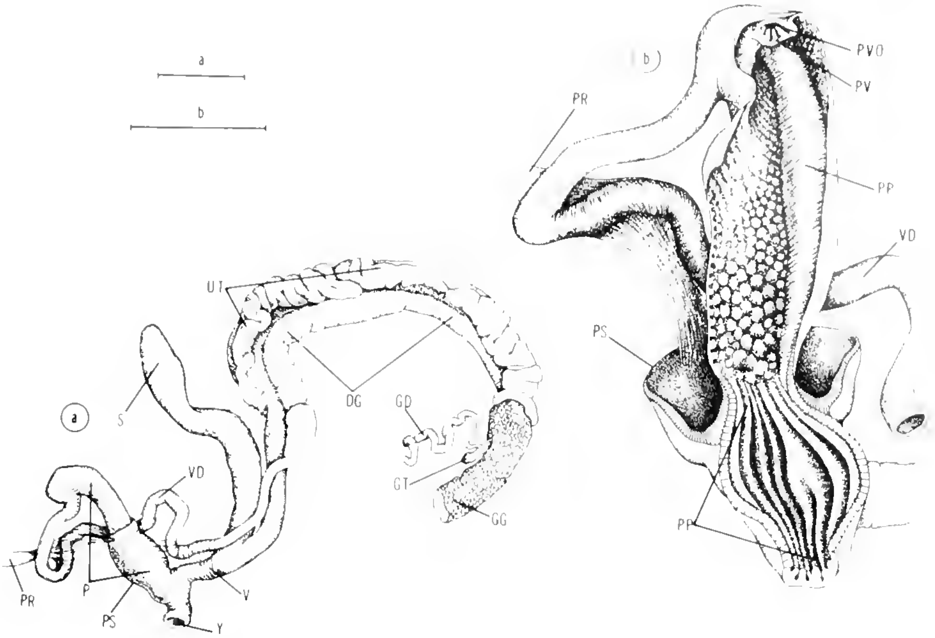


FIG. 4. *Genitalia of* Triodopsis (Neohelix) divesta *(Gould) FMNH 176082, Magazine Mt., Logan Co., Arkansas.* **a,** *terminal genitalia,* **b,** *interior of penis and penis sheath. Scale lines equal 5 mm.*

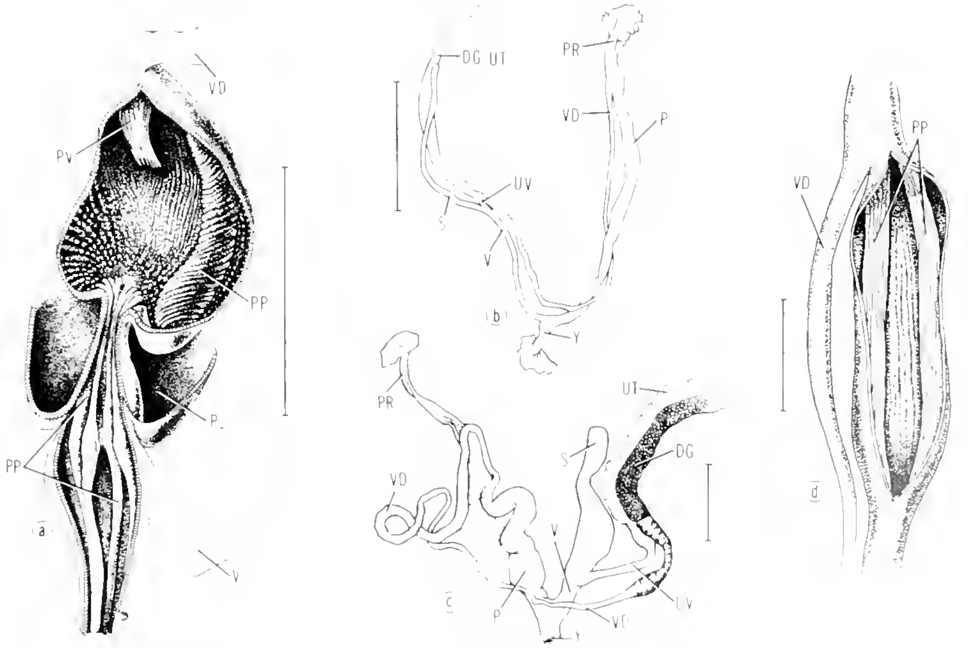


FIG. 5. *Genitalia of* Triodopsis (Neohelix) albolabris alleni *(Wetherby) and* Mesodon (M.) clenchi *(Rehder).* **a, c,** T. (N.) a. alleni *FMNH 176127, Tenkiller State Park, Sequoyah Co., Oklahoma.* **a,** *interior of penis,* **c,** *terminal genitalia,* **b, d,** M. (M.) clenchi *(Rehder) FMNH 176059 Mt. Nebo State Park, Yell Co., Arkansas.* **b,** *juvenile terminal genitalia,* **d,** *interior of apical penis region. Scale lines for* **a-c** *equal 5 mm, scale line for* **d** *equals 1 mm.*

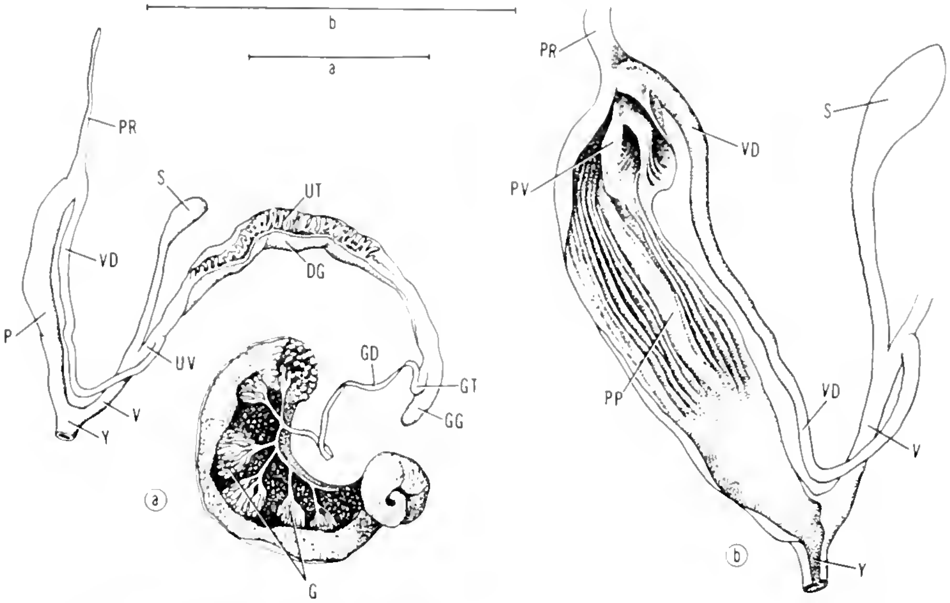


FIG. 6. *Genitalia of* Mesodon (M.) clausus *(Say) FMNH 176220 Calico Rock, Izard Co., Arkansas.* **a,** *genitalia,* **b.** *interior of penis. Scale lines equal 5 mm.*

(PV) is a very large, conical structure with terminal pore. In the often sympatric *T. divesta* (fig. 4 *b*), the verge is a flap-like opening to one side of the slightly recurved main pilaster and the pore (PVO) is quite large. The differences in chamber lengths, papillae size and number, and verges between *T. a. alleni* and *T. divesta* probably are sufficient to prevent hybridization.

Equally significant variations can be found in species of *Mesodon*. *M. clausus* (fig. 6 *b*) has a vergic papilla through which the vas deferens opens and only a single elevated pilaster (P); *M. clenchi* (fig. 5 *d*) has two pilasters of equal size and apparently no vergic papilla; and *M. binneyanus* (fig. 7 *e*) has two unequal pilasters that join apically into a flap-like arrangement, but with the vas deferens entering through a simple pore (DP) above the pilaster junction. A talon (GT) is well developed in *M. binneyanus* (fig. 7 *b*), but is only a reflexed area in *M. clausus* (fig. 6 *a*), without being differentiated from the hermaphroditic duct (GD). All examined *Mesodon* had a relatively long vagina (V), short free oviduct (UV), spermatheca (S) with slender shaft, finger-like albumen gland (GG) and showed no unusual features in the prostate (DG) and uterus (UT). The ovotestis (G) of *M. clausus* (fig. 6 *a*) is illustrated, but most other taxa had this organ in a reduced stage and it was not studied.

Mesodon binneyanus (fig. 7) has a very large penis that is substantially longer than the shell diameter. Pilsbry (1940: 740, fig. 445, D) used cross-sections of the penis to establish basic structures. The more detailed drawings presented here provide further details of structure. The apical portion (fig. 7 *e*) has a short, lower, second pilaster that gradually merges into the penis wall. The main pilaster is very high, thin, and apically forms a flap-like stimulator. In mid-penis (fig. 7 *c*) the main pilaster is reduced in height, thicker, and there are no obvious subsidiary structures on the penis wall. In the basal section (fig. 7 *d*) the main pilaster is almost circular in shape, becoming flatly ovoid at the atrium, and there is a complex set of minor pilasters on the penis wall. Unlike the situation in *M. clausus* (fig. 6 *b*) there is no pilaster-free basal area to the penis.

JAW AND RADULAR STRUCTURE

A strongly ridged jaw with denticulated lower margin is characteristic of the Polygyridae. No study of jaw variation in ribbing or microstructure has been published. References to the jaw usually are restricted to

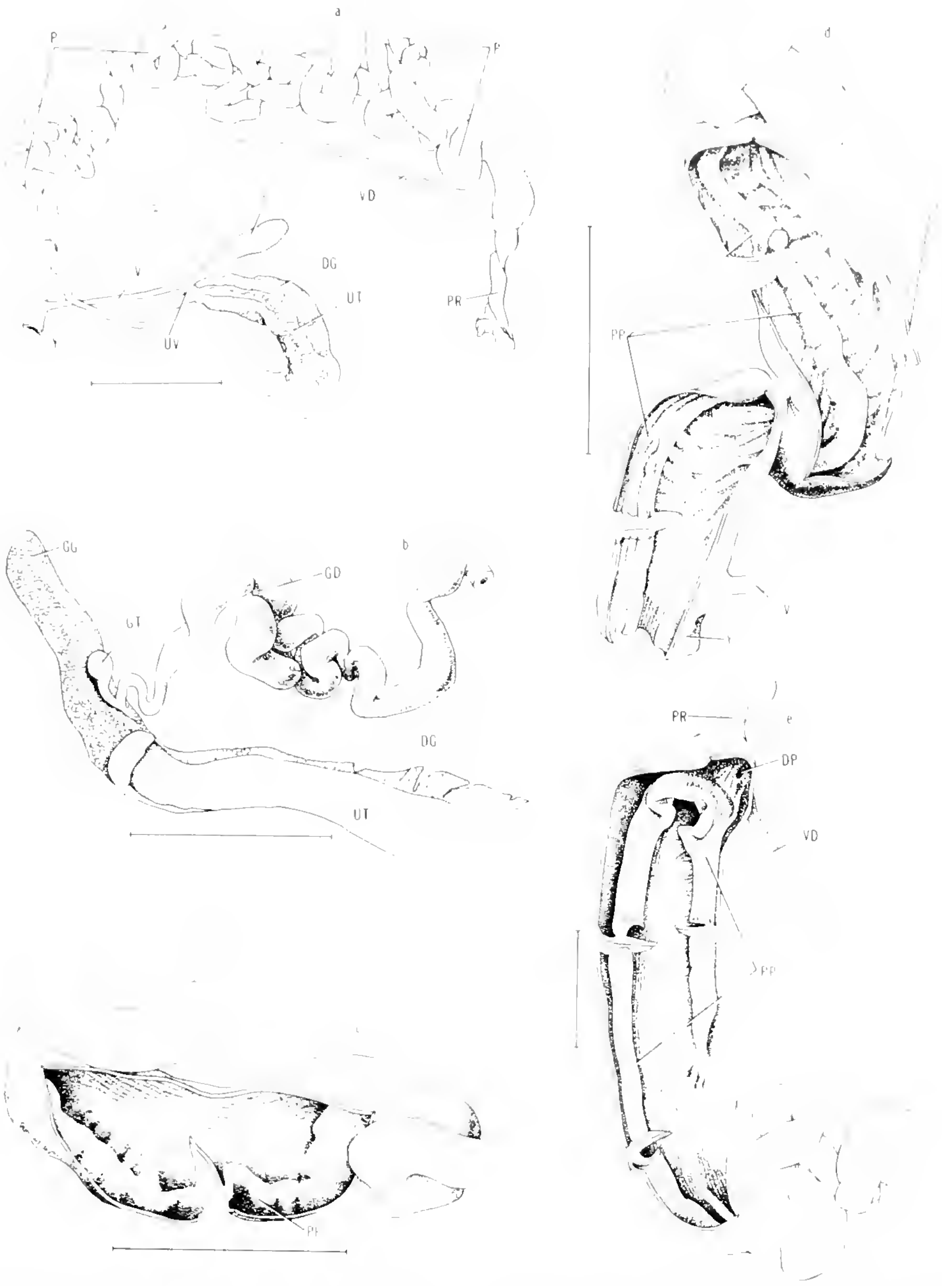
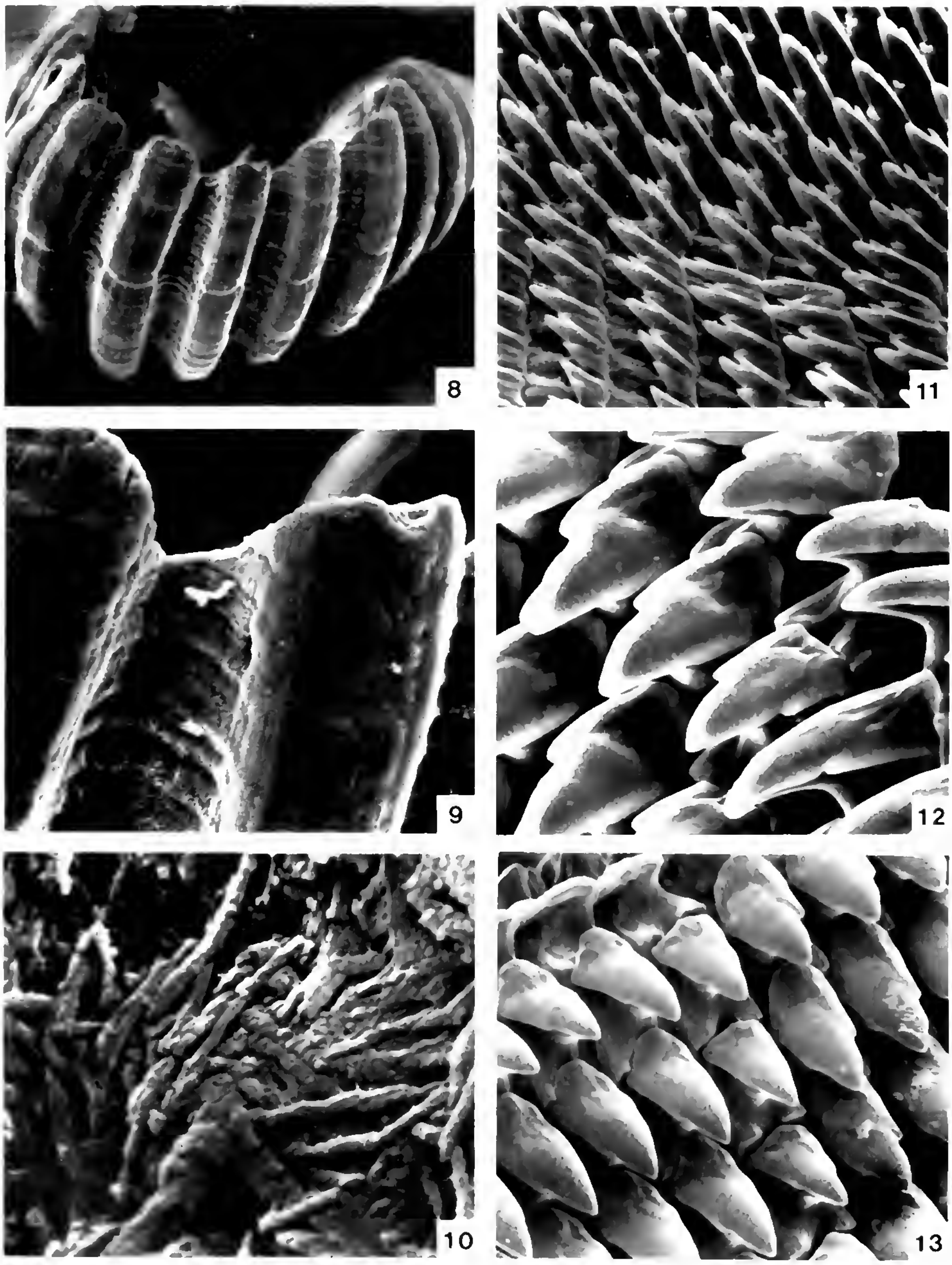


FIG. 7. *Genitalia of* Mesodon (M.) binneyanus *(Pilsbry) FMNH 176008, Rich Mt., Polk Co., Arkansas:* **a,** *terminal genitalia,* **b,** *apical genitalia exclusive of ovotestis;* **c,** *interior of mid-penis region;* **d,** *interior of basal portion of penis;* **e,** *interior of penis apex. Scale lines equal 5 mm. for* **b-e** *and 10 mm. for* **a.**

a few outline sketches indicating rib numbers (see Pilsbry, 1940: 912, fig. 522). The jaw of *Triodopsis albolabris alleni* (figs. 8-10) is illustrated here to show the typical shape (fig. 8), to demonstrate the wear surfaces on the denticulated lower margin (fig. 9), and to indicate that the jaw structure is fibrous in nature (fig. 10). Examples of the other species studied showed no significant differences. Indeed, the jaw microstructure is very similar to that of the helminthoglyptid *Humboldtiana fullingtoni* Cheatum, 1972 from Texas (see

Solem, 1971: figs. 3-5). Both series of photographs clearly show the horizontal incremental pattern of jaw growth and demonstrate the interlocking, basically vertical orientation of the microfibers.

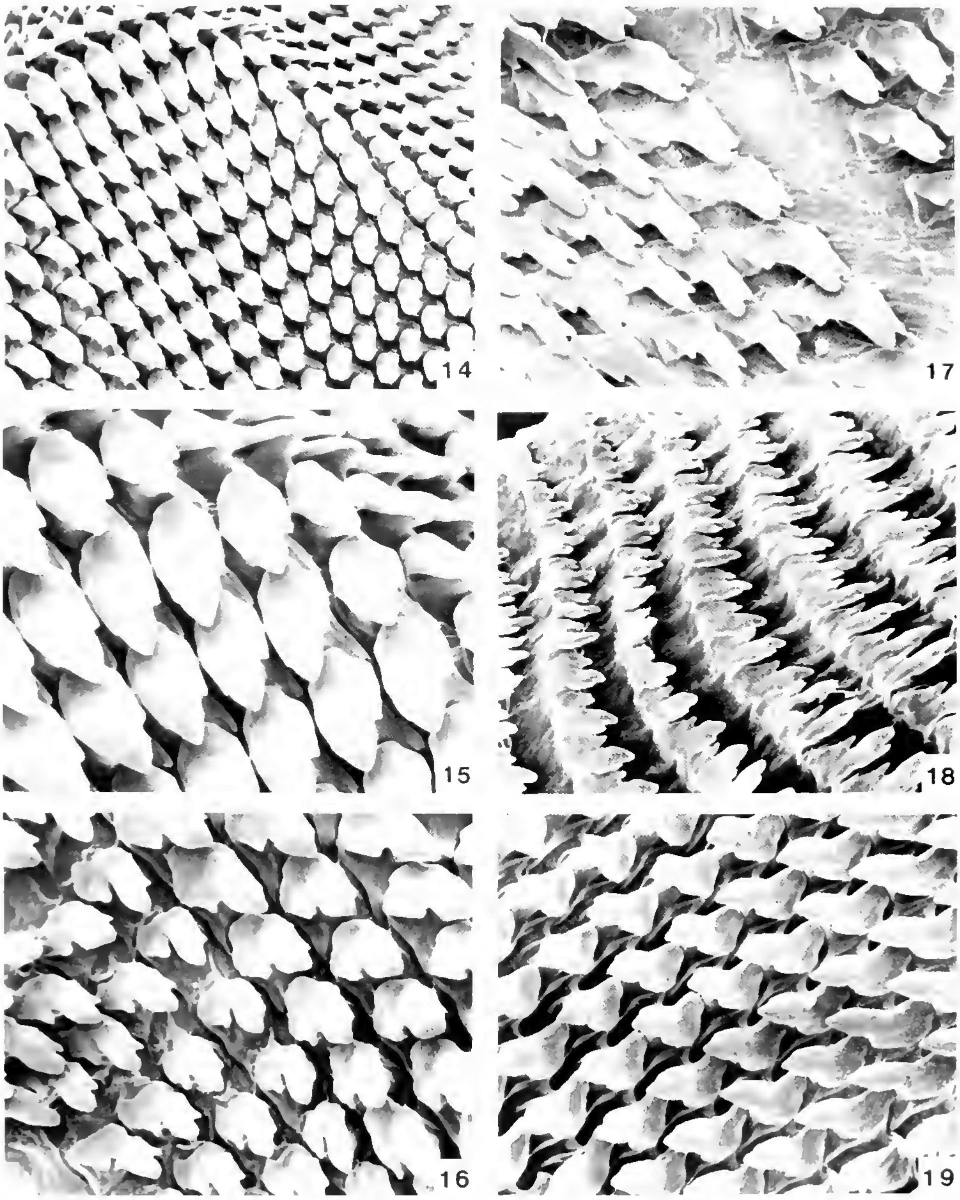
Radular data on polygyrids is equally



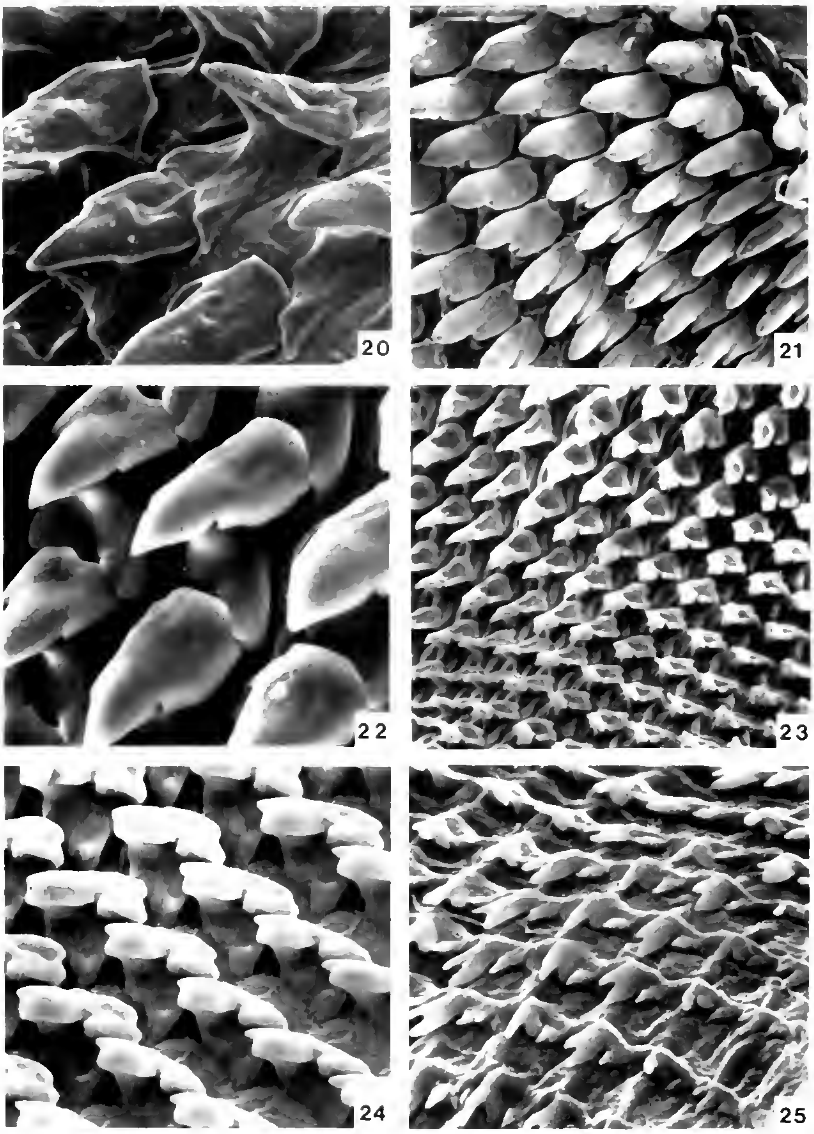
FIGS. 8-13. *Jaw and radular teeth.* Figs. **8-10.** *Jaw of* Triodopsis (Neohelix) albolabris alleni (Wetherby) *FMNH 176127.* Fig. **8.** *Entire jaw, lower margin at top of figure.* 92×. Fig. **9.** *Detail of two ridges on lower margin and inter-ridge area.* 375×. Fig. **10.** *Fibrous area between two ridges shown in Fig. 9, greatly enlarged.* 5,725×. Figs. **11-12.** *Radular teeth of* T. (N.) a. alleni *(Wetherby) FMNH 176127.* Fig. **11.** *Transition zone between lateral (upper) and marginal (lower) teeth near posterior end of radula.* 370×. Fig. **12.** *Central (tricuspid) and early lateral teeth.* 625×. Fig. **13.** *Central and early lateral teeth of* Triodopsis (T.) platysayoides *(Brooks) Leslie Hubricht 11860.* 350×.

meager. Pilsbry (1940: 703) summarized reported variation in *Mesodon*, where several species apparently lack ectocones. I suspect that this is partly individual variation and partly results from the deficiencies of optical viewing. *Mesodon clausus*, for example, is supposed to lack ectocones on all but the outermost marginals, yet traces can be seen (figs. 26-27) on the first laterals and there are prominent ectocones on the outer teeth (figs. 28-29). *M. clausus* does differ in having the cusps on the outer marginals serrated (fig. 29), but even this may be subject to individual variation.

The prominence of the side cusps on the rachidian (central) tooth vary from the large and conspicuous ones found in *M. clenchi* (up-

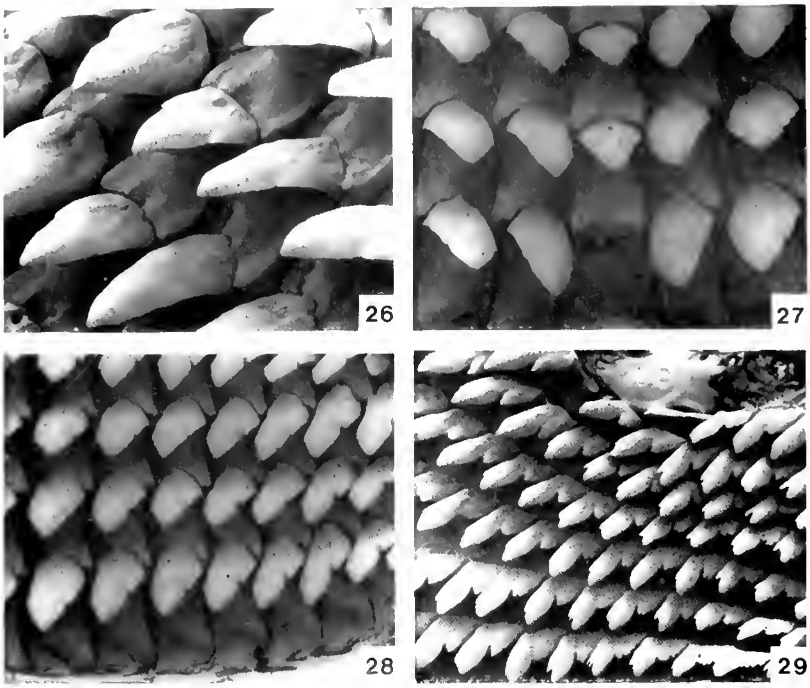


FIGS 14-19. *Radular teeth*. Figs. **14-17.** Triodopsis (T.) platysayoides *(Brooks) Leslie Hubricht 11860*. Fig. **14.** *Part row of teeth not including outer marginals 140×*. Fig. **15.** *Transition zone between laterals and marginals 345×*. Fig. **16.** *Outer marginals 355×*. Fig. **17.** *Outermost marginals. 355×*. Figs. **18-19.** Mesodon (M.) binneyanus *(Pilsbry) FMNH 176008*. Fig. **18.** *Outermost marginals 332×*. Fig. **19.** *Transition between laterals and marginals. 342×*.



FIGS 20-25. *Radular teeth* Figs. **20-21.** Mesodon (M.) binneyanus *(Pilsbry) FMNH 176008* Fig. **20.** *Central and 1st lateral teeth 670×* Fig. **21.** *Transitional between lateral (upper left) and marginal (lower right) teeth. 395×.* Figs. **22-25.** Mesodon (M.) clenchi *(Rehder) FMNH 176059* Fig **22.** *Central and early lateral teeth. 762×* Fig **23.** *Transition between lateral (left) and marginal (right) teeth. 305×* Fig **24.** *Transitional change in basal plate structure between laterals (left) and marginals (right) 535×.* Fig. **25.** *Outermost marginal teeth. 600×.*

per left of fig. 22) and *Triodopsis albolabris alleni* (fig. 12), to a total absence in *T. platysayoides* (fig. 13). *M. clausus* (fig. 26) and *M. binneyanus* (fig. 20) are intermediate in cusp prominence. Ectoconal size on the early lateral teeth correlates with the side cusp prominence on the central tooth. If the central tooth has prominent side cusps, the laterals have a prominent ectocone, and small cusps occur on both at the opposite extreme (see figs. 12, 13, 20, 22, 26). These same illustrations show that the pattern of interrow tooth support for the central and early lateral teeth is nearly identical. The anterior flare on a lateral tooth under stress fit neatly into a groove on the outer side of the basal plate on the next anterior lateral tooth (see figs. 12, 13, 20, 22, 26, 27). The central tooth has a raised buttress on each



FIGS. 26-29. *Radular teeth of* Mesodon clausus *(Say) FMNH 176220.* Fig. **26.** *Central and first lateral teeth. 595×* Fig. **27.** *Central and early lateral teeth seen from a low posterior viewing angle. 425×.* Fig. **28.** *Transition between lateral and marginal teeth. 335×* Fig. **29.** *Mid-marginal and outer marginal teeth. 365×.*

side of the basal plate. Because of the angle at which these photographs were taken, the impression is given that the anterior flare of the lateral tooth is not or only slightly curved upwards. In fig. 23, the angle of view is such that the upward curve (see left side of photograph) of the anterior flare is more evident.

The change from lateral to marginal teeth involves a number of alterations. Fig. 11 shows clearly the higher angle of the cusps in the laterals (upper), with the change to a much lower angle in the marginals (lower) occurring in just a few teeth. Seen in more vertical view (figs. 14, 15, 19, 21, 23, 28), the coherent pattern of cusp change that involves narrowing and elongating the mesocone, an increase in ectoconal prominence, change in shape for the anterior flare, often (figs. 15, 28) a centerwards shift in angle for the mesocone, and appearance of a small endocone, is clearly demonstrated. The change in the basal plate, which involves shortening, first reduction and then loss of the support ridge, then gradual elimination of the anterior flare, is shown in figs. 24 and 28 particularly well because of the viewing angle (fig. 24) and partly torn radula (fig. 28).

The marginal teeth, particularly the outermost (figs. 17, 18, 23, 25, 29) ones, can become multicuspid, normally show endoconal development, and may become quite shortened and probably are almost without function in feeding. They are held parallel to the basal membrane, which is quite in contrast to the high elevation of lateral teeth (figs. 11, 20).

In terms of basic structure and pattern of functioning, the radulae examined here show no major differences between species, much less between genera. The different angles of view do permit interpreting functional aspects. Several species have been illustrated to emphasize their essential similarity.

DISCUSSION

Particularly within *Triodopsis*, the variation in verges, papillae of the upper penis chamber, penis sheath length and muscle attachment, present characters potentially of high value in assessing relationships. Radular cusp variation is greater within *Mesodon* and *Triodopsis* than between the two genera. Shell differences between the sympatric taxa involve growth patterns and columellar-umbilical region structures.

Triodopsis platysayoides is a rare and potentially endangered species, but *Mesodon clenchi* was found to be more widely distributed than had been suspected and it seems in no danger of extinction at the present time. The other species discussed here have wide distributions and may be considered common at the present time.

Because the barrier-free *Mesodon* and *Triodopsis* of Missouri, Arkansas and Oklahoma are widely distributed, frequently sympatric, usually highly variable in size and color, they present excellent potential for studies of ecological differences under sympatry and for variational analysis.

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TREMATODE PARASITISM IN THE SPHAERIIDAE CLAMS, AND THE EFFECTS IN THREE OTTAWA RIVER SPECIES

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ABSTRACT

There is a seasonal occurrence of rediae of the trematode, Crepidostomum cooperi *Hopkins, in the digestive gland of* Musculium securis *(Prime) in Britannia Bay of the Ottawa River near Ottawa, Canada. Growth and longevity of infected clams do not appear to be affected but reproduction is usually inhibited. Similar effects seem to occur in parasitized specimens of* Musculium transversum *(Say) and* Sphaerium striatinum *(Lamarck). A review of the incidence of trematode parasitism in Sphaeriidae is given.*

INTRODUCTION

While the incidence of trematode parasitism in Sphaeriidae is well documented (see Table 3), there is very little known on the effects of this parasitism. The purpose of this study is to examine the effects of trematode parasites on growth, longevity, and reproduction in *Musculium securis*, *Musculium transversum*, and *Sphaerium striatinum* that were collected seasonally from Britannia Bay in the Ottawa

River near Ottawa. A review is given to bring together all studies that relate to trematode parasitism in Sphaeriidae.

MATERIALS AND METHODS

A standard Ekman grab (15 cm × 15 cm, with screen on top) was used to take quantitative samples of the population of *M. securis*. Grab samples were taken from the 3 to 4 m depths until at least 30 specimens were collected. Collections were taken for three years from May, 1970 to May, 1973 in usually two-week intervals in the summer and one-month intervals in the winter. A total of 1,764 specimens of *M. securis* were examined for trematode parasites. In addition, 123 specimens of *M. transversum* and 158 specimens of *S. striatinum* were collected from the 1 to 3 m depths in the same manner from May to November, 1971 and 1972, respectively, and examined for parasites. The lengths (mm, anterior to posterior), heights (mm, top of umbone to ventral edge), number of concentric annuli (for *S. striatinum* only), and the numbers of brood sacs and larvae per sac were determined on all specimens (the number of annuli were not determined for *M. securis* or *M. transversum* because they have only a one-year life span).

THE STUDY AREA

Fifteen species of sphaeriids are present in Britannia Bay; *M. transversum* and *S. striatinum* are common species in the 1 to 3 m depths and *M. securis* is dominant in the 3 to 4 m depths (Mackie, 1971; Mackie and Qadri, 1973). Other common benthic species include the oligochaetes, *Uncinais uncinata* and *Peloscolex* sp., the amphipods, *Hyalella azteca* and *Gammarus fasciatus*, the mayfly, *Hexagenia* sp. (especially in the 3 to 4 m depths), the damselfly, *Enallagma signatum*, the chironomids, *Pseudochironomus*, and *Dicrotendipes*, and the gastropods, *Lymnaea catascopium*, *Amnicola limosa*, and *Valvata tricarinata*. The mean summer temperature (18 C) is reached in mid-June. Other physical and chemical characteristics of the water are given in Mackie (1973). Several species of fish are present in Britannia Bay, the most common being catfish, *Ictalurus punctatus*, walleye, *Stizostedion vitreum*, and pike, *Esox lucius*.

EFFECTS OF PARASITISM

The trematodes in *M. securis* and *M. transversum* were identified as *Crepidostomum cooperi* Hopkins, 1931. A specific identification of the trematodes in *S. striatinum* was not made but they also belonged to the genus, *Crepidostomum*. Redial stages were found developing only in the digestive glands. No other life history stages were found. The rediae contained ophthalmoxiphidiocercariae which escape into the water and encyst in mayfly nymphs (Gibson, *pers. comm.).* Hopkins (1934) cites *Hexagenia* sp. as the second intermediate host of *C. cooperi;* this genus is very common in Britannia Bay, especially in the 3 to 4 m depths. Adults of *C. cooperi* are common in many species of fish, including catfish and walleye (Gibson, *pers. comm.*) which are also abundant in Britannia Bay.

There was a seasonal occurrence of the redial stage in *M. securis* (Table 1) and only adults longer than 3.50 mm were infected. An insufficient number of *M. transversum* and *S. striatinum* were infected to permit a determination of seasonal occurrence of parasitism but only adults longer than 5.00 mm contained rediae. In *M. securis*, parasitism occurred with maximum frequency in late July and early August. The percentages given in Table 1 are based on infected adults that were alive at the time of sampling. Empty shells of *M. securis* commonly appeared in samples collected in July

TABLE 1. *Percentage of parents of* Musculium securis *that were parasitized in the summer months of 1970, 1971, 1972. Only clams collected in July, August, and September were parasitized with rediae*

1970			1971				1972			
July 13	July 29	Aug. 18	July 15	July 29	Aug. 3	Sept 2	July 5	July 17	Aug 20	Sept. 2
22.8	27.8	5.0	2.0	13.3	25.0	4.0	4.0	20.0	21.8	2.0

TABLE 2. *Mean lengths (mm) of three species of parasitized and nonparasitized fingernail clams in their last month of life or with one annulus. The numbers of specimens examined are in parentheses.*

Species	*Nonparasitized clams*	*Parasitized clams*
Musculium securis	4.09 (38)	4.39 (12)
Musculium transversum	7.81 (24)	7.63 (8)
Sphaerium striatinum	10.10 (32)	9.77 (5)

and August but it is not known whether natural causes or parasitism brought about the death of these clams. Only 16% of *M. transversum* and 12% of *S. striatinum* were infected. The only parasitized clams of *M. transversum* were found in collections taken in July and August and of *S. striatinum* in September and October.

Adult specimens of *M. securis* as long as 5.50 mm, of *M. transversum* as long as 8.13 mm, and of *S. striatinum* as long as 9.05 mm were parasitized, suggesting that parasitism did not affect the growth of clams. Moreover, the mean lengths of parasitized and nonparasitized clams did not appear to differ substantially (Table 2), although it is possible that infected clams had been parasitized only recently. However, if development of the intramolluscan phase requires only 40 to 50 days, as for many gorgoderids which also parasitize sphaeriids (Olsen, 1967), then *M. securis* and *M. transversum* would have to be parasitized very early in life, perhaps even during larval life, since they require 35 to 60 days to grow from birth to adulthood (Mackie *et al*, 1975; Gale, 1969).

Both *M. securis* and *M. transversum* have a one-year life span and the adults die in the fall after producing their young (Mackie *et al*, 1975; Gale, 1969). The presence of parasitized adults of both species during August indicates that the longevities were not strongly affected by trematode parasites.

Sphaerium striatinum lives for 18 to 24 months (Avolizi, 1971) and it was more difficult to study the effects of parasitism on growth and longevity because of overlapping generations in Britannia Bay. However, using annuli in the shell as an indication of age, adults that were more than one year old were parasitized but were of similar size as the noninfected clams (Table 2). If these clams were parasitized only recently then parasitism occurred so late that the growth of the clams would have been almost complete and any effects of parasitism on growth and longevity would not have shown.

Parasitism by *C. cooperi* appears to have its greatest effect on the reproductive capacities of sphaeriids. Of the parasitized adults of *M. securis*, approximately 96% were devoid of brood sacs; the remaining 4% contained brood sacs but larvae were either absent or poorly developed. Uninfected adults of the same age and length class contained 3 to 6 brood sacs with 2 to 8 larvae per sac. Also, the gonads could not be found in two parasitized clams. All other parasitized specimens appeared to have their gonads intact. It was not determined if gametogenesis in the intact gonads was inhibited as in other mollusks (Cheng and Snyder, 1972).

Of the parasitized adults of *M. transversum* and *S. striatinum* none contained brood sacs even though nonparasitized adults of the same size classes were gravid with 2 to 14 larvae in 3 to 6 brood sacs. Gale (1973) also reported the absence of embryos in parasitized clams of *M. transversum*. Cheng and James (1960) attributed the death of adults of *S. striatinum* to the destruction of the clam's hepatopancreas after repeated infections with *Crepidostomum cornutum*. Other sphaeriids appear to be similarly affected. Meier-Brook (1970) found larval trematodes in *Pisidium nitidum*, *Pisidium subtruncatum*, *Pisidium milium*, and *Pisidium conventus* and concluded that *Crepidostomum* sp. affects the reproductive ability (and longevity) of *P. nitidum*. Heard (1965) reported a lack of embryos in parasitized specimens of *Pisidium casertanum* and *Pisidium compressum*. The effects of larval trematodes on other bivalve and gastropod hosts has been reviewed by Cheng and Snyder (1972).

REVIEW OF TREMATODE PARASITISM IN SPHAERIIDAE

Sphaeriids are common intermediate hosts for several species of digenetic trematodes. Only two families, the Allocreadiidae and Gorgoderidae, contain species that require sphaeriids for development of the sporocyst, rediae, and/or cercariae.

In the family, Allocreadiidae, miracidia penetrate the gill filaments and the mantle where they transform into sporocysts (although this developmental stage has never been found (Olsen, 1967)) and then into rediae. The rediae contain either daughter rediae or cercariae, or both, with large rediae usually infesting the hepatopancreas (Olsen, 1967). The cercariae, having eyespots, a stylet, and thick-walled excretory vesicle are known as ophthalmoxiphidiocercariae (Schell, 1970). At least 13 species of allocreadiids use sphaeriids as the first intermediate host. Table 3 lists the species of Sphaeriidae in which parasites have been found and gives the second intermediate hosts and final hosts for each parasite.

The miracidia of the family Gorgoderidae are active swimmers and enter fingernail clams in the incurrent water flowing through the branchial siphon. Upon penetrating and entering the

TABLE 3. *Incidence of trematode parasitism in Sphaeriidae and other hosts of the parasites.*

Sphaeriid species	*Trematode species*	*Second intermediate host*	*Final host*	*Reference*
Sphaerium corneum	*Allocreadium isoporum*	Mayflies	Fish	Dollfus (1949)
S. corneum	*Crepidostomum transmarinum*	Mayflies, Amphipods	Salmon *(Salmo)*	Dollfus (1949)
S. corneum	*Bunodera luciopercae*	Cladocera, Ostracoda, Copepoda	Fish	Wisniewski (1958)
S. corneum	*Phyllodistomum simile*	Odonata, Trichoptera	Brown trout *(Salmo trutta)*	Thomas (1958)
Sphaerium occidentale	*Allocreadium neotenicum*	None	Beetles *(Dytiscus, Acilius)*	Crawford (1940a), Peters (1955, 1957), Schell (1970)
S. occidentale	*Gorgoderina attenuata*	Tadpoles	Amphibians *(Rana, Triturus)*	Rankin (1939)
Sphaerium rivicola	*A. isoporum*	Mayflies	Fish	Dollfus (1949)
S. rivicola	*B. luciopercae*	Cladocera, Ostracoda, Copepoda	Fish	Wisniewski (1958)
Sphaerium striatinum	*Crepidostomum cornutum*	Mayflies	Crayfish	Ameel (1937), Cheng & James (1960)
S. striatinum	*Crepidostomum isostomum*	Mayflies	Perch *(Perca)*	Hopkins (1934)
Musculium lacustre[1]	*Phyllodistomum staffordi*	Damselflies, Trichoptera	Brown Bullhead *(Ictalurus nebulosus)*	Schell (1967)
Musculium partumeium	*Gorgodera amplicava*	Snails	Amphibians *(Rana, Bufo, Ambystoma)*	Goodchild (1948), Krull (1935)
M. partumeium	*Phyllodistomum caudatum*	Unknown	Black Bullhead *(Ictalurus melas)*	Beilfuss (1954)
Musculium securis	*Crepidostomum cooperi*	Mayflies?	Catfish *(Ictalurus)*?	This study (intermediate and final hosts not confirmed)
Musculium transversum	*C. cornutum*	Mayflies	Crayfish	Henderson (1938), Hopkins (1934) Abernathy (1937)
M. transversum	*C. cooperi*	Mayflies	Fish	Hopkins (1934), Olsen (1967), This study
M. transversum	*Megalogonia ictaluri*	Mayflies	Bullheads *(Ictalurus, Micropterus, Noturus)*	Hopkins (1934)
M. transversum	*Phyllodistomum lohrenzi*	Trichoptera	Green Sunfish *(Lepomis cyanellus)*	Beilfuss (1954)
Pisidium amnicum	*Crepidostomum farionis*	Mayflies, Amphipods	Salmon *(Salmo)*	Brown (1927)
Pisidium casertanum	*Allocreadium alloneotenicum*	Snails	Trichoptera *(Limnephilus)*	Wooton (1957)
P. casertanum[2]	*C. cooperi*	Mayflies	Trout *(Salvelinus fontinalis)*	Choquette (1954)
P. casertanum[2]	*Phyllodistomum solidum*	Dragonflies	Salamanders *(Desmognathus, Eurycea).*	Goodchild (1943, 1946), Groves (1945)
P. casertanum[3]	*Bunoderina eucaliae*	Unknown	Fish *(Eucalia inconstans, Umbra limi)*	Hoffman (1955)
Pisidium compressum	*C. cooperi*	Mayflies	Trout *(S. fontinalis)*	Choquette (1954)
Pisidium idahoense	*Bunoderella metteri*	Trichoptera, Chironomidae	Tailed Frog *(Ascaphus truei)*	Anderson, Schell & Pratt (1965)
Pisidium lilljeborgi	*C. cooperi*	Mayflies	Trout *(S. fontinalis)*	Choquette (1954)
Pisidium nitidum	*C. cooperi*	Mayflies	Trout *(S. fontinalis)*	Choquette (1954)
Pisidium subtruncatum	*C. cooperi*	Mayflies	Trout *(S. fontinalis)*	Choquette (1954)
Pisidium spp	*Phyllodistomum americanum*	Damselflies, Trichoptera	Amphibians *(Bufo boreas, Ambystoma tigrinum)*	Crawford (1954)
Pisidium sp	*Allocreadium lobatum*	Amphipods	Fish *(Semotilus atromaculata, Catostomus commersoni)*	Degiusti (1962)

[1] Cited by Schell (1967) as *M. ryckholti*

[2] Cited by Goodchild (1943), Groves (1945), and Choquette (1954) as *P. abditum*

[3] Cited by Hoffman (1955) as *P. noveboracense*

gills, the miracidia transform to mother sporocysts. Development of daughter sporocysts requires 40 to 50 days. The daughter sporocysts become ventrally located between the inner and outer lamellae of the inner gills of the clams and contain fully developed cystocercous cercariae. The cercariae have a tail with a chamber at one end and encloses the larval fluke. The cercariae are released into the suprabranchial chamber of the clam and are then expelled with the excurrent water through the anal siphon (Olsen, 1967). At least 7 species of gorgoderids require sphaeriids as the first intermediate host (Table 3).

From a study of Table 3, it is worthwhile noting that, with the exception of only a few species, especially *C. cooperi*, only one parasitic species has been found in a single species of sphaeriid. This may indicate that either there is some degree of host specificity or that an insufficient number of sphaeriid populations have been examined to show that there is in fact more than one parasitic species of trematodes per species of fingernail clam.

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THE GENUS *EPIROBIA* IN CHIAPAS, MEXICO

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The genus *Epirobia* consists of small slender urocoptoid land snails that are found characteristically on limestone in wetter areas of eastern Mexico and northern Guatemala. The description of two new forms is presented so that they may be included in a report on the land mollusks of Chiapas by Allyn G. Smith. I wish to express my appreciation to him for allowing me to examine pertinent material in the collections of the California Academy of Sciences (CAS). Other material cited in this paper is deposited in the Florida State Museum, University of Florida (UF) and the Delaware Museum of Natural History.

Epirobia swiftiana alternans *new subspecies*

Fig. 1, c and d. Fig. 2, a.

Shell. — Elongate fusiform-turreted, thin, translucent. Spire complete; upper $^{3}/_{4}$ of spire gradually tapering to the third or fourth from last whorl; shell 0.19-0.21 times as wide as long; narrowly umbilicated. Color light brown with alternating patches of white ribs. Whorls 19.5-20.5 (20.2 in holotype). Suture moderately impressed, not crenulate. Embryonic whorls 2.9-

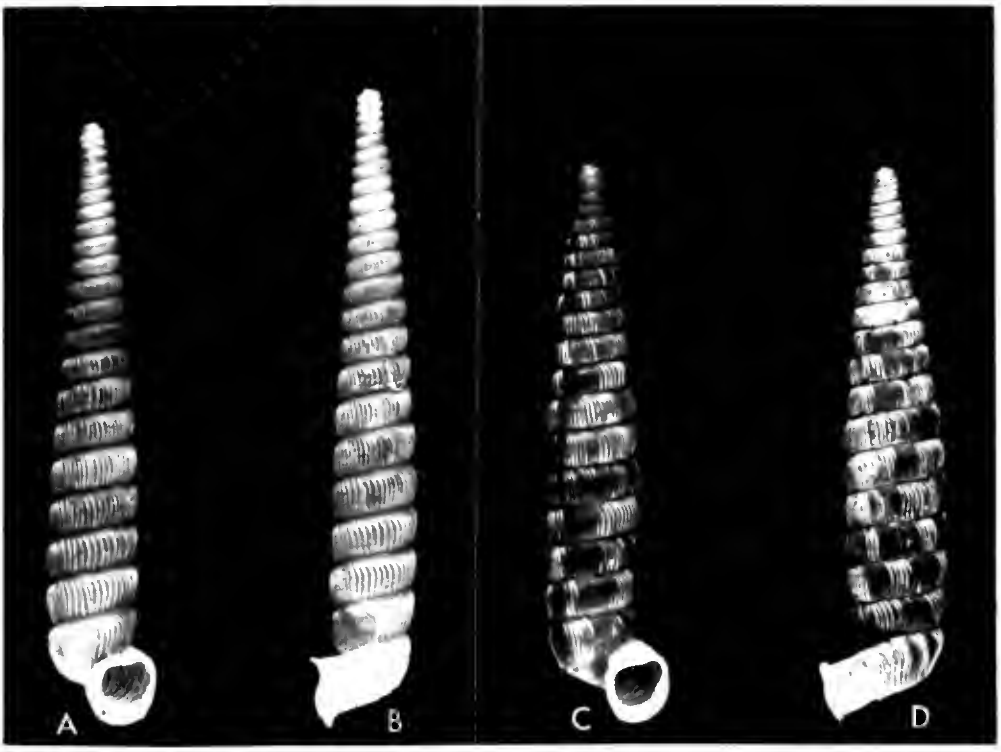

FIG. 1. Epirobia lurida *new species.* **a,** *holotype 16.3 mm.,* **b,** *paratype.* Epirobia swiftiana alternans *new subspecies.* **c,** *holotype* **d,** *paratype.*

3.4 (3.1 in holotype), relatively weakly arched, smooth and nearly equal in size. Following whorls nearly uniformly rounded at periphery, more so near sutures. Neck of last whorl rounded, below, without any indication of a basal keel. Whorls sculptured with clusters of narrow, graceful, sigmoid white ribs. Clusters separated from each other by nearly equally wide smooth zones. About 3-10 ribs per cluster and about 5-6 clusters per whorl on lower whorls. Ribs about half as wide as their intervals. Rib intervals and smooth zones light brown. Aperture free from preceding whorl, projecting forward and offset laterally. Aperture broadly ovate, slightly higher than wide, slightly oblique; about 0.60-0.69 times the width of the last whorl. Peristome white, moderately reflected, narrowest along posterior corner; widest along columellar margin. Axis hollow and about 1/4 diameter of whorls. Axis weakly concave within each whorl; sculptured with weak, slightly oblique vertical ribs bearing small spines and nodes that are irregularly sized and spaced.

Measurements in mm of mature specimens are as follows (measurements of the holotype are in parentheses): length, 13.0-14.2 (13.8; width, 2.6-2.8 (2.6); aperture height, 1.7-1.85 (1.8); aperture width, 1.6-1.8 (1.7). (14 specimens measured).

Type locality — Chiapas, 4.5 miles north of Jitotol, 5400 feet altitude HOLOTYPE: UF 22451; collected 6 July, 1965 by Fred G. Thompson. PARATYPES: UF 22452 (12); and Delaware Mus. Nat. Hist. 102474 (1) same data as the holotype. The type series was found in a thick cluster of moss growing on the side of a limestone ledge along a ravine. The area consisted of semi-wet mountain broadleaf forest which had been partially cut over.

Remarks — This subspecies differs from *E. S. swiftiana* (Crosse) by being shorter, having fewer whorls, more embryonic whorls and having a rounded base on the last whorl. *E. s. swiftiana* is about 18 mm long, has 21 whorls, including 1.5 embryonic whorls, and the last whorl is obsoletely subangulate below. The nominate subspecies is known only from the type specimen, which comes from an unspecified locality (Crosse, 1863; 388-389. 1867: 200-201, pl.s. fig. 5. Fischer and Crosse, 1878: 407). It probably occurs in Chiapas, as does *E. s. alternans.*

Epirobia lurida *new species*

Fig. 1, a and b. Fig. 2, b.

Shell — Elongate-turreted, very slender, 0.15-0.17 times as wide as long. Spire complete, uniformly increasing in diameter through the fourth from last whorl. Moderately thin, only slightly transparent when alive. Umbilicus narrowly perforate, visible from oblique view. Color light yellowish-gray, lusterless, dull, interior of aperture white. Whorls 22.5-25.0 (23.2 in holotype). Suture deeply impressed. Embryonic whorls 3.0-3.2 (3.1 in holotype), smooth, strongly arched peripherally with a deeply impressed suture; nearly equal in size. Following whorls gradually increasing in diameter through about the eighteenth whorl; sculptured with regularly spaced ribs. Ribs on lower whorls are about twice as high as wide, slope obliquely forward and are about one fourth as wide as their intervals. There are 35-49 ribs on penultimate whorls (38 in holotype). Ribs strongly arched in a reverse sigmoid curve. Periphery of postembryonic whorls strongly rounded on upper spire. Lower whorls flat sided and almost scalariform. The flattened periphery is slightly oblique to the axis of the shell. Base of last whorl rounded, without indication of a basal keel. Aperture free from preceding whorl, offset laterally and extended forward by about $^{1}/_{2}$ diameter of shell. Aperture broadly auriculate in shape; about 0.73-0.80 times width of shell; posterior corner narrowly rounded. Peristome moderately reflected; narrowest around posterior corner; widest along baso-columellar margin. Outer lip sigmoid in lateral profile, corresponding in outline to curvature of ribs on previous whorl. Plane of aperture slightly oblique to axis of shell. Axis hollow, about $^{1}/_{8}$ diameter of whorls, nearly straight, slightly twisted in lower whorls. Axis uniformly wide or slightly concave within each whorl; sculptured with small granular spines which tend to form oblique series.

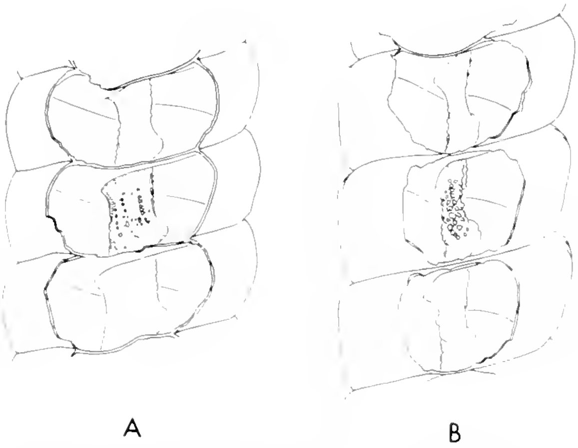

FIG. 2. *Camera lucida drawings of the columellar structure in the penultimate whorls of* **a**, Epirobia swiftiana alternans *new subspecies and,* **b**, Epirobia lurida *new species.*

Measurements in mm of mature specimens are as follows (measurements of the holotype are in parentheses); length, 15.5-18.3 (16.3); width, 2.4-2.7 (2.6); aperture height, 1.8-2.1 (2.0); aperture width, 1.8-2.1 (1.95).

Pallial organs — The pallial cavity is about 4 whorls long. The kidney is about $^{3}/_{4}$ whorl long, narrow, reniform sigmurethrous. The secondary ureter is about equal in diameter to the intestine and is tightly bound to the latter. The heart is about ¼ the length of the kidney. The aorta lies along the ventral margin of the lung and is weakly branched throughout most of its length. It divides into 5-6 small arterioles just behind the mantle collar.

Trophic structures — Jaw solid, arcurate. Salivary glands plumiform, appressed against the side of the esophagus; short, about half the length of the pharynx. Salivary ducts about half the length of the glands. Radular sac short, coiled in a loop against posterior end of pharynx. Radular formula 17-1-17 with the teeth lying in broadly accurate transverse rows about 390 μ wide (Fig. 3, b-c). The central tooth is hexagonal in shape and has a large mesocone and a small ectocone on each side. The central is about 19 μ high and 14 μ wide. The transition from the laterals to the marginals occurs at the fifth through seventh rows. The laterals each bear a large blunt mesocone and a small ectocone. The mesocone of the seventh tooth and subsequent marginals is pointed where both the mesocone and the ectocone are bicuspid.

Muscular system — Columellar retractor long,

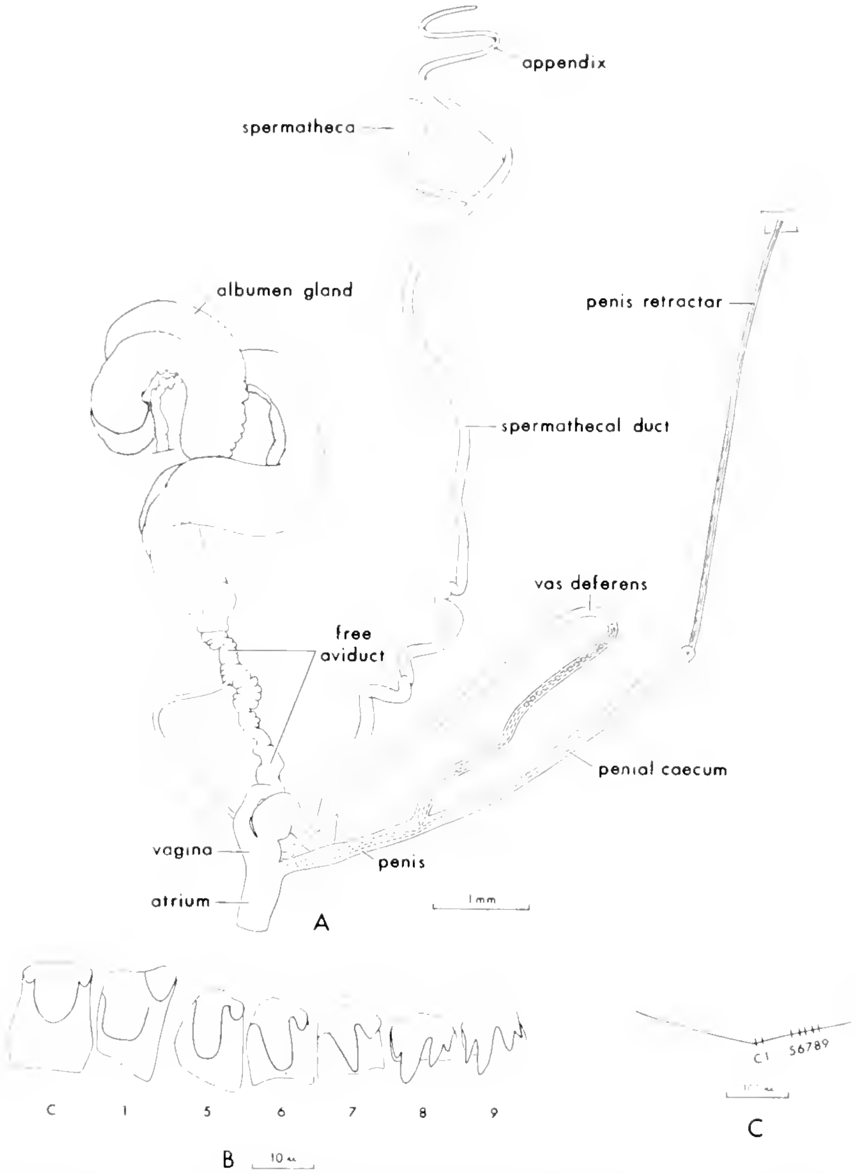

FIG. 3. Epirobia lurida *new species.* **a,** *reproductive system exclusive of the gonad.* **b,** *radula.* **c,** *diagrammatic view of a transverse row of the radula showing the respective positions of the teeth illustrated in* **b.**

extending seven whorls into spire; dividing at the third whorl to give rise to the pedal retractor basally, the pharyngeal retractor dorsally and the right and left ocular retractors laterally. The ocular retractors respectively give rise distally to the right and left labial retractors. The pharyngeal retractor divides into four narrow bands at base of pharynx. Two insert laterally and two insert basally.

Reproductive System (Fig. 3, a). – The genital atrium is medium in length, moderately stocky and opens behind and below the right ocular tentacle. The right ocular retractor muscle passes through the penioviducal angle. The penis is long and slender, being about twice the length of atrium and has four longitudinal fleshy folds internally, one of which is larger than the others along the upper third of the penis. There is not verge. The apex of the penis bears a long slender compressed caecum which is about twice the length of the penis. The penis retractor muscle is long and slender. It originates on the inner wall of the lung about ½ whorl above the penis and inserts on the distal end of caecum. The vas deferens is relatively stocky above the penis and is weakly enlarged as an epiphallis for a distance about equal to the length of the penis. It enters the wall of the free oviduct below the prostate and oviduct. The spermathecal duct enters the free oviduct to form a short vagina immediately above the atrium. The base of the duct is enlarged into a thick-walled muscular bulb. The duct is branched distally. The spermatheca lies appressed against the outer base of the albumen gland. The spermathecal appendix lies along the columellar side of the oviduct and albumen gland. The free oviduct is about 1.5 times the length of the penis, is strongly convoluted and becomes moderately wide a little above the insertion of the spermathecal duct. The albumen gland lies about four whorls above the genital atrium and is strongly creased on its outer surface by the intestine. A talon and a carrefour are absent.

Type locality — Chiapas, 15.8 miles northwest of Ocozocoautla on road to Mal Paso, 2700 feet altitude. HOLOTYPE; UF 22449; collected 20 July, 1965 by Fred G. Thompson. PARATYPES UF 22450 (116); Delaware Mus. Nat. Hist. 102475 (5); same data as the holotypes; UF 22448 (4), CAS 55555 (30); topotypes, collected 6 October, 1974 by Dennis E. Breedlove. The type locality is an area covered by a heavy quasi-rainforest on low, rolling limestone hills. Live snails were found only on damp moss-covered limestone boulders.

Remarks — *E. lurida* is distinguished from other species of the genus by its flat sided whorls, its high sigmoid riblets and its slender straightsided axis with granular spines arranged in irregular oblique rows. It is similar to *E. poloygyra* (Pfeiffer) from Veracruz in general aspects of size, shape and whorl count, but the latter species has evenly rounded whorls, the riblets are fine threadlike striae and the axis is convex within each whorl with the rough granular sculpture confined primarily to the center of the convexity. *E. polygyrella* (von Martens) from Alta Verapaz has shorter, more strongly rounded whorls, the aperture is nearly rotund, the axis has slender retracted riblets that lack granular sculpture and the shell is smaller.

DISCUSSION

There are seven species and two subspecies of *Epirobia* known. Three are recorded from Veracruz, four from Chiapas, one from Alta Verapaz, and one was described without any locality. For a review of the genus see Pilsbry, 1903: 59-66.

Three other snails that were described as species of *Epirobia* from northeastern Mexico are now placed elsewhere. *E. coahuilensis* Bartsch, 1906, has been referred to *Coelostemma (Apertaxis)* by Thompson (1971: 301) and *E. (Propilsbrya) nelsoni* Bartsch, 1906 was elevated to generic rank as *Propilsbrya nelsoni* by Pilsbry (1953: 136). The status of *E. (Gyrocion) mirabilis* Pilsbry, 1903a is problematic. It is known only from a single immature shell, and its generic status is questionable. Certainly *Gyrocion* is very different from *Epirobia s.s.*

Epirobia (s.s.) contains two species groups. One group, consisting of *E. berendti* (Pfeiffer), *E. b. albida* (Fischer and Crosse) and *E. gassiesi* (Pfeiffer), includes species that have relatively short obese shells. The second group, consisting of *E. s. swiftiana* (Crosse), *E. s. alternans* n. ssp., *E. apiostoma* (Pfeiffer), *E. polygyra* (Pfeiffer), *E. polygyrella* (v. Martens) and *E. lurida* n. sp., includes species that are relatively long and slender.

Previously two taxa were recorded from Chiapas, *E. b. albida* and *E. gassiesi*. Neither of these is known from a more exact locality than the state of Chiapas and both belong to a different species group than do the two new forms. *E. s. alternans* and *E. lurida* establish the first exact records of the genus within Chiapas. They come from an area forming more nearly a geographic continuum from Veracruz to Alta Verapaz for the species group to which they belong.

Epirobia is a member of the family Eucalodiidae, subfamily Holospirinae because of its non-decollate shell, solid jaw, trimorphic radular teeth, the presence of an appendix on the spermathecal duct, the absence of a verge within the penis and the absence of a talon and a carrefour. It is unique among the eucalodiid genera for which the anatomy is known by having a long, slender, compressed penial caecum, a large muscular bulbous base on the spermathecal duct, the vas deferens entering the oviduct wall below the prostrate, and the mesocones and ectocones of the central and lateral teeth having large rounded cusps. Unfortunately anatomical information is not available on most other genera within the Holospirinae, and comparisons are not possible at present.

The above anatomical characterization of *Epirobia* is based exclusively on *E. lurida* because of a lack of data on other species. Strebel and Pfeffer (1880) describe and illustrate portions of the reproductive system and the radula recovered from a dried *E. apiostoma* (Pfeiffer). Pilsbry (1903: 60) expresses doubt about the identity of the radula. Strebel and Pfeiffers' description of the reproductive system are very different from that of *E. lurida*, to the extent that doubt about the identity of their material is even more warranted, and comparisons involving *E. apiostoma* cannot be made at this time. It is possible that *Epirobia* is a compound genus based on shell convergences.

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A NEW SPECIES OF *CALLISTOCHITON* IN THE CARIBBEAN

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ABSTRACT

A new species of chiton, Callistochiton portobelensis *Ferreira, sp. nov., is described and figured. Found at Portobelo, Panama (type locality) and off Key West, Florida, it closely resembles* C. elenensis *(Sowerby) from the eastern Pacific.*

In the Caribbean, the genus *Callistochiton* (Carpenter in Dall, 1879) has been thought to be represented by a single species, *Callistochiton shuttleworthianus* Pilsbry, 1893. In February 1975, while on a collecting trip to the Caribbean shores of Panama, I came across several specimens of what subsequent investigation proved to be an undescribed species of *Callistochiton*.

Class Polyplacophora de Blainville, 1816
Subclass Neoloricata Bergenhayn, 1955
Family Callistoplacidae Pilsbry, 1893

Callistochiton portobelensis new species

Figs. 1-6

Diagnosis — Chiton small, less than 1 cm long, greenish cream color. Anterior valve with about 12 subdued radial ribs; posterior valve with none or a few obsolete radial ribs. Mucro

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FIG. 1. Callistochiton portobelensis *Ferreira, new species.* Paratype. *Portobelo, Panama. 6.7 mm in length.*

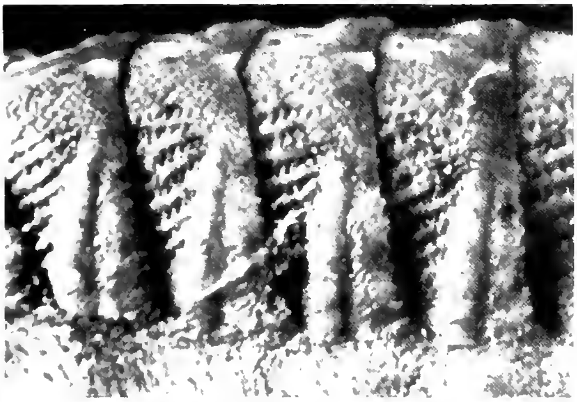

FIG. 2. *Side view of lateral areas of paratype.*

slightly anterior. Lateral areas bicostate, with minute tubercles along the posterior margins. Central areas somewhat diagonally ribbed, and latticed. Jugal area smooth. Girdle scales cylindroid, small, weakly imbricated, outer surface oval and minutely granulose.

Description of the holotype — The specimen, dried but fully extended, measures (including girdle) 6.7 mm in length, 3.6 mm in width, and 1.2 mm in height. Width to length ratio = 0.53. Jugal angle about 96°. Tegmentum of a rather uniform greenish cream color, with occasional small darker green blotches peppering the shell in a random manner; the general surface is microgranular throughout. Anterior valve shows 12 low-profile radial ribs, better defined towards the periphery where they seem more like undulations than ribs on the tegmentum. Posterior valve shows a well defined but not conspicuous mucro, slightly anterior; the post-mucro area is moderately concave, with only the faintest indication of radial ribbing. Intermediate valves have moderately elevated lateral areas bearing 2 broad, slightly granose, low ribs which show no tendency to split; the space between the two radial ribs is well defined but shallow. The posterior of the two ribs in the lateral areas tends to have a few minute, almost obsolete tubercles along its sutural edge. The central areas have longitudinal riblets, about 10 per side, diagonally disposed by diverging forward as a whole at about a 20° angle from the midline; there is no "wedge" figure on valve ii (Ferreira, 1974: 163). The longitudinal riblets are about as wide as the space that separates them, and united by some discrete latticing. The central

FIG. 3. Callistochiton portobelensis *Ferreira, new species. Holotype.* SEM *microphotographs (courtesy of Hans Bertsch) of girdle scales. Approx. 400*X.

FIG. 4. *Girdle scale of holotype. Approx. 500*X.

FIG. 5. *Detail of girdle scale of holotype. Approx. 1500×.*

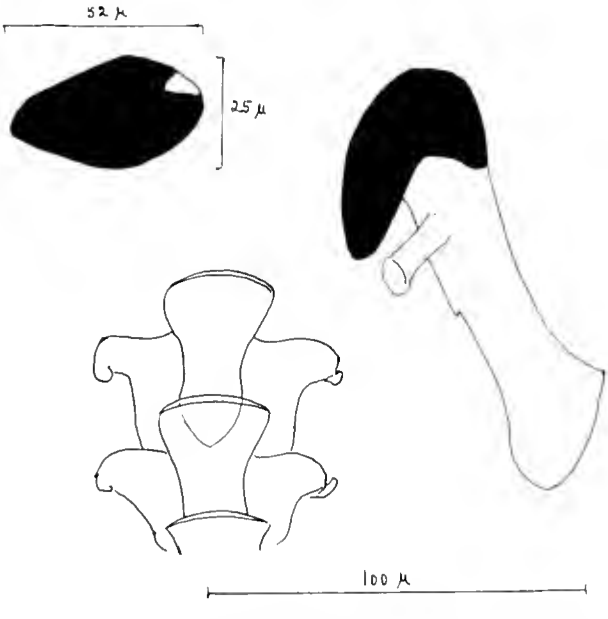

FIG. 6. Callistochiton portobelensis *Ferreira, new species. Holotype. Radula (Camera lucida drawing).*

sculpture becomes obsolete towards the jugal area, which is mostly smooth. The articulamentum is white but, by transparency, shows some occasional small dark blotches. Insertion teeth are straight edged except at the corners where they tend to be a bit thicker and rounded. There is no clear cut festooning or scalloping in any of the teeth. Slit formula 11-1-9. The slits correspond well with the tegmental undulations or ribs. Sutural laminae are sharp, semioval, short, and continue with no visible demarcation or notch with the sinusal lamina. Sinus is relatively shallow. Eaves short and solid. The callus inside valve viii is suffused with dark-brown pigmentation. The girdle has a uniform width of 0.5 mm; it is the same color as the tegmentum but softly banded with green. The scales measure about 80μ in length. They are weakly imbricated, standing close together like cobblestones on a pavement. Somewhat cylindrical in shape, their sides (juxtaposed, and therefore hardly visible in the undisturbed girdle) are neatly ribbed vertically, while its outer (distal) surface, oval in outline, and slightly convex is minutely pustulose. (Figs. 3, 4, 5). The radula measures about 1.6 mm in length, and has 44 rows of teeth. The median plate (tooth) is wider anteriorly (30μ) with a very thin blade, markedly narrowed medially (12μ), and again somewhat dilated posteriorly to terminate rapidly in a blunt point. The intermediate (first lateral) plate has a small superiorly recurved uncinated growth at the outer-anterior corner. The uncinate (second lateral, major lateral) plate has a long and thick (25μ × 8μ) tubercle inwardly directed, and a unicuspid blade, about 52μ long by 25μ wide, with a small posterior notch (Fig. 6).

Type material — Holotype (disarticulated valves, excised fragments of the girdle, and mounted radula) and a paratype (Figs. 1, 2), are deposited with the California Academy of Sciences, Department of Invertebrate Zoology (CASIZ Type Series 679 and 680; CASIZ Type Slide Series 493 and 494). Color slides of some paratypes are deposited with the California Academy of Sciences, Department of Zoology (CASIZ Color Slide Series nos. 3259, 3260, and 3261).

The paratypes vary in size from 5.1 mm to 6.9 mm in length. They all have the same general coloration (with one exception — a uniform brick-red specimen, with faint creamish banding of the girdle), and some irregular, small, greenish blotches. Paratypes deposited with the Los Angeles County Museum of Natural History, United States National Museum of Natural History (USNM no. 710720), Academy of Natural Sciences of Philadelphia, and in my own private collection.

Type locality — 5 km west of Portobelo (latitude 9° 30′ N; longitude 79° 42′ W), Panama. The specimens were all collected on February 15, 1975, by myself, in about 1 to 10 feet of water, under rocks or fragments of old coral resting on sand. They came from two collecting stations (AJF 222, and 223), about 1 km west of Portobelo (1 specimen, 5.5 mm long), and 5 km west of Portobelo (10 specimens, including the here designated holotype), respectively. The species is called *portobelensis* in reference to its type locality, Portobelo.

Further distribution — Another specimen of *Callistochiton portobelensis* was found by the author on April 28, 1975, while diving from aboard the *R/V Coral Reef* with the Steinhart Divers of the California Academy of Sciences, in 5 m of water by the Northwest Channel (latitude 24° 30′ N; longitude 81° 54′ W), off Key West, Florida. The specimen measures 9.0 mm in length. This finding extends the known range of *C. portobelensis* some 1,000 miles northward.

Discussion — Callistochiton portobelensis bears little resemblance to *C. shuttleworthianus*, the only member of the genus *Callistochiton* hitherto known in the Caribbean (KAAS, 1972). Instead, in size, color, general shape, sculpture of the tegmentum, and girdle scales, *C. portobelensis* is remarkably similar to *Callistochiton elenensis* (Sowerby, 1832) from the tropical eastern Pacific. Compared with randomly selected specimens from several lots of *C. elenensis* in my collection, *C. portobelensis* was found to differ by 1) its smaller size, 2) a much more subdued sculpturing of the valves, particularly of the radial ribs in valves i and viii, 3) a more rounded and smoother jugal area, 4) no "upswept" valves (see Thorpe in Keen, 1971:875), and 5) thicker longitudinal riblets, separated by narrower interspaces.

Still, the affinities between *C. portobelensis* and *C. elenensis* are so close as to make them sibling species. Likely, they evolved from the same parent population and became geographically isolated by the emergence of the isthmus of Panama in the Pliocene.

ACKNOWLEDGEMENTS

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A NEW FOSSIL *ASHMUNELLA* (PULMONATA: POLYGYRIDAE) FROM THE GUADALUPE MOUNTAINS NATIONAL PARK, TEXAS

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ABSTRACT

A new species of fossil polygyrid land snail, Ashmunella nana, *is described. The species is known only from deposits of Pleistocene age in the southern*

Guadalupe Mountains, Culberson County, Texas. An associated molluscan fauna in these deposits is recorded and remarks are made concerning Oreohelix socorroensis *Pilsbry.*

INTRODUCTION

Pine Spring Canyon in the southern Guadalupe Mountains, Culberson County, Texas, has received considerable attention malacologically. It is the type locality of *Holospira montivaga breviara* Pilsbry, 1946, of *Holospira pityis* Pilsbry and Cheatum, 1951, and of *Ashmunella kochi amblya* Pilsbry, 1940. The canyon is now in a central position in the Guadalupe Mountains National Park.

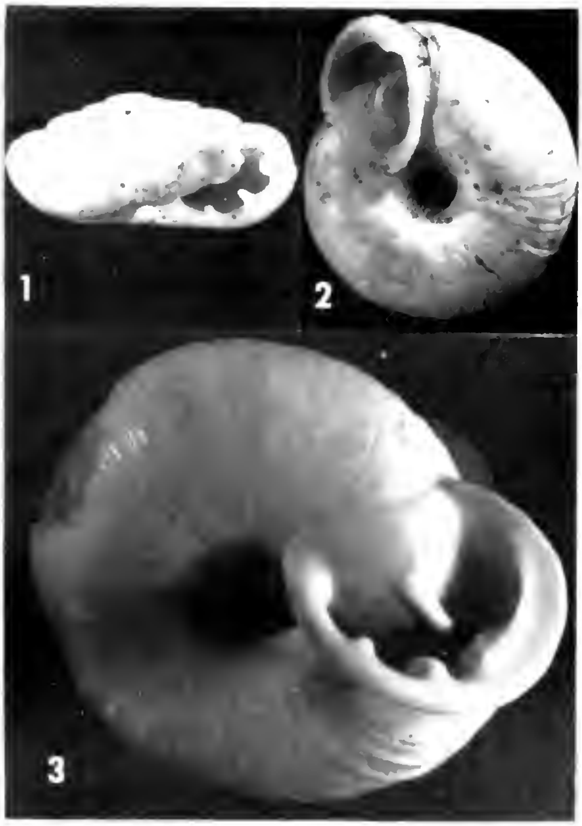
Exposed in walls of Pine Spring Arroyo are thick alluvial deposits that contain fossil mollusks. On slopes of the canyon above the arroyo there are fossiliferous colluvial deposits. At the locality reported here, there are two strata of rubbly colluvium (to be referred to, hereafter, as "lower rubble" and "upper rubble") separated by reddish silt, containing scattered, subrounded stones. The rubble is predominantly of small, sharply angular limestone fragments of the type interpreted by Galloway (1970 : 245), in the Sacramento Mts. (120 km to the northwest, in New Mexico), to be periglacial deposits of frost rubble. It seems probable that the upper rubble was deposited during the latest Wisconsinan Glaciation. The reddish deposits probably represent a paleosol appertaining to an interstade or interglaciation and the lower rubble seemingly represents either an earlier Wisconsinan or still earlier time when periglacial conditions existed in the mountains.

The molluscan fauna found in the lower rubble comprises, among others listed below, *Ashmunella rhyssa* (Dall) and a new species, described below. Neither species is known to live in the Guadalupe Mts. at present and the latter seems to be an extinct species. *A. r. rhyssa* still flourishes in the Sacramento Mountains. In the upper rubble a different *Ashmunella*, *A. kochi amblya* Pilsbry, occurs. This species presently inhabits Pine Spring Canyon and other parts of the southern Guadalupe Mts. The sequence suggests that the two former species of *Ashmunella* became extinct in the Guadalupe Mts. between the times of deposition of the lower and upper rubbles and that *A. kochi amblya* appeared in the mountains during the time of the latest glaciation. [Vagvolgyi (1974 : 143) suggested that the subspecies *amblya* might better be synonymized with the nominal subspecies.]

Ashmunella nana *new species*

Figs. 1-3

Description of Holotype: Shell small (for genus), moderately depressed, 10.6 mm in diameter, 5.0 mm high; body whorl rounded peripherally and descending only slightly; umbilicus round, deep, contained 5.4 times in diameter; aperture obliquely oriented, 3.2 mm in oblique distance between inner corners of lip; aperture bearing four denticles; parietal



FIGS. 1, 2. *Holotype of* Ashmunella nana *new species (10.6 mm diameter).* FIG. 3. *Apertural view of paratype of* A. nana.

tooth oblique, simple, 1.7 mm long, .4 mm high; palatal tooth rectangular, 1.1 mm long and .5 mm high, basal lip with two teeth, both compressed, 1.0 mm apart, upper tooth rising .6 mm and lower tooth rising .2 mm above inner rim of lip; lip slightly expanded and recurved, grooved behind; first $1\frac{1}{4}$ whorls smooth, except for minute pits; succeeding whorls finely wrinkle-striate to last half of body whorl, which bears *ca.* 26 low but distinct ribs, better developed dorsally and progressively thicker distally; total number of whorls, 4.75. Etymology: *nana* = dwarf (L., fem., subst.).

Variation: For fifty paratypes from the type locality, the following measurements (mm) and proportions were obtained (mean outside parenthesis; range inside parenthesis); Diameter: 10.07(9.1-11.2); Height: 4.53(4.0-5.2); Diameter/Height: 2.21(1.98-2.47); Width of Umbilicus: 1.96(1.4-2.5); Diameter/Width of Umbilicus: 5.17(4.32-6.50); Length of Parietal Tooth: 1.51(1.2-1.8); Length of Palatal Tooth: 1.24(0.7-1.5); Number of Whorls: 4.86(4.6-5.25). All specimens observed had four denticles (except where exfoliated), which showed only minor variation in shape and size. There was variation in degree of ribbing, ranging from few ribs to specimens in which most or all of the body whorl bore ribs dorsally and peripherally. Measurements of four specimens taken *ca.* 60 m southeast of the type locality (see below) fell within the limits enumerated above.

Comparisons: A. nana is among the smallest of Ashmunellas. The only members of the genus reported to be as small are *A. proxima harveyi* Pilsbry (Pilsbry, 1940 : 959) with a specimen reported as being 10.3 mm in diameter and 5.0 mm high and *A. intricata* Pilsbry (Pilsbry, 1948 : 203) with specimens recorded as 9.6 and 10.6 mm in diameter and 4.7 and 4.8 mm high.

A. nana seems to bear little resemblance, conchologically, to any known species of *Ashmunella*, living or fossil, from the region east of the Rio Grande Valley. In general shape and in number and arrangement of denticles it resembles the *A. proxima* Pilsbry complex of the Chiricahua Mts., Arizona. However, *A. nana* is much less tightly whorled, less angular peripherally and is much more ribbed than members of the *proxima* complex. A close relationship with this distant group seems unlikely.

In contrast to *A. nana*, in regard to size, is *A. kochi amblya*, which may exceed diameters of 20 mm. Thus, one of the largest and one of the smallest of Ashmunellas have inhabited Pine Spring Canyon. *A. nana* seems to bear little relationship either to *A. kochi amblya* or to the other living species of the Guadalupe Mts., *A. edithae* Pilsbry and Cheatum and *A. carlsbadensis* Pilsbry. The wide, shallow umbilici of the latter three species are in marked contrast to the narrow, deep umbilicus of *A. nana*.

Type Locality: Texas, Culberson Co., Guadalupe Mts., Pine Spring Canyon, 3.2 km (2 mi.) WNW of village of Pine Springs. 104° 50′ 45″ W Long, 31° 54′ N Lat; 1912 m (6270 ft.) elevation. Deposits are exposed in banks of a small arroyo of high gradient, tributary, from the west, to the main arroyo of the canyon. Deposits occur *ca.* 30 m west (on east-facing slope) and up-slope from a right-angle bend in the main arroyo (changing from west to north, up-canyon). This sharp bend is .65 km (.4 mi.) south of the "H" in "Devil's Hall" (U.S.G.S. Guadalupe Peak, Texas, 15 min. topographic quadrangle, 1933).

Types: Holotype, Acad. Nat. Sci., Philadelphia 338703; Paratypes: ANSP 338704; Dallas Museum Nat. Hist. 4400; The Delaware Museum Nat. Hist. 100700; University of Arizona 17382; Museum of Arid Land Biol., U.T. El Paso 4165, 4170.

ASSOCIATED FAUNA

In association with *A. nana* and *A. r. rhyssa*, the following species of snails have been taken in the lower rubble: *Cochlicopa lubrica* (Müller), *Gastrocopta pilsbryana* (Sterki), *Pupilla sonorana* (Sterki), *Pupilla blandii* Morse, *Vallonia gracilicosta* Reinhardt, *Vallonia perspectiva* Sterki, a succineid, *Holospira montivaga breviara* Pilsbry, *Discus cronkhitei* (Newcomb), *Helicodiscus eigenmanni* Pilsbry, *Retinella indentata* (Say), *Hawaiia minuscula* (Binney), *Zonitoides arboreus* (Say), *Striatura meridionalis* (Pilsbry and Ferriss), *Vitrina pellucida alaskana* Dall, *Oreohelix socorroensis* Pilsbry and *Humboldtiana ultima* Pilsbry. Recent collecting by Fullington shows that all these species except probably the *Oreohelix* still occur in the Guadalupe Mts. but several species now occur only at higher elevations.

Oreohelix socorroensis was taken in both the lower and upper rubble. It also occurs in alluvium along Pine Spring Canyon Arroyo. Probably specimens of *O. yavapai compactula* Cockerell reported by King (1948 : 145) were of this species. *O. socorroensis* has been found, as a fossil, in the Sacramento and San Andres Mts., New Mexico, and in the Franklin, Hueco and Guadalupe Mts., Texas. It still lives in the Gallinas Mts. in central New Mexico. It is surely allied to the *O. yavapai* Pilsbry complex of northern New Mexico and Arizona, especially to *O. yavapai neomexicana* Pilsbry. However, elucidation of relationships probably would involve a taxonomic revision of the entire *yavapai* group, a task not undertaken lightly.

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TENTACLE-BRANCHING IN THE PERIWINKLE, *LITTORINA LITTOREA*

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Abnormalities in mollusks have been noted by many observers and are the subject of a treatise by P. Pelseneer (1920). In gastropods, supplementary or multiple tentacles have been noted in several cases, but, as Pelseneer noted, they are more common on one side than the other. Branching has been particularly noted in *Littorina*. Pelseneer's own observations may be summarized as follows:

Jeffreys (1862) noted a specimen of *L. littorea* which had two tentacles branched. He also commented in reference to a supplementary tentacle observed in a specimen of *L. obtusata*, that the *extra* tentacle is not far removed from the normal one.

Hanko (1912) in a paper delineated the varieties of tentacle-branching which have been observed in *Nassarius mutabilis* (L.).

Crabb (1927) studied forked tentacles in the pond snails *Physa gyrina* and *Lymnaea stagnalis appressa*.

Wong and Wagner (1956) reported on the effect of ultraviolet light on the tentacles (among other things) of *Oncomelania nosophora* and *O. quadrasi*. Exposure to ultraviolet light causes *abnormal growth structures* in many individuals of these species. However, abnormal tentacles tended to be lost over a period of time.

Davis, Moose & Williams (1965) described a specimen of a hybrid *Oncomelania* with tentacle abnormalities and stated "It is known that the tentacles of *Oncomelania* are prone to abnormal branching." The authors suggested that inheritance might be involved in tentacle branching.

Richards (1969) in an important paper showed that inheritance appears to play a part in tentacle branching of the freshwater pulmonate mollusk *Biomphalaria glabrata*.

While observing 50 living periwinkles which had been selected for experimental purpose from near the low tide mark of the intertidal region of Northwest Harbor, Deer Isle, Maine, the summer of 1971, the writer noticed one specimen with a bifurcated tentacle (fig. 1). Subsequently, four collections of periwinkles, consisting of 1,026 living specimens were examined with the following results:

TABLE 1. *Tentacle-branching in the Littorina*

Species	*Number of Individuals Noted*	*Tentacle* *Left*	*Right*
L. littorea	1	—	1
L. rudis (saxatilis)	5	—	5
L. obtusata	3	3	—

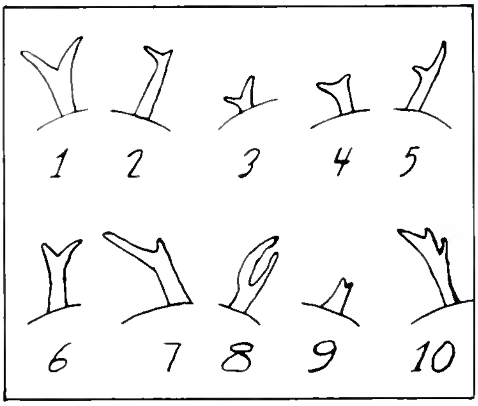
TABLE 2.

Date	*Number Observed*	*Number with Forked Tentacles*
(1971)		
July 27	100	2
July 29	303	4
July 30 (lot 1.)	318	3
July 30 (lot 2.)	305	1
	1,026	10

The periwinkles with the forked tentacles were subsequently brought back to the writer's laboratory aquariums in Princeton, New Jersey, for continuing observation. In contrast to the findings of Wong and Wagner (1956) on the ultraviolet light induced tentacle growth abnormalities in *Oncomelania*, the branched tentacles of these periwinkles appeared permanent and stable, certainly as "normal" as normal tentacles, for the period of over eleven months during which they were under observation.

Each fork of a tentacle shows independent activity. Both forks in the tentacle shown in drawing 1 moved separately and conducted independent searching movements. This was also true in specimen 8, which was surprisingly prehensile in appearance and movement.

Small forks in numbers 4, 5 and 6 showed more independence of motion than the smaller forks of numbers 2 and 7.



FIGS. 1-10. *Abnormal branching in the tentacles of* Littorina littorea *(Linné)*.

Microscopic examination of numbers 1 and 8 showed no difference internally or externally in the organization of the forks. Tentacle forks are organized tissue and certainly not "cancer-like." Number 10 was the only case found with multiple forking.

A further analysis of lot 2 collected on July 30 containing 305 specimens gave the following results of the 18 abnormal specimens (5.9%):

TABLE 3.

Tentacle Abnormality	*Left Tentacle*	*Right Tentacle*
Missing	1	1
Short	12	1
Bent	0	2
Forked	0	1
Totals	13	5

No periwinkles were observed in which both tentacles appeared to be abnormal.

It should be noted that forking is not restricted to the phylum Mollusca but occurs in other instances involving the regeneration of structures. In the case of lizards which cast off their tails to escape being eaten, regeneration occurs in such a manner as to give a forked tail.

It is possible that the bites of very small fish in some instances do not remove but only injure the tentacles of periwinkles in such a manner that regeneration results in similar forking.

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*OBSERVATIONS ON MOLLUSKS FROM A NAVIGATION BUOY WITH SPECIAL EMPHASIS ON THE SEA SCALLOP *PLACOPECTEN MAGELLANICUS*

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ABSTRACT

Twelve species of postlarval mollusks were found among fouling organisms collected from a navigation buoy. Length data for the three most abundant species, Placopecten magellanicus, Anomia aculeata, *and* Mytilus edulis, *were analyzed in an attempt to explain normal and log-normal frequency distribution patterns. Molluscan community relationships on the buoy were closely observed and reported. The ocean bottom under the buoy was sampled by dredge, and the population composition of mollusks on the bottom did not include the postlarval forms found on the buoy.*

INTRODUCTION

Many objects floating at the ocean's surface eventually acquire an imposing community of sessile marine organisms. An impressive body of literature exists with reference to such fouling organisms (Woods Hole Oceanographic Institution Contribution No. 580, 1952). In this paper, we present the results of a study of the mollusks attached to an ocean buoy. One specific purpose of this study was to learn more of the early life history of the sea scallop, *Placopecten magellanicus* (Gmelin).

United States Coast Guard navigation buoys come in many shapes and sizes. Those for ocean duty are usually made up of a superstructure carrying a light and a bell or whistle, a cylindrical float chamber, and a stabilizer to hold the buoy upright. They are anchored to large blocks of concrete by heavy chain.

Immediately upon launching, buoys become attractive bases for colonization by marine organisms. The organisms which settle, survive, and grow are, for the most part, species which are able to attach themselves securely. When the buoy is returned for cleaning and servicing, the entire community of organisms can be conveniently observed and sampled. The outside buoy surfaces are subjected to strong tidal currents and wave action, which restrict attachment to those organisms with the most tenacious holdfasts. The inside of the stabilizer tube (Fig. 1) offers a more sheltered environment with considerable, but gentler, water exchange as the buoy surges up and down. Here are found the densest populations, and here the struggle for space is readily observed (Merrill, 1965).

FIG. 1. *Typical navigation buoy. Arrow indicates the sheltered, inner portion of the stabilizer tube.*

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METHODS

The collection was taken from the Nantucket Shoals Lightship (NSLS) buoy. The buoy was placed on station October 8, 1957, at N. lat. 40°33′; W. long. 69°28′, 1 mile north of the Nantucket Lightship, and returned to the Coast Guard Base at Woods Hole for cleaning and repairs on May 10, 1958. It offered a particularly attractive fouling community for study, since the buoy had been on station for only a limited time (7 months), and during a period when many species with pelagic larvae were not spawning (the winter months).

The NSLS buoy is 24 ft long and its greatest diameter is 9 ft. About half of the buoy is submerged when in position. Collecting was restricted to the area 8 ft inward from the mouth (bottom) of the buoy stabilizer, which is 2 ft in diameter (see arrow, Fig. 1). This area, approximately 50 sq ft, was carefully scraped and then wire-brushed to loosen many small individuals still hidden in crevices. The total sample of 1½ gal (12 pt) was taken to the laboratory for sorting, study, and analysis.

Since the buoy had been out of water about 3 weeks, the fouling community had dehydrated slowly and was in excellent condition for collection and study. Much of the material consisted of sizable thin pieces of rust (Fig. 2) with animals and plants attached in their original positions.

Measurements of mollusks were made to the nearest 0.1 mm with the aid of an ocular micrometer. The greatest overall size, height or length was used as the basic measurement.

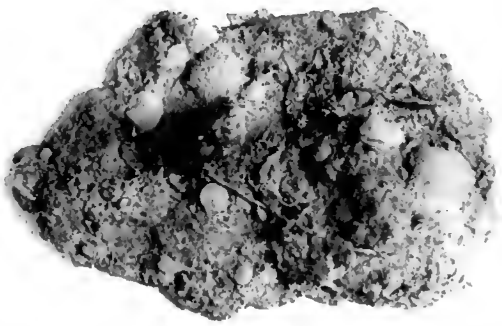

FIG. 2. *A piece of iron rust removed from within the stabilizer tube of a buoy. The material dried slowly and a number of organisms can be seen adhering in their original positions.*

Hydrographic data for the area were available from the nearby lightship.

To compare the population of the buoy with that of the bottom below, the area was dredged on May 26, 1958, about 2 weeks after the buoy was brought in. A 10-ft-wide sea scallop dredge with a ¾-inch stretched mesh liner was towed from the Bureau of Commercial Fisheries Research Vessel *Albatross III* to make the collection. The contents of a 5-min tow which covered approximately 15,000 sq ft of bottom area were analyzed.

RESULTS

Three species of pelecypods — the sea scallop, *Placopecten magellanicus*, the jingle shell, *Anomia aculeata*, and the common, blue mussel, *Mytilus edulis* — dominated the community found on the buoy. Because the two latter species were so numerous, a 1-pt subsample (of the 12-pt total sample) was taken and all specimens were counted and measured. The length-frequency distributions obtained of the three most common mollusks are shown in Figure 3. As a check on the validity of this subsample, all molluscan species in the total sample, except the numerous *A. aculeata* and *M. edulis*, were also counted and measured. Figure 4 shows the frequency distribution of *P. magellanicus* found in the total sample.

The frequency distributions in Figures 3 and 4 are strongly skewed to the right and only that for *M. edulis* is obviously polymodal. In the subsample, there were 731 *P. magellanicus* with a range in size of 0.5-13.2 mm and a mode at about 3 mm; 2,217 *A. aculeata* with a range of 0.5-14.0 mm and a mode at about 4 mm; and 1,550 *M. edulis* with a range of 0.4-24.3 mm and obvious modes at about 1.7 and 2.8 mm (Fig. 3). In the total sample, there were 9,806 *P. magellanicus* with a range of 0.5-13.4 mm and modes at about 2.5 and 2.8 mm (Fig. 4).

The mussel produces a stout and intricately woven byssus, and the jingle shell a short thickened byssal plug, both of which are capable of holding shell remains securely to a substrate after drying. The thin byssal threads of scallops become brittle upon drying and break easily. Therefore, the size-frequency data presented in Figure 3 for the mussel and jingle

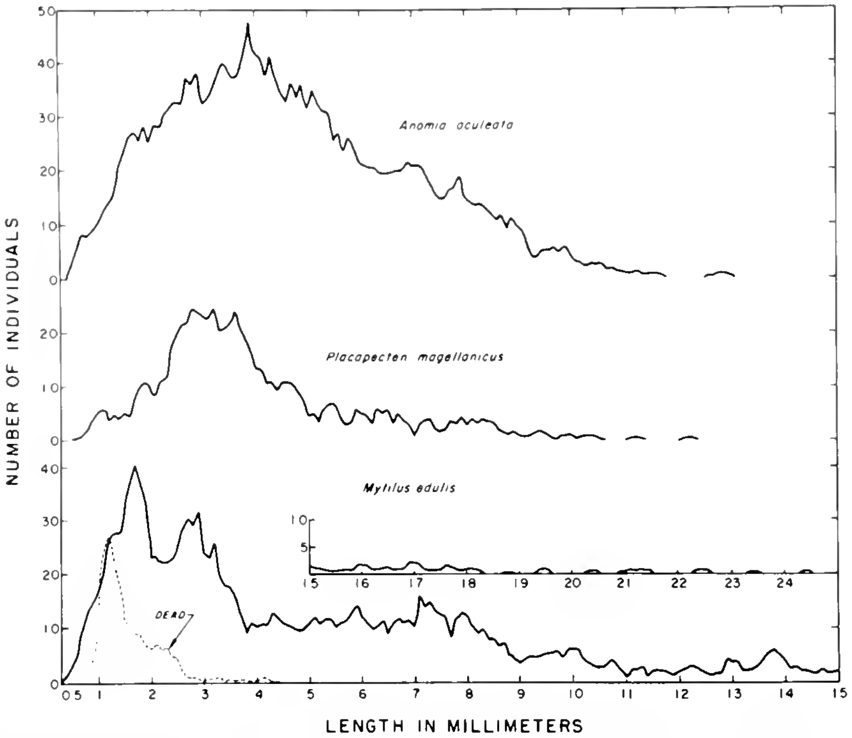

FIG. 3. *Size-frequency distribution of the three common mollusk species found on the Nantucket Shoals Lightship buoy (1-pt subsample).*

shell are possibly more representative of the total sample than for the scallop. Proportionally, there were fewer small *Placopecten* in the pint subsample than in the total sample, and the mode was about 0.5 mm higher. Apparently, some of the smaller scallops settled to the bottom of the original scrapings before the aliquot was obtained. However, aside from these

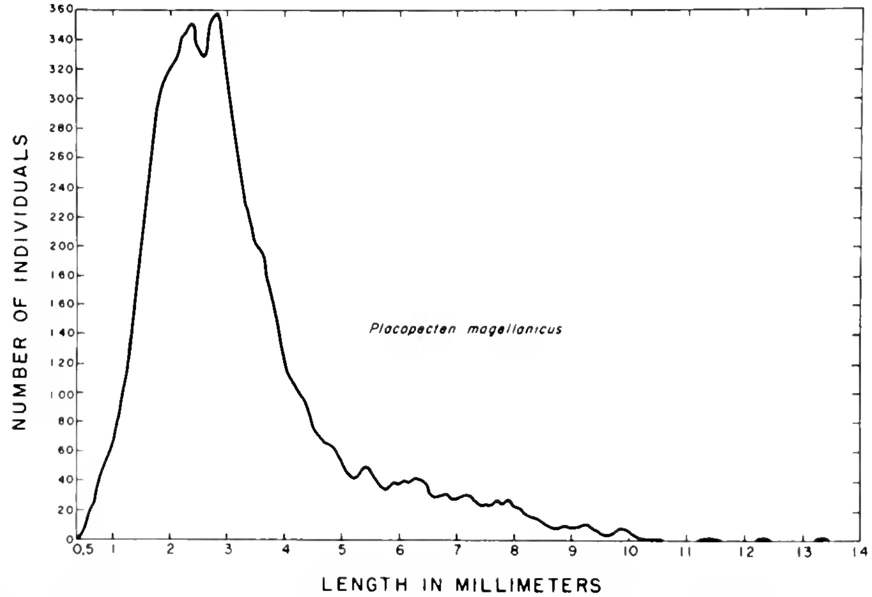

FIG. 4. *Size-frequency distribution of the sea scallops found on the Nantucket Shoals Lightship buoy.*

TABLE 1. *Frequency by size of the mollusks taken from the Nantucket Shoals Lightship buoy*

Species	*Size (mm)*											*Total*		*Range*
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Live	Dead	*in size*
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*mm*
GASTROPODA														
Mitrella lunata Say		1	13	12	12							41	3	1.4- 4.6
Lacuna neritoidea Gould	7	6										13	1	0.3- 1.8
Spiratella lesueuri D'Orbigny		2										2		1.7
Anachis avara Say		1										1		1.1
Unidentified	2											2		0.3
PELECYPODA														
Placopecten magellanicus Gmelin	148	1,845	3,433	2,174	868	425	371	275	154	86	27	9,806		0.5-13.2
P. magellanicus (dead)		118	84	23	4	1	2	1					233	2.0- 6.9
Anomia aculeata Gmelin	396	2,400	3,900	4,608	4,452	3,516	2,472	2,160	1,500	732	468	26,604*	108*	0.5-13.0
Mytilus edulis Linnaeus	744	3,792	3,144	1,824	1,284	1,452	1,248	1,536	840	636	2,100	18,600*		0.4-24.3
M. edulis (dead)	204	1,800	396	60	21	48	12	12	12				2,568*	0.4- 8.3
Hiatella arctica Linnaeus		4	14	14	6	5	3	1		1		48	2	1.1- 9.3
Anadara ovalis Bruguière			1									1		2.5
Tellina agilis Stimpson	1											1		0.9
Periploma papyratium Say		1										1		1.1
												55,120	2,915	

*Calculated from 1/12 aliquot of total sample.

minor differences, the scallop size-frequency distribution in the aliquot (Fig. 3) is similar to that in the total sample (Fig. 4).

All the mollusks collected from the buoy are listed in Table 1, together with their size-frequency by 1-mm groups. The size-frequency of the shells of dead *P. magellanicus* and *M. edulis* is also given. The total number of *A. aculeata* and *M. edulis* is estimated on the basis of subsample counts. The total number of living mollusks from the 50-sq-ft area was 55,120 or an average of 7.7 individuals per square inch.

The material obtained by dreding the bottom under the buoy was compared with the sample from the buoy (Table 2). The bottom was of a mud-sand texture; the sand dollar, *Echinarachnius parma,* proved to be the commonest species of the area with over 1,200 captured. Some of the larger gastropods such as *Lunatia heros* and *Buccinum undatum* were present in fair numbers, and there were many dead double valves of the bivalve, *Arctica islandica.* The molluscan faunal composition of the bottom was completely different from that of the buoy except that it contained a few large sea scallops. None of the same larval mollusk species that had settled on the buoy found their way to the bottom in this area.

TABLE 2. *Number of live and dead mollusks collected in the dredging of a 5-min tow on May 28, 1958, in the area of the Nantucket Shoals Lightship buoy.*

Species	*Number of specimens*	
	Live	*Dead*
Gastropoda		
Colus pygmaea Gould	1	5
Nassarius trivittatus Say[a]	8	3
Buccinum undatum Linnaeus	62	60
Lunatia heros Say	74	64
Crepidula plana Say[b]	78	0
Pelecypoda		
Placopecten magellanicus Gmelin[c]	6	1
Artica islandica Linnaeus[d]	8	125
Ensis directus Conrad[d]	0	5
Astarte castanea Say	2	0
Venericardia borealis Conrad	5	0
Modiolus modiolus Linnaeus	1	1
Anomia simplex d'Orbigny	1	0
Spisula solidissima Dillwyn[d]	9	1

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[a] This species had deposited numerous egg cases on the interior of practically every dead valve of the mahogany clam (*Arctica islandica*).

[b] Found attached inside large dead shells, usually *Lunatia heros.*

[c] The heights of these in millimeters were 59.9, 85.2, 117.8, 131.7, 157.4, 164.7; one upper valve, 28.2.

[d] The animal lives in the substratum, consequently not adequately collected by the type of dredge used.

DISCUSSION

Each species exhibited patterns of preference in utilizing the substrate within the 8-ft length of buoy tube. The spat of *Mytilus*, for example, first attached directly to the substrate, and later tended to aggregate and intermingle their byssal threads to form colonies. Even though the mussel may detach and reestablish elsewhere (Field, 1922), our observations showed that in some cases unusually dense masses of byssal threads may entrap certain segments of a population. As a result, some mussels became smothered, or grew at a slower rate than neighboring specimens. *Anomia* spat attached directly to solid substrate, preferring crevices, but did attach to all other available surfaces. Individual *Hiatella* were randomly distributed and grew competitively within aggregates of mussels, or freely on open substrate. The spat of *Placopecten* showed a marked preference for areas that were free from other mollusk association. The smallest scallops, those under 1 mm, were invariably attached to the filaments of bryozoa, to the byssal threads of *Mytilus*, or directly to shells, where they could move about freely. Scallops over 1.5 mm were generally attached to solid substrate, far removed from other organisms, when possible.

Young sea scallops do not seem to compete well in fouling communities. The mantle is apparently easily injured, and evidence of serious shell malformation was seen in situations where other organisms were in close proximity to the scallop. This was particularly noticeable when an occasional larger specimen had been trapped within the byssal maze of a *Mytilus* colony. Young *Anomia*, *Mytilus*, and *Hiatella*, unlike *Placopecten*, adjust to the necessity for living close to other organisms. *Anomia* conforms easily to close contact; if an obstacle in the immediate area interferes with normal development, the individual will change shell symmetry and become elongate in any plane which offers the opportunity for further growth. *Mytilus* and *Hiatella* suffer least from close contact, probably because their siphons, not their mantle edges, are most exposed. However, both species are known to exhibit shell distortion in conventional habitats – *Hiatella* in peat and coral burrows, and *Mytilus* in dense colonies.

Baird (1953), in examining many "bushy" organisms obtained from dredgings, found only the bryozoan *Gemellaria* to be a consistent host for settling sea scallop larvae. He suggested the possibility of a direct relationship between *Gemellaria* and *Placopecten* in the larval ecology of the scallop. In light of our observations, we wish to amend this slightly. Apparently when the scallop spat settles, it is too delicate to take advantage immediately of bottom substrate, composed entirely of particulate matter continuously shifting with the bottom currents. Thus, those that land on sedentary branching plants and animals, *or any other hard surface* on or above the ocean floor which offers freedom of shell movement on all sides, may have a distinct survival advantage.

It should be noted that, as with *Placopecten*, many of the smallest individuals of *Mytilus* and *Anomia* were attached to bryozoa and to byssal threads; however, just as many of the smallest were attached to solid substrate. From observations on the distribution of these species in the buoy, it appears that all are able to disengage themselves and travel some distance —the mussels to aggregate, the scallops to spread out, and the jingle shells to seek any solid substrate available. *Mytilus* and *Anomia* appear to fix more or less permanently at an early age, while *Placopecten* and *Hiatella* may continue to disengage from time to time.

Several of the smallest scallops from the buoy measured as little as 0.5 mm. The prodissoconch measured about half this size, so these smallest specimens had approximately doubled in size since settling. To our knowledge, these are the smallest metamorphosed sea scallops ever collected.[1]

After death, the ligamental structure in the hinge of the scallop continues to hold the valves together, but gaping. In this condition, sea scallop valves tend to tangle in filamentous bryozoa or amongst the byssal threads of the mussels. There were 233 dead specimens of scallops in the total population, the mode at about 2.0 mm. Size-frequencies for the dead and live scallops (Table 1) show similar curves which suggests that valves do not remain long in the buoy after death. The pint sample contained 214 dead mussels (Fig. 3, dotted line),

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[1] We have since taken from buoys scallops as small as 0.3 mm, the prodissoconchs having barely a fringe of dissoconch growth.

many of them of smaller size. In fact at about 1.2 mm, more dead than live mussels were counted. Some of these were found trapped in aggregates of mussels, while many were found partly or completely buried in the light layer of fine silt and debris that builds up in the buoys. The great mortality in the smallest mussels occurred over a period of time, judging from the various degrees of shell decomposition observed. The top and bottom valves of *A. aculeata*[2] soon separate after death and shell remains are quickly flushed from the buoy; hence, dead specimens are rarely found.

In order to discuss growth, the time of setting must be ascertained with some degree of accuracy. It is possible to determine quite closely the spawning season (and hence the probable time of setting) for two of the major species on this buoy. Observations on the spawning of sea scallops have been made by several investigators. These observations have been summarized by Dickie (1955, p. 848) and show that the spawning period, for all geographical areas, may extend from mid-July to early October. From extensive study, we can definitely state that scallop spawning in the offshore area of Cape Cod occurs between late September and the middle of November. Allowing as much as an extra month in the larval state, all spat should have settled by mid-December. This means larvae of the sea scallop could, and probably did, settle on the buoy during the first few weeks after it was placed on station, and, judging by the similarity of their population structures, so did the other species as well.

In Milford Harbor, Connecticut, spawning of *M. edulis* is restricted to those months when the temperature is approaching and above 60°F[3] (Engle and Loosanoff, 1944). In "Marine Fouling and Its Prevention" (Woods Hole Oceanographic Institution, Contribution No. 580, 1952), early to late June is indicated as the beginning of the breeding season for *Mytilus* at Woods Hole, Massachusetts. *Mytilus* larvae, then, must have been in the water after the buoy was placed on station, and, because of the low temperatures that prevailed, there could have been no further sets in the spring before the buoy was taken off station. No spawning information is available for *A. aculeata*, but the size-frequency distribution suggests that the spat of this species settled about the same time as the other two species.

Both *M. edulis* and *A. aculeata* showed signs of polymodal distribution not obvious in *P. magellanicus*. The use of probability paper in an attempt to define polymodal distribution as outlined by Harding (1949) failed to show any significant secondary set or group for the sea scallops. However, similar analysis of the *Anomia* data indicated possible modes at 3.7 mm and 7.2 mm, and for the mussel at 1.6 mm, 2.8 mm, 7.0 mm, and possibly others. This suggests that, within the spawning period, one strong set of sea scallops and two or more heavy sets for the other two species settled on the buoy.

From observations of the buoy material, there is indirect evidence that more than one group of larvae settled. For instance, many small *Anomia* were seen attached to larger shells of the same species; a small *Anomia* and a small *Mytilus* were found attached to the inner valve of a much larger dead mussel; and there were many instances in which one organism grew upon another in such a way as to suggest that it set some time after the other. Indirect evidence can also be found in the data; for instance, the smallest mussel was 0.4 mm and the largest just under 25 mm — far too much difference in growth, it is felt, for a single set.

The average and maximum sizes of the four common species of pelecypods found in the buoy were:

	Average	*Maximum*
Placopecten magellanicus	2.9 mm	13.2 mm
Mytilus edulis	3.9 mm	24.5 mm
Hiatella arctica	3.7 mm	9.5 mm
Anomia aculeata	4.5 mm	13.2 mm

The averages represent shell growth for 6 to 7 months after setting, and during the coldest months of the year. The maximum sizes attained are an indication of the amount of

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[2] Abbott in the second edition of *American Seashells* (1974, p. 452) follows Winckworth, 1922, and others, in calling this species *squamula* Linné, 1758.

[3] Temperature records for the time and locality involved in this study are available in published form (Day, 1959a; 1959b).

growth that can be achieved under the existing conditions.

The location of the NSLS buoy is such that pelagic bivalve larvae could be transported from many coastal areas, and this could effectively extend the setting season. The currents that sweep over Nantucket Shoals undoubtedly carry planktonic larvae originally spawned in many different estuaries and bays of the Massachusetts coast, as well as from a large area of the Gulf of Maine. It seems most reasonable to suggest that, for *Mytilus* at least, the peak of setting may have occurred for several weeks after the buoy was on station. Initial settlers would have had less competition from their own kind, as well as a warmer and longer period in which to grow.

It should be pointed out that a factor such as overcrowding might lead to arrested growth. Arrested growth in one segment of the population might yield a mode that possibly could be interpreted as indicative of age.

The strongly skewed size distributions of Figure 3 deserve further mention. Such distributions are not uncommon in youthful populations of many organisms, and can conceivably arise in one or more ways, including (1) simple differences in growth due to time of setting, especially when spatfall occurs over a period of time associated with a change in temperature; (2) decreased growth rate for later arrivals due to increased density and competition; and/or (3) some characteristic of the buoy that causes unusual mortality (or loss to the buoy) amongst the larger individuals.

The sea scallop size-frequency is well fitted by a log-normal transformation, as can be seen in Figure 5. The length-frequencies of *Mytilus* and *Anomia* are not so well fitted, perhaps because more than one set is represented in the data. However, since any one or any combination of the factors mentioned above can result in a log-normal distribution, this transformation does not of itself shed additional light on the subject.

It would appear that the observed skews can be largely attributed to setting over a period of time during which sea surface temperatures were cooling. The possibility that many *Mytilus* and *Anomia* settled after temperatures were too cool for any further significant growth cannot be dismissed. The problem is worthy of further study, and material from buoys may be particularly useful in this respect.

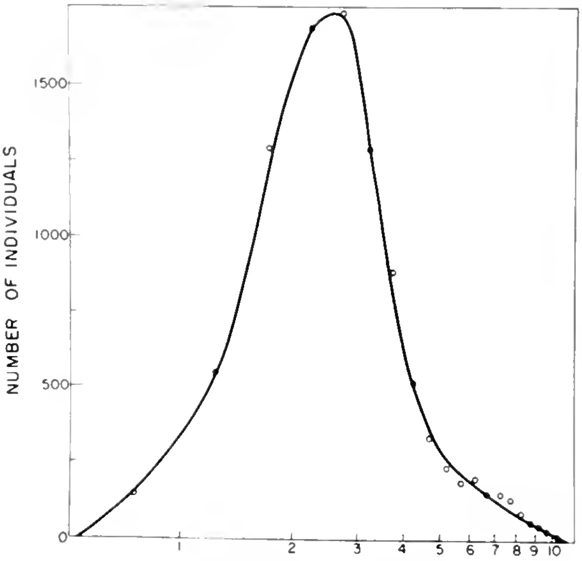

FIG 5. *Size-frequency distribution of the sea scallops found on the Nantucket Shoals Lightship buoy plotted on semilogarithmic paper to produce the symmetry of a log-normal curve.*

SUMMARY

1. All the mollusks within an area of 50 sq ft were collected from within the stabilizer tube of a heavy duty navigational buoy. Twelve species were recovered from approximately 55,000 mollusks that made up the fouling population. Three species, *Placopecten magellanicus*, *Anomia aculeata*, and *Mytilus edulis*, were found in the largest number.

2. The ocean bottom under the buoy was dredged, and the population composition and structure were found to be completely different from the buoy population.

3. The population structure and the interrelationships of species in the mollusk community were closely observed. Methods of attachment and distributional patterns, particularly patterns of preference in utilizing surface area, are discussed in some detail.

4. Analysis of the length-frequency distribution, using probability paper to define polymodal groups, suggested one heavy set of *P. magellanicus* and two or more of *A. aculeata* and *M. edulis*.

5. Taking into consideration the season and

length of time the buoy was on station (7 months from October 8, 1957, to May 10, 1958) and using available evidence regarding the time in which sea scallops and mussels spawn, it was possible to predict that these species had settled on the buoy before the first of the year. Hence, growth was related to the size-frequency distribution after that time.

6. Size-frequency graphs for the three common species on the buoy show that large numbers of small individuals form obvious modes and that a persistent but diminishing number of larger specimens spread over a considerable range; i.e., the major modes for the three species are skewed to the right. Possible reasons for such size-frequency distribution are discussed.

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Vol. 90

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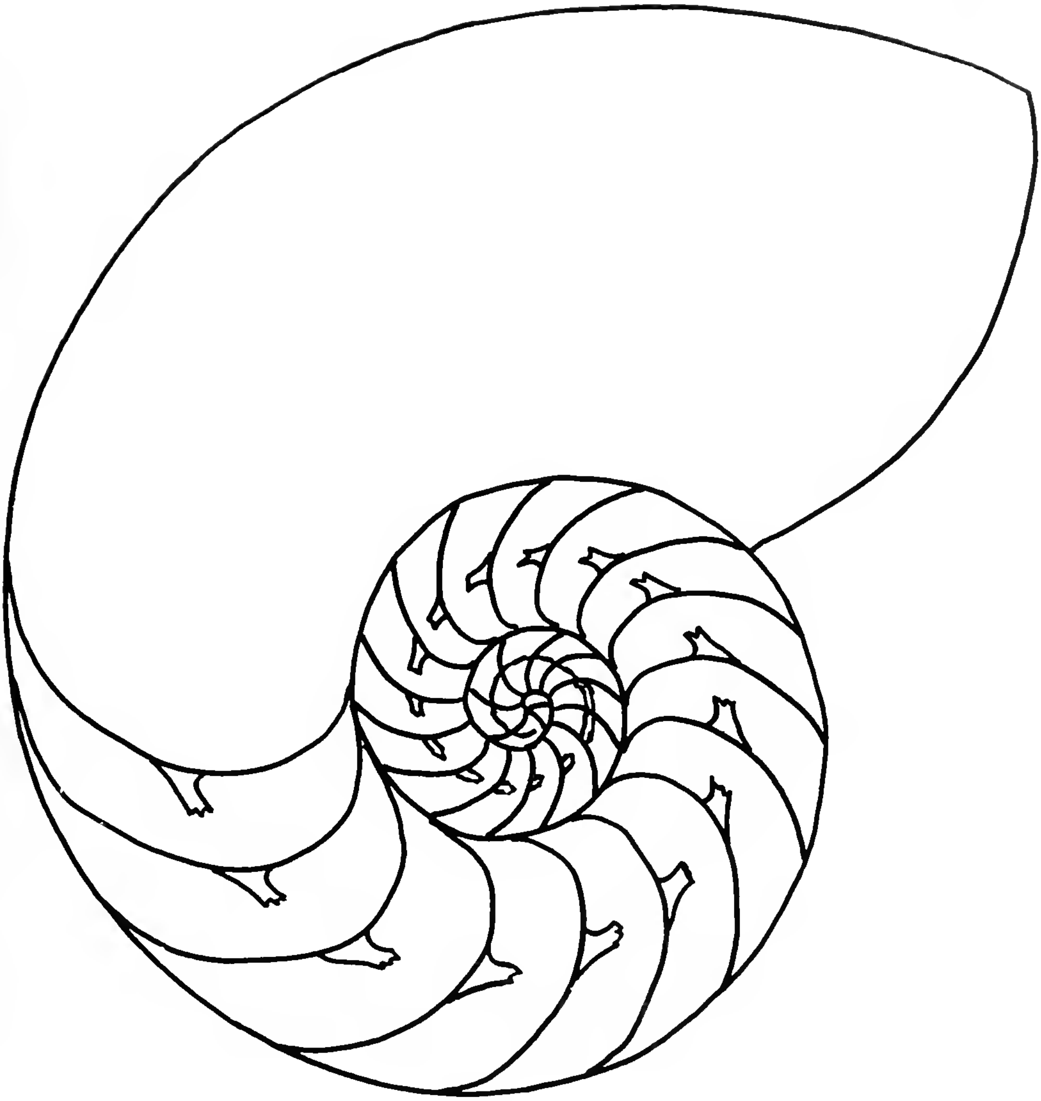
devoted to
malacology and
the interests of
conchologists



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THE
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NOTICES

WESTERN SOCIETY OF MALACOLOGISTS

The ninth annual meeting of the Western Society of Malacologists will be held from June 23—27, 1976, on the Asilomar State Conference Grounds, Pacific Grove, California. The program will feature contributed papers, symposia, displays, shell auction and field trips. Send inquiries to Mr. Clifton Martin, 324 Kennedy Lane, Oceanside, California 92054.

1976 AMU MEETING

The meetings will be held on the campus of the Ohio State University, Columbus, with registration Monday afternoon (Aug. 2) and the opening of the sessions that evening. Air-conditioned rooms with private bath at the University Residence Halls are only $11.00 per single and $15.00 per double occupancy. Banquet, Thursday, Aug. 5; Field Trip, Friday, the 6th. Amateur night will feature a shell book auction and bazaar. Forms will be mailed to members in May. Inquiries: AMU '76, Museum of Zoology, Ohio State University, 1813 North High Street, Columbus, Ohio 43210.

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REVIEW

THE BEST OF THE NAUTILUS. *A bicentennial Anthology of American Conchology.* By Abbott, R. Tucker (editor). 1976. viii + 280 pp. American Malacologists, P.O. Box 4208, Greenville, Delaware 19807. $13.95.

In this Bicentennial year it is most appropriate to look back over "the best of the *Nautilus.*" Dr. R. Tucker Abbott, current editor-in-chief of the *Nautilus* has done this for us, and for our pleasure and enlightenment he has assembled a special volume to serve both as a source of some classic studies in early American conchology and of some historically interesting papers not available to those who do not have a complete set of the *Nautilus.* Not only original papers are included, but brief notes, news items, obituaries, advertisements and exchange offers (but don't answer any of them!) are sprinkled throughout. There is something here for everyone—reports for the serious student, advice for the shell collector, warnings for the environmentalist, nostalgia for the antiquarian, oddities for the curious, and humor for everyone. Even verse is included. Everyone will appreciate "Salute to the *Nautilus,*", a verse by Henry Dodge, the only piece not originally published in the *Nautilus,* and the only item of recent date. Stress is given throughout the volume to the romance of shell collecting and the human side of malacology.

Coverage is the first 40 years of publication (1886-1926), out of a total of 90 years, beginning with a reproduction of the postal card which formed issue No. 1 of Volume 1, then known as *The Conchologists Exchange,* and Pilsbry's introduction to the *Nautilus,* beginning with Volume 3.

Selections are grouped according to geographic areas—the Atlantic Coast, the Pacific Coast; the major habitats—land, fresh-water, marine; foreign collecting; departed friends; and miscellaneous. Familiar names of the giants of conchology—Pilsbry, Simpson, Johnson, Clench, Henderson, Roper, Morse, Winkley, Keep, Fred Baker, Frank Baker, Oldroyd, Eyerdam, Ferriss, Frierson, Cockerell, Goodrich, Walker, etc. appear on every page. Many articles are prefaced with editorial notes of a biographical nature.

Illustrations include a color plate of 11 selected, colorful marine, freshwater, and land shells, many drawings of shells, diagrams of antique apparatus (in the ads), and reproduction of the original figures illustrating each article.

Having read through many volumes of the *Nautilus* for my own studies, and as official abstractor for *Biological Abstracts* over a long period of time, I can assure the reader that Tucker Abbott has made a most interesting selection of material to exemplify what professional and amateur conchologists and malacologists were doing, thinking, and writing to advance the study of mollusks over the first 40 years of the *Nautilus,* and to share with us the excitement they experienced.

Ralph W. Dexter
Dept. of Biological Sciences
Kent State University
Kent, Ohio

THE MITRIDAE OF THE GALAPAGOS ISLANDS

Gale G. Sphon

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Santa Monica, Calif. 90402

ABSTRACT

Eleven species of Mitridae are known to occur in the Galapagos archipelago. Of these, three are endemic. The range of Mitra mitra *is extended to include the Eastern Pacific. The generic or subgeneric standing of four species is changed. A new species,* Subcancilla edithrexae, *is described from the Galapagos Islands.*

The family Mitridae ranks as one of the largest in the molluscan phylum. Cernohorsky (1970) recorded over 800 valid species and stated that 2624 names had been proposed. The majority of mitrids are found in the Indo-Pacific. In the Eastern Pacific, I recognize about 30 valid species. Within the Galapagos Islands, this number is reduced even further. As far as I have been able to determine there are only eleven species occurring in the archipelago.

First, a new record for the Eastern Pacific: *Mitra (Mitra) mitra* (Linnaeus, 1758). In the Indo-Pacific this is a very common species, but Eastern Pacific records are based on only three specimens, one adult living specimen taken off the coast of Costa Rica and two adult, but dead, specimens dredged by Jacquline and Andre DeRoy in the Galapagos. The DeRoys retained one specimen for their own collection and deposited the other at the Charles Darwin Research Station. The Costa Rican specimen is in the collection of the Los Angeles County Museum of Natural History.

The next species is *Mitra (Isara) effusa* Broderip, 1836. *Mitra effusa* is not common anywhere within its range from Mazatlan, Mexico, to Ecuador and the Galapagos. However, it has been dredged in several locations in the Galapagos by the DeRoys. Cernohorsky (1970) synonomized the subgenus *Isara* with *Mitra* s.s. However, the shape of the shell with its drooping lip is distinct enough to warrant its separation as a valid subgenus.

The third species is evidently endemic to the archipelago. This is *Mitra (Mitra) gausapata* Reeve, 1845. Keen (1971) placed this species in the subgenus *Strigatella*. I am here reassigning it to the subgenus *Mitra*, based on the radula and shell morphology. Apparently this is one of the sand-dwelling *Mitra* and occurs subtidally throughout the archipelago. It appears to be relatively common within its restricted range.

The fourth species is *Mitra (Mitra) crenata* Broderip, 1836. Again, the subgenus is changed here from *Strigatella* to *Mitra* s.s. Specimens I have seen indicate that it is probably a good species and not the young of something else, even though at the present time the radula is still unknown. The range of the species is from Guaymas, Sonora, Mexico, south to and throughout the Galapagos Islands.

Its authors put *Subcancilla sphoni* (Shasky and Campbell, 1964) in the subgenus *Strigatella*. Keen (1971) questioned this. Neither the shape nor the spiral sculpture are characteristic of *Strigatella* and it is here changed to the genus *Subcancilla*. It ranges from Guaymas, Sonora, Mexico, to the Galapagos Islands.

The sixth species is a common intertidal species throughout most of its range, from the head of the Gulf of California to Peru. However, *Mitra (Mitra) lens* Wood, 1828 is rare in the Galapagos. To my knowledge it has only been taken once in the Archipelago at Academy Bay, Santa Cruz Island by Carmen Angermeyer in 1964. This specimen is now in the American Museum of Natural History. *Mitra lens*, also, should be removed from the subgenus *Strigatella* and placed in the subgenus *Mitra* on the basis of the radular structure.

The seventh species is the only true *Strigatella* in the Eastern Pacific and this is *Strigatella tristis* (Broderip, 1836). This is prob-

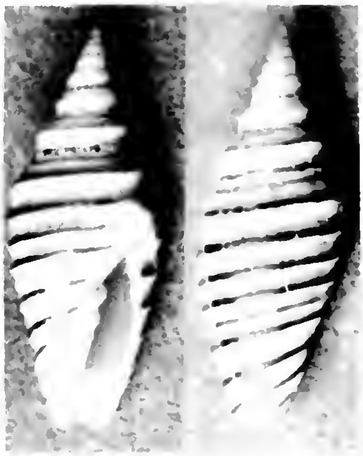

FIG. 1. Subcancilla edithrexae *Sphon, new species. Holotype Length 22.6 mm. Width 9 mm.*

ably the most common Eastern Pacific *Mitra.* It ranges from the head of the Gulf of California, south to Ecuador and the Galapagos Islands.

Although *Strigatella* is a large group, all the members resemble one another in their pyriform shape. Some authors have used *Strigatella* as a genus, and I tend to agree with them even though there is little difference in the radula of *Mitra s.s.* and *Strigatella.*

The next three species all belong to the genus *Thala.* The type locality for *Thala gratiosa* (Reeve, 1845) is the Galapagos and it has a much larger range than the others, namely from the Gulf of California to Panama. It has also been, mistakenly, called *Thala solitaria* (C. B. Adams, 1852). *T. solitaria* occurs from Banderas Bay, Mexico, to the Galapagos and was described from Panama. The true *Thala solitaria* is one of the rarer Eastern Pacific miters. The third species of *Thala* is *T. jeancateae* Sphon, 1969 and it is known only from a half dozen specimens from the Galapagos.

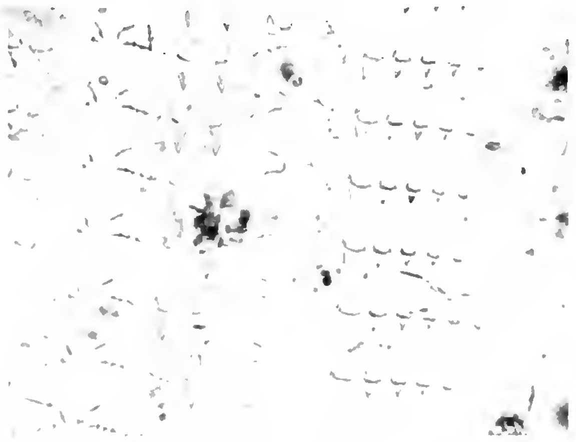

FIG. 2. *Radula of* Subcancilla edithrexae *Sphon, new species (from a paratype).*

The eleventh and last mitrid species is new to science, and I take great pleasure in naming it in honor of a very dear friend, Miss Edith Rex.

Subcancilla edithrexae Sphon, *new species*

Shell of moderate size, to 22 mm in length; shape ovate with raised reddish brown ribs about one quarter to one half the width of the white interspaces; periostracum thin and brownish; interspaces marked by numerous irregular growth lines; columella with 3 or 4 plications; spire attenuate, angle acute; aperture narrow, slightly more than half the shell length; Radula formula 1-1-1; Triangular-shaped rachidian wider than high, with 6 cusps, the center 4 being of equal size and prominent, the outer ones being one-third as large, a small denticle present on the ends nearest to laterals; laterals with eleven cusps, the two outer ones mere denticles, next six progressively larger nearing the median tooth; third cusp from the median largest; innermost two reduced in size; lateral tooth plate basically rectangular in shape with slight curve to lower portion.

The holotype was collected by the Ameripagos Expedition, in 10-20 feet of water on March 25, 1971. The type locality is Punta Alfaro, Isabela Island, Galapagos Islands, Ecuador. It is deposited at the Los Angeles County Museum of Natural History (LACM 1735). There are numerous paratypes in the following institutions and private collections: American Museum of Natural History; California Academy of Sciences; Charles Darwin Research Station; and several private collections.

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OBSERVATIONS ON THE ECOLOGY OF THE FLORIDA TREE SNAIL, *LIGUUS FASCIATUS* (MÜLLER)

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ABSTRACT

Four South Florida populations of Liguus fasciatus *were studied over an eight month period. Growth was calculated by means of size frequency diagrams and age class groupings, and was found to be roughly linear.* L. fasciatus *hatches at a size of 7 mm, grows aproximately 10 mm per year, and reaches sexual maturity in its fourth year at a size of about 48 mm. Copulation occurs in the months of July, August and early September, and nesting follows in late September. Mass mortality of adult snails was observed soon after nesting. The young emerge with the rains in April and May, but are fully developed long before. Tree snails are eaten by many vertebrates and invertebrates, and predation may exert a powerful selective pressure on this species.* L. fasciatus *displays a marked preference for smooth barked host tree species, preferential listings of which are included.* L. fasciatus *is not an endangered species in South Florida.*

Liguus fasciatus (Müller) is a tree snail of Antillean origins which probably arrived from Cuba shortly after the emergence of the Florida peninsula in the late Pleistocene. In Florida, *L. fasciatus* is found exclusively in hammocks, assemblages of tropical hardwood trees scattered island-like in the 'Glades and pinewoods of the extreme southern part of the state. Hammocks provide *Liguus* protection from fire, predators, cold spells, and dessication.

The species exhibits great variability in coloration of the shell which is often of striking beauty. Consequently this snail has long been popular with collectors, and an enormous literature exists dealing almost exclusively with its systematics and zoogeography. Surprisingly, little has been published on the ecology of *L. fasciatus*. What has been published on the subject consists largely of scattered notes, or passing references in larger, systematic works (Pilsbry 1946, Simpson 1929, Weber 1953, etc.). The best account to date is in a popular article by Davidson (1965), but the ecological literature on this snail is, as a whole, exceedingly sketchy. It is hoped that this paper will help to fill this gap.

METHODS

This study was carried out over an eight-month period from August 1969 to March 1970 during which weekly field observations were made. Attention was centered on four *Liguus* populations, three on the east coast of Florida near Miami (Matheson, Brickell, and Timm's Hammocks) and one on the eastern edge of the Big Cypress Swamp (Pinecrest #5, Pilsbry 1946) about fifty miles west of Miami.

Snails were sighted and collected either by hand or with the aid of a "Lig pole", three interlocking four foot aluminum tubes with a cup on the end into which the snail was shoved. Measurements of living snails were taken in the field: total length from the apex of the shell to the base of the aperture.

Eggs were incubated in one-pint Mason jars kept outdoors and occasionally sprinkled with water. Young were maintained for short periods in an indoor terrarium and provided with wet bark on which to feed.

All of the dead shells on several square meters of forest floor were collected for predation studies. When studying tree preference, the hammock was "walked" and all trees closely scrutinized for snails.

RESULTS AND DISCUSSION

Reproduction: *Liguus fasciatus* mates in the summer primarily in the months of July, August and early September, which is the rainy season. I have, however, observed copulating pairs as late as September 20. Snails on trees and on the ground often appear to follow the mucus tracks of others, and individuals may locate each other prior to mating in this way. Mating was only observed on trees. A long interval of intertwining precedes copulation.

Gestation takes from three to six weeks, and at the first heavy rain the snails descend to lay their eggs. The nesting procedure is as follows: the snail anchors part of its foot on the base of the tree, and tentatively stretches out across the leaf litter. Reassured, it releases its hold, and begins probing the humus for a suitable nest site. This operation may occupy some half hour or more. After locating a spot, the snail begins to pull itself into the humus by extensions and contractions of the foot until only the apex of the shell remains above ground. Here it hollows out a nest in the earth consisting of a vertical tunnel, 10 to 15 mm in diameter, which widens to form a chamber for the eggs. The depth of the nest varies from 40 to 50 mm. The entire nesting process lasts between 59 and 75 hours, during which time the snail is extremely vulnerable to terrestrial predators.

In 1969, snails were observed laying eggs only from 14-27 September. The peak of egg laying activity was from the 14th to the 19th, after some exceptionally heavy rains. Of nineteen snails observed nesting in Matheson Hammock on September 16, the range in clutch size and mean clutch size was 14-**19**-30 eggs. The range in size and average size of nesting snails was 40-**48.3**-60 mm. No correlation was observed between size of snail and clutch size. The eggs of *L. fasciatus* are oval, 6.5-8.0 mm long and 5.5-6.0 mm wide, brittle, and pinkish brown (Ridgway's Color Guide's *Light Vinaceous Fawn* (Weber 1953)) in color.

Many snails die soon after nesting. This is evidenced by the disproportionately large numbers of freshly dead snails observed for a month or so after the egg laying period, a phenomenon also noted by Simpson (1920). This field observation was later verified by examining size frequency diagrams (Figs. 1 and 2). Here, it is seen that the number of snails per size range drops off considerably for sizes greater than 48 mm, the average size at nesting, indicating low post-reproductive survivorship. High post-reproductive mortality may

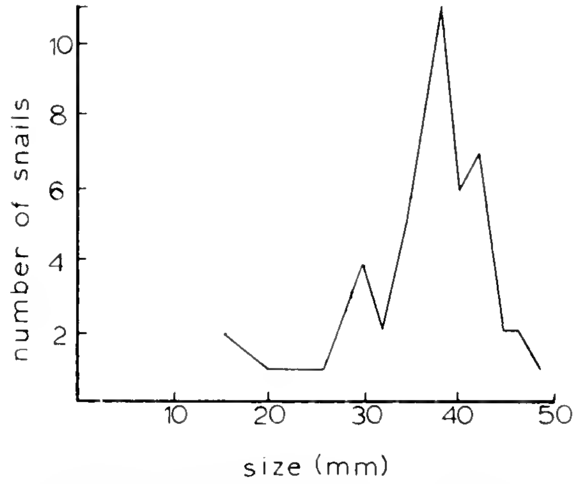

FIG 1 *Size frequency distribution of a sample of 52* Liguus *from Timm's Hammock.*

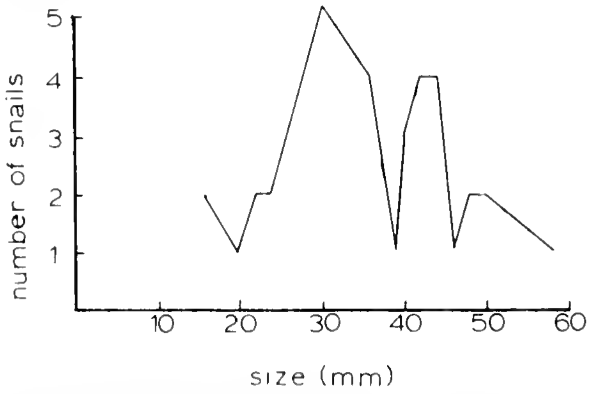

FIG. 2. *Size frequency distribution of a sample of 34* Liguus *from Brickell Hammock.*

function to reduce competition between nonproductive adults and their potentially productive young.

Hatching occurs after the first heavy rains in April or May apparently due to increasing warmth and moisture, as the snails are fully developed after six weeks (Weber 1953). Snails removed from the egg by me after fifteen weeks, and provided with wet bark to feed on, began to grow immediately; snails left in the egg did not hatch for another three months. The newly hatched young measure 6.0-7.0 mm long.

Aestivation and Feeding: During the winter months from November to March, the dry season in southern Florida, *Liguus fasciatus* secretes a mucus seal which cements the shell to the tree, protecting the animal from dessication. During this time the shell does not grow. Upon resumption of feeding with the spring rains, shell growth begins anew, and a growth line appears where lip growth ceased during the winter. By counting the number of these growth lines, the age of the snail can be determined with a fair degree of accuracy. Occasional winter rains may occur, and after these snails may be seen feeding for a while before resuming aestivation.

Liguus fasciatus is largely nocturnal, and is most active after heavy rains which soften the confervoid algae (Simpson 1929) and lichens on which it feeds. This growth is abundant on tree bark, the normal substrate for *L. fasciatus*, and the feeding snail cuts visible swaths in this growth as it moves.

Growth: In an organism such as *Liguus fasciatus* in which reproduction is seasonal, discrete generations are present, and these generations should appear as peaks of size frequency when the measurements of large numbers of individuals from a given population are graphed. Such was found to be the case, and graphs of size versus frequency for the Timm's and Brickell Hammock populations are given in Figures 1 and 2. Peaks represent successive generations and the distance between them a years growth. Averaging the data from the two populations, and assuming that the young hatch at a size of 7 mm, it is found that *L. fasciatus* grows approximately 9 mm the first year, 14 mm the second, 11 mm the third, and 7 mm the fourth. Measurements throughout were taken from the apex of the shell to the base of the aperture.

TABLE 1 *Average size of snails from three hammocks grouped according to annual growth marks (total length in mm.) M = Matheson Hammock; B = Brickell Hammock; T = Timm's Hammock; in the column "mean growth" the snails assumedly hatched at 7 mm.*

YEAR	*M*	*Hammock* *B*	*T*	*Mean size*	*Mean growth*
1	18	23	18	19.6	12.6
2	28	30	29	29.0	9.4
3	34	43	36	37.6	8.6
4	49	49	42	46.6	9.0

A second method employed in estimating growth was that of grouping the snails by annual growth marks (discussed in the preceding section), and averaging the sizes of individuals in each group. Year class averages calculated by this method (Table 1) yield the following figures for growth: first year 13 mm, second year 9 mm, third year 9 mm, fourth year 9 mm.

Data derived from both of the above methods were plotted on the same graph (Figure 3), and growth (measured as total length) was found to be approximately linear. Mean size of nesting individuals was found to be 48 mm, and by locating this size on the line fitted to the data points in Figure 3, it is found that reproduction occurs at the end of the fourth year of growth.

Tree Preference: While observing tree snails, it was noted that they displayed a marked preference for certain tree species. This ten-

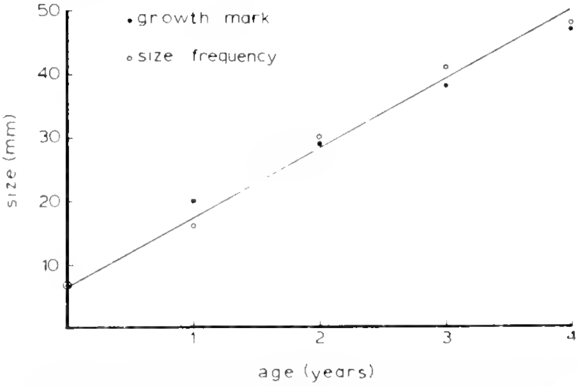

FIG. 3. *Size (total length) vs age for* Liguus. *Data derived from size frequency diagrams and age class groupings.*

TABLE 2. *Host trees of 50* liguus *from Timm's Hammock*

Number of snails	*Host tree species*
34	Tamarind *Lysiloma bahamensis*
5	Poisonwood *Metopium toxifera*
3	Jamaica Dogwood *Piscidia piscipula*
2	Paradise Tree *Simarouba glauca*
2	*Tetrazygia bicolor*
2	Live Oak *Quercus virginiana*
1	Strangler Fig *Ficus aurea*
1	dead wood

TABLE 3. *Host trees of 21* Liguus *from Matheson Hammock*

Number of snails	*Host tree species*
7	Strangler Fig *Ficus aurea*
2	Paradise Tree *Simarouba glauca*
2	Seagrape *Cocoloba uvifera*
1	Mastic *Mastichodendron foetidissimum*
1	Live Oak *Quercus virginiana*
1	Jamaica Dogwood *Piscidia piscipula*
7	Miscellaneous (ground, palmetto leaves, dead wood, etc.)

dency has been noted before in the literature (Simpson 1929, Craig 1973), but quantitative data has not been made available.

The host trees of 50 *Liguus fasciatus* were tallied, and the results are given in Table 2 (Timm's Hammock). In this hammock, 65% of the snails were found on *Lysiloma*, 9% on *Metopium*, and 6% on *Piscidia* with the remaining 20% being found sparingly on four other species.

The host trees for 22 *Liguus fasciatus* from Matheson Hammock are listed in Table 3. In this hammock, *Lysiloma* and *Metopium* are absent or scarce. The trees most frequented in this case were *Ficus* (32%), *Simarouba* (9%), and *Cocoloba* (9%). An unusual number of snails were found on atypical substrates on the day when this survey was made.

Other trees on which I have commonly observed *Liguus* are the Mastic *(Mastichodendron foetidissimum)*, and the Guava *(Psidium guajava)*. Citrus groves in or near hammocks are often found to contain numbers of tree snails. Simpson (1929) found *L. fasciatus* on cypress trees *(Taxodium)*, and White Buttonwood *(Conocarpus erecta)* in fresh and salt water swamps respectively. It seems unlikely that these represented breeding populations considering the terrestrial nesting habits of these snails. It is possible that Simpson's specimens were isolated individuals accidentally dropped by birds, or snails which had wandered away from hammocks in the dry season, to be later isolated by rising water.

It appears from the preceding data that *L. fasciatus* strongly prefers certain tree species over others. In each case, the preferred species are smooth barked trees. On such trees there is an abundance of algal growth on the bark, the smooth surface of which permits the snail to crawl easily, and presumably permits a long, unobstructed sweep of the radula. It should be noted however, that *L. fasciatus* will feed over any smooth algae covered surface including concrete walls and the sides of wooden outhouses (personal observations).

Predation: In southern Florida, *Liguus fasciatus* is preyed upon by a wide variety of vertebrates and invertebrates. While the contribution of *L. fasciatus* to the food budget of individual predator species may be small, their cumulative effect on tree snail populations may be quite large.

The carnivorous gastropod *Euglandina rosea* has long been known to devour *L. fasciatus*, and Baker (1903) observed that it likewise devours the much larger native tree snail *Orthalicus*. Davidson (1965) observed and photographed *E. rosea* predation on *L. fasciatus*. *E. rosea* seems to be primarily a terrestrial species associated with rocky substrates, but I have often observed it on concrete walls, and it may climb trees as well.

Pilsbry (1946) stated that he had "seen no evidence that the tree snails are molested by native birds", but friends have repeatedly observed Blue Jays *(Cyanocitta cristata semplei)* devouring *L. fasciatus*, and I have frequently noted broken shells in areas where other predators are scarce. Further, the condition of many freshly broken empty shells is too intact for any but a beaked animal to have removed the snail.

Rats have often been reported as a major predator on *L. fasciatus*. Pilsbry (1946) believed that they would soon exterminate these snails in all accessible hammocks. Timm's, Matheson and Brickell hammocks have been surrounded for many years by human habitations, however, and their snail populations continue to thrive. Clench (1975) has suggested the ameliorating effects which domestic cats and dogs may have on the hammock rat populations, and contends that rats may indeed prey rather heavily on *L. fasciatus*.

The native land hermit crab, *Coenobita clypeatus* may also prey on tree snails. Davidson (1965) observed possible predation on *L. fasciatus* by this crab, but in a fit of anthropomorphic compassion removed the crustacean before it could eat (?) the snail. I have occasionally seen crabs of this species inhabiting tree snail shells in Brickell Hammock, but as *Coenobita* will occupy any suitable empty gastropod shell it encounters, this cannot be taken as proof of predation.

The land crab *Cardisoma guanhumi* may also eat *L. fasciatus*, for its burrows are often surrounded by the broken shells of this species. Rhoads (1899) reported that *L. fasciatus* is "eaten by tree crabs which bite the shell in half during their winter hibernation". He cites the occurrence of broken basal portions cemented on trees as evidence. This seems an unlikely hypothesis as *Cardisoma* does not climb, and *Coenobita*, a good climber, seems too small to break a snail shell in two: Davidson's photograph shows *Coenobita* inserting its claws into the aperture. I would imagine that Rhoad's "tree crabs" are in fact raccoons or oppossums which frequently climb and have been reported as preying on *L. fasciatus*.

Of 189 empty tree snail shells collected in the leaf litter of Matheson Hammock (where all of the above predators occur), 52% of the shells were intact, indicating natural death or *Euglandina* predation; 38% of the shells were crushed leaving only the apex, suggesting raccoon, oppossum, rat, or crab predation. The remaining 10% were broken open on one side only, suggesting predation by birds. These conclusions are only speculative, but if the sample was a representative one, then it indicates that nearly half of tree snail mortality is due to predation, which must then be viewed as a powerful selective force impinging on *Liguus* populations. If so, and if a significant number of predators locate *L. fasciatus* visually, then the elaborate banding patterns of this snail may have a much greater adaptive significance than has been hitherto recognized. This is a fertile field for further research.

Contrary to the cries of alarmist conservationists, *Liguus fasciatus* does not appear to be an endangered species in South Florida. It is quite commonly found in the tropical hammocks of the area, and these hammocks are largely preserved within the county, state and federal parks. It is true that certain local and rare color varieties have been exterminated by collectors and developers, but the species as a whole continues to thrive.

ACKNOWLEDGMENTS

I wish to thank my parents, Dr. Gilbert L. and Mrs. Nancy A. Voss for their constant assistance and encouragement. I would also like to thank Mr. Arthur Peavy, Director of Dade County Parks, for permission to work with tree snails in the county parks; Mr. John C. Eckhoff for his enthusiasm and assistance; Mrs. Rita Sturgeon of the Florida Department of Agriculture; the Rosenstiel School of Marine and Atmospheric Sciences for the use of its library. I also extend my thanks to Dr. William J. Clench for critically reviewing the manuscript, and to Dr. Walter B. Miller for his helpful suggestions.

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NEW SPECIES OF *SONORELLA* (PULMONATA: HELMINTHOGLYPTIDAE) FROM NEW MEXICO AND TEXAS

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ABSTRACT

Two new species of land snails of the genus Sonorella (metcalfi *and* todseni) *are described from Doña Ana County, New Mexico, and El Paso County, Texas.*

Sonorella orientis Pilsbry, 1936, was first collected in 1897 by C. H. T. Townsend in Fillmore Canyon, Organ Mountains, Doña Ana County, New Mexico, as stated by Pilsbry and Ferriss (1905). The type lot, including live snails, was collected by Ferriss and Pilsbry in 1922, at Dripping Springs in Ice Canyon, Organ Mountains, just south of Fillmore Canyon, and was described as a subspecies of *Sonorella hachitana* (Dall, 1895) by Pillsbry (1936). I collected it in Fillmore Canyon on 7 June 1965, but was unable to obtain live specimens for dissection. Subsequently, Artie L. Metcalf, of the University of Texas at El Paso, sent me live specimens from several localities in Fillmore Canyon, Ice Canyon, and Rock Springs Canyon. Dissection of several series of specimens revealed that the reproductive anatomy differed significantly from that of *S. hachitana*. This information, plus evidence obtained in my laboratory (unpublished hybridizing experiments) that *S. hachitana* is apparently an obligate calcicole, with peculiar nutritional or growth factor requirements, were considered sufficient to infer probable reproductive isolation and accordingly, Bequaert and Miller (1973) raised *S. orientis* to specific rank.

Since 1967, Artie Metcalf and Thomas Todsen have continued to collect in the Organ Mountains, as well as in the San Andres Mountains to the north, the Doña Ana Mountains to the west, and the Franklin Mountains to the south. They have kindly sent me many specimens from their collections. Examination of shell characteristics as well as reproductive anatomy of the collected specimens reveals the presence of two new species of *Sonorella*, one in the Franklin Mountains and one in the Doña Ana Mountains. I take great pleasure in naming these new species after their discoverers, Dr. Artie L. Metcalf of the Department of Biological Sciences, University of Texas at El Paso, and Dr. Thomas K. Todsen, of the White Sands Missile Range, New Mexico. I also wish to thank the Commander, White Sands Missile Range, and his staff for permitting this scientific exploration of the San Andres Mountains.

Sonorella metcalfi new species

Figs. 1 and 4

Description of holotype. Shell depressed-globose, heliciform, thin, glossy, light tan, with chestnut spiral band on the well-rounded shoulder; umbilicate, the umbilicus contained 10 times in the diameter and about ¼th covered by the reflected columellar lip. Embryonic shell of 1½

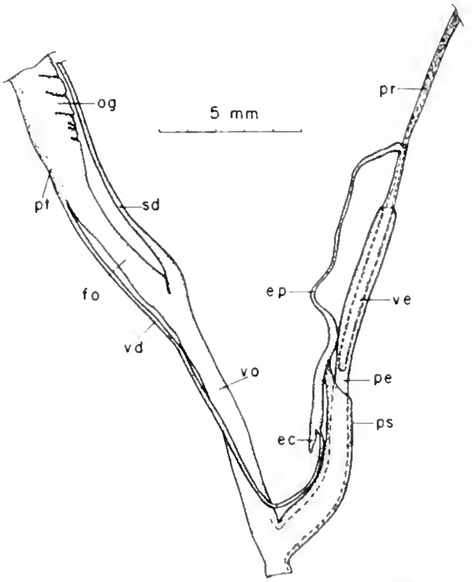

FIG. 1. Sonorella metcalfi, *new species, W. B. Miller. Distal reproductive structures. Drawing made from stained whole mount. Abbreviations:* **ec** *epiphallic caecum;* **ep** *epiphallus;* **fo** *free oviduct;* **og** *oviducal gland;* **pe** *penis;* **pr** *penal retractor;* **ps** *penal sheath;* **pt** *prostate;* **sd** *spermathecal duct,* **va** *vagina;* **vd** *vas deferens;* **ve** *verge.*

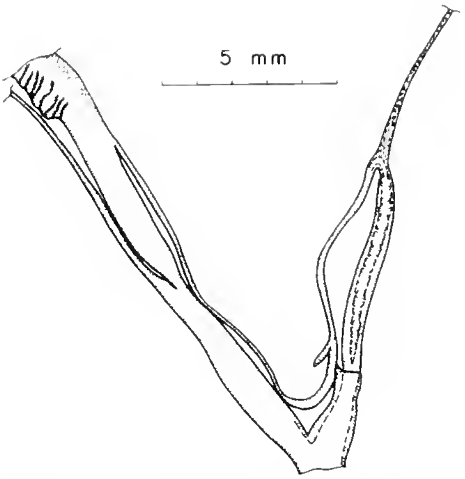

FIG. 2. Sonorella todseni, *new species, W. B. Miller. Distal reproductive structures. Drawing made from stained whole mount.*

whorls, silky-smooth, not glossy, with light, radial ripples and traces of descending, spiral threads above the suture, visible at about 10× to 20× magnification. Post-embryonic whorls marked with light growth wrinkles. Last fourth of body whorl with light, incised spiral lines, most pronounced near shoulder. The periostracum has a silky, lustrous appearance. The last whorl descends abruptly to the slightly expanded peristome. Aperture oblique, rounded, slightly wider than high, with margins converging; parietal callus thin. Shell measurements, in mm: diameter 19.8, height 12.0, umbilicus 2.0, 4¼ whorls.

Reproductive anatomy. The ovotestes, hermaphroditic duct, seminal vesicle, albumen gland, spermoviduct, spermatheca, and spermathecal duct are typical of the genus. The penis contains a long, thin cylindrical verge bluntly rounded at its tip; the verge is slightly less than half as long as the penis. A penial sheath covers the distal half of the penis. Epiphallus very thin distally, the distal end embedded in the penial retractor muscle, then enlarging proximally to its junction with the vas deferens and the short, free, epiphallic caecum. Vagina about ¾th the length of the penis. Lengths, in mm, as follows: Penis 13; penial sheath 6.5; verge 6; epiphallus 14; epiphallic caecum 0.8; vagina 10.

Type Locality. North Franklin Mountain, El Paso Co., Texas, in a northwest arm of Fusselman Canyon, above spring. Latitude 31° 53.7′ N, longitude 106° 29.0′ W; elevation *ca* 5300 feet. Collector: Artie L. Metcalf, 11 May 1972.

Type Material. Holotype, United States National Museum No. 760816. Paratypes: Delaware Museum of Natural History, No. 99172; Academy of Natural Sciences of Philadelphia, No. 338227; Museum of Arid Land Biology, U. T. El Paso, No. 4374, and the author, No. 5938.

Distribution. Sonorella metcalfi is found in the Franklin Mountains of Texas and in the southernmost part of the Organ Mountains of New Mexico. It has been collected at the following localities: Franklin Mountains: (1) Several localities in Fusselman Canyon, (2) Tom Mays Park, 0.2 mi SW of West Cottonwood Spring, (3) West slope of South Franklin Mountain, at *ca* 5500 feet. Organ Mountains: head of Finley Canyon at *ca* 6000 feet. All collections by Artie L. Metcalf.

Sonorella todseni new species

Figs. 2 and 4

Description of holotype. Shell depressed-globose, heliciform, thin, glossy, light tan, with narrow, chestnut spiral band on the well-rounded shoulder; umbilicate, the umbilicus contained 7 times in the diameter and only slightly covered by the reflected columellar lip. Embryonic shell of 1½ whorls, dull with minute radial ripples on which are superimposed many spirally descending and ascending interrupted threads and granules. Postembryonic whorls marked with light growth wrinkles and granules, the granules becoming absent on the body whorl. The periostracum has a silky, lustrous appearance. The last whorl descends abruptly to the slightly expanded peristome. Aperture oblique, rounded, slightly wider than high, with margins converging; parietal callus very thin. Shell measurements, in mm: diameter 17.9, height 9.6, umbilicus diameter 2.6; 4¼ whorls.

Reproductive anatomy. Ovotestes and proximal accessory structures as in other *Sonorella.* The penis contains a long, thin, unevenly corrugated verge tapering to a pointed tip; the

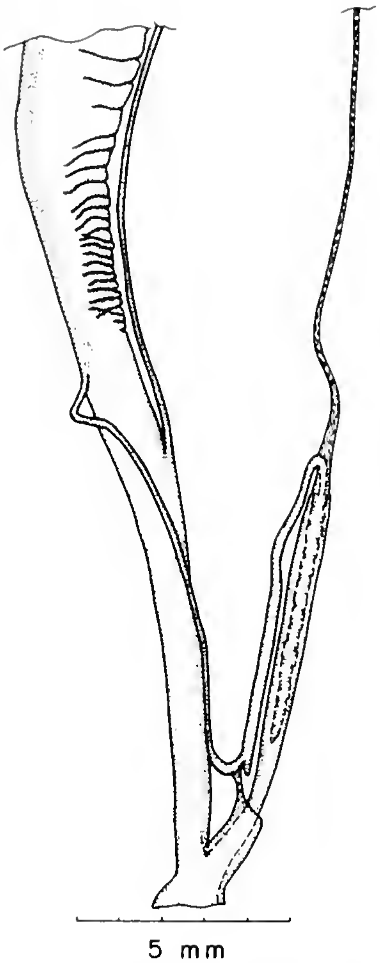

FIG. 3. Sonorella orientis *Pilsbry. Distal reproductive structures. Drawing made from stained whole mount.*

verge is about ⅔ the length of the penis. A penial sheath envelops the distal third of the penis. Epiphallus thin, the distal part embedded in the penial retractor muscle; a very short, free, epiphallic caecum is present. Vagina about ¾ the length of the penis. Lengths in mm, as follows: penis 8, penial sheath 2.5, verge 5.5, epiphallus 6.5, epiphallic caecum 0.7; vagina 6.

Type Locality. Doña Ana Mountains, Doña Ana Co., New Mexico, on NW slope of Doña Ana Peak (NW ¼, SW ¼, NE ¼, Sec. 25, T 21 S, R 1 E); elevation *ca* 5300 feet. Collector: Artie L. Metcalf, 28 August 1972.

Type Material. Holotype, United States National Museum No. 760817. Paratypes: Delaware Museum of Natural History, No. 99171; Academy of Natural Sciences of Philadelphia, No. 338228; Museum of Arid Land Biology, U. T. El Paso No. 2809; private collection of the author, No. 5973.

Distribution. Sonorella todseni is known only from the Doña Ana Mountains of New Mexico, a small, detached outlier of the Organ Mountains, just north of Las Cruces. It was originally collected on 1 October 1967 by Dr. Thomas L. Todsen (ALM #850; WBM #5023), a small lot of shells only. Subsequently, a lot containing one live adult was collected by Edward Stern and Artie Metcalf on 23 January 1969 (WBM #5103). The type lot, consisting of many live adults as well as shells only, was collected by Artie Metcalf on 28 August 1972.

Remarks. Compared to *S. metcalfi, S. todseni* has a generally smaller, lower, more widely umbilicate shell, with the umbilicus less covered by the reflected columellar lip. Fresh shells tend to show heavier granulation under high magnification. It is in the anatomy that differences are more easily discerned. *S. todseni* has a coarsely corrugated verge, tapering to a

FIG 4. *Top row,* Sonorella todseni, *new species, W. B Miller. Middle row,* Sonorella metcalfi, *new species, W. B Miller. Bottom row,* Sonorella orientis *Pilsbry.*

pointed tip; the walls of the penial chamber surrounding the verge are relatively smooth. *S. metcalfi* has a nearly smooth, cylindrical verge, bluntly rounded at its tip; the walls of the penial chamber surrounding the verge are thickened, glandular, and finely corrugated. Although dimensions of anatomical structures show much variability, certain length ratios, such as verge/penis (ve/p), vagina/penis (va/p), and penial sheath/penis (ps/p) appear to be consistent and diagnostically useful. Approximate values of these ratios are: *S. todseni*, ve/p $^{2}/_{3}$, va/p $^{3}/_{4}$, and ps/p $^{1}/_{4}$; *S. metcalfi*, ve/p $^{1}/_{2}$, va/p $^{3}/_{4}$, and ps/p $^{1}/_{2}$.

Both *S. metcalfi* and *S. todseni* appear to be closely related to *S. orientis* Pilsbry 1936, and all three species probably speciated relatively recently from a common ancestral population. *S. orientis* (Figs. 3 & 4) has a usually larger, widely umbilicate shell. It has a long, coarsely corrugated, tapering verge, in a smooth-walled, capacious penial chamber with ve/p *ca* $^{2}/_{3}$, va/p *ca* 1 or >1, and ps/p *ca* $^{1}/_{5}$. *S. orientis* is found throughout the Organ Mountains except perhaps the southernmost part (Finley Canyon) where *S. metcalfi* is found; the possibility of their being sympatric there needs to be confirmed by additional collecting and dissection. It is also found in the San Andres Mountains (confirmed by dissection, WBM#'s 5978 and 5983) where it has been collected on Salinas Peak by Thomas Todsen and Artie Metcalf (MALB-3145, WBM 5978) on 10 September 1972 and in Ash Canyon by Artie Metcalf (MALB-3156, WBM 5983) on 23 September 1972. Shells from Sierra Blanca Mountain (Pilsbry, 1936) and the Sierra Vieja of Texas (Cheatum, Fullington, and Pratt, 1972) may also be *S. orientis* but need to be confirmed by dissection.

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THE COMMENSAL CLAM, *PARAMYA SUBOVATA (BIVALVIA: MYIDAE) AND THALASSEMA HARTMANI (ECHUROIDEA) OFF GALVESTON, TEXAS*

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Studies of macrobenthic assemblages offshore Galveston, Texas, have revealed the presence of the commensal bivalve, *Paramya subovata* (Conrad, 1845). The highest concentrations of *P. subovata* were found in May 1975 in the Bolivar Roads entrance channel (13.5 m depth) at 29° 19′ 15″ N. Lat. and 94° 38′ 42″ W. Long. A total of 242 living specimens, ranging in length from 1.5 to 6 mm, were collected at this site in five replicate spade corer samples. The average calculated abundance was 745/m². The specimens agree with the description in Abbott (1974, p. 537, Fig. 5989).

Jenner and McCrary (1970) reported *Paramya subovata* to be commensal specific with the echiuroid worm, *Thalassema hartmani* Fisher, 1947. *T. hartmani* has also been found during the present study. At the Bolivar Roads entrance channel site in May, a total of 261 individuals of *T. hartmani* were collected with an average calculated abundance of 805/m². Though direct observations of the commensalistic behavior of *Paramya subovata* were not made, this non-leptonid bivalve has rarely been found during the present studies in the absent of *T. hartmani*.

Ladd (1951) and Ladd, *et al.* (1957) reported dead specimens of *Paramya subovata* from the Lydia Ann Channel in the vicinity of Aransas Pass, Texas. As far as I am able to ascertain, this is the first report of the occurrence of living specimens of *Paramya subovata* from Texas, other than a beach-stranded specimen found alive after a hurricane on Galveston West Beach (Odé and Speers, 1970). *Thalassema hartmani* is also previously unreported from Texas coastal waters. I would like to thank Dr. R. Tucker Abbott who confirmed the identification of *Paramya subovata* (Del. Mus. Nat. Hist. no. 102595) and encouraged the development of this report. This research was supported by Contract No. DOA RES DAC W64-75-0070 from the Waterways Experiment Station, U. S. Army Corps of Engineers.

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THE OCCURRENCE OF THE DATE MUSSEL, *LITHOPHAGA BISULCATA* (MYTILIDAE), IN LIVING OYSTERS OFF GALVESTON, TEXAS

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ABSTRACT

The date mussel, Lithophaga bisulcata, *was found boring live oysters* Crassostrea virginica *and* Ostrea equestris *at three petroleum platforms off Galveston, Texas. A specimen of* Lithophaga aristata *found boring into* Ostrea equestris *is reported from Galveston.*

In the course of conducting survival and growth studies of commercial oysters (*Crassostrea virginica* Gmelin, 1791) at an offshore oil platform in the Northwest Gulf of Mexico, it was noted that the oysters had been burrowed by the date mussel *Lithophaga bisulcata* (Orbigny, 1842). Experiments during the past 2 years (1973-1974) were undertaken to determine the feasibility of culturing oysters offshore in the Gulf of Mexico, utilizing petroleum platforms for suspension culture. These experiments, under the direction of Dr. S. M. Ray[1], have utilized platform B of the Atlantic Richfield Company located 8 miles offshore from High Island, Texas, east of Houston in approximately 10 m of water. The salinity varies from 23 to 31 ppt over the year with an average of 26 ppt. Temperature varies from 14° to 29°C with a yearly average of 22°C. Mussels were first noted during June 1974 in oysters that had been suspended at the platform for 17 months. Ten oyster shells were carefully broken apart and the number of mussels determined (Table 1) on three different occasions.

Shell boring pholad clams identified as *Diplothyra smithi* Tryon, 1862 were also found in the oysters, two examined in June, five in

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[1] Head of Moody College of Marine Science

TABLE 1. *Intensity of mussel infestations in* C. virginica

Date	*Average oyster size (mm)*	*No. of mussels per oyster*	*Size of mussels (mm)*	
			Average	*Range*
June 1974	98	24	7	2-12
Sept 1974	93	21	6	2-19
Dec. 1974	106	13	12	4-21

September and three in December of 1974. The pholad borers were all from oysters suspended in the upper 4 m of water. The boring mussels were found in oysters suspended throughout the water column.

No borers were noted during the 16 months prior to June 1974 that oysters were suspended offshore. It is suggested that both species of borers settled during the summer of 1974. Burrows of *L. bisulcata* were found in all parts of the oyster shell as indicated by the radiograph (Figure 1). The greatest number of mussels was found anterad, close to the umbo, possibly due to the greater thickness of the shell in this area. In some cases the burrows penetrated into the interior cavity of the shell. Several oysters were actively depositing shell material in response to the boring activity of the mussels (Figure 2).

In November 1974, oysters occurring naturally on oil platforms were collected utilizing SCUBA. Both *Ostrea equestris* Say, 1834 and *C. virginica* were collected at depths of 6-12 m from a platform 12 miles south (173°) of the Galveston lighthouse. No date mussels were found, but burrows were observed in both specimens of *C. virginica* collected. *Ostrea equestris*, the only oyster species observed on another oil platform 29 miles south (173) of the Galveston lighthouse occurred in the water from 12 to 21 m. Eleven *O. equestris* examined were infested with an average of three to five *L. bisulcata*. In addition, one specimen of *Lithophaga aristata* (Dillwyn, 1817) 24 mm long was found.

Odé and Speers (1970) report *L. bisulcata* from old oyster valves at Port Aransas, Texas and less commonly at Galveston. They report *L. aristata* from Port Aransas and Port Isabel, Texas, in rocks. The author is unaware of any account of *L. bisulcata* burrowing into living oysters. Turner and Boss (1962) report this species as burrowing into living corals and into "living shells such as *Strombus*" (p. 112). Both *C. virginica* and *O. equestris* were found to be burrowed by *L. bisulcata* in this study. The species *L. aristata* has been reported to burrow into *Ostrea* as well as a variety of other shells (Turner and Boss, 1962) including the shell plates of a chiton (Bullock and Boss, 1971).

These findings thus represent a new pest of

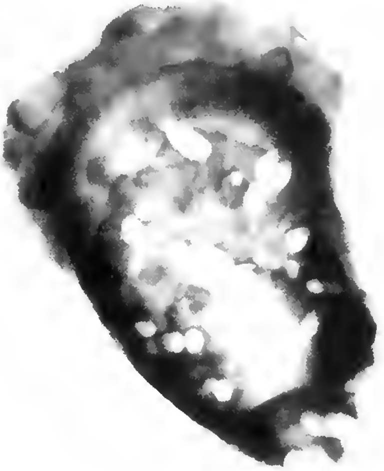

FIG. 1. *Radiograph of oyster shell (actual size) showing location and position of infesting mussels* L. bisulcata.

FIG. 2. *Photograph showing blisters on interior of shell due to infestation by the mussel* L. bisulcata *(white rectangle represents one cm)*

the Virginia oyster *(Crassostrea virginica)* that will be of concern to persons attempting to culture oysters commercially in offshore waters of the Gulf of Mexico.

ACKNOWLEDGMENTS

Appreciation is expressed to Captain J. Roberts for the use of his boat *Starfish*, to his son Mr. J. Roberts for Captaining the vessel, and to Mr. T. Bullington and Mr. D. McLaughlin for assistance in data collection. Drs. D. V. Aldrich and W. J. Wardle reviewed the manuscript and offered many helpful suggestions and constructive criticism. Appreciation is also expressed to the people at Public Health Department in Galveston for doing the X-ray and to Mr. J. Kelsey for aid in the darkroom. Voucher specimens are deposited in the Delaware Museum of Natural History, no. 106621.

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REPRODUCTIVE HABITS OF FOUR POPULATIONS OF *MUSCULIUM SECURIS* (BIVALVIA: SPHAERIIDAE) NEAR OTTAWA, CANADA[1]

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ABSTRACT

Comparative reproductive habits of populations of Musculium securis *(Prime) in two temporary forest ponds, a river and a permanent pond near Ottawa, Canada were determined from samples collected seasonally for one to three years, and from laboratory and field experiments. Gametogenesis is most active during the summer months. Spermatogenesis and oogenesis usually occur simultaneously although protogyny is often apparent. Four to ten brood sacs per inner gill are produced but only two to four sacs usually mature. Only 31 to 63% of the larvae in each brood sac are viable from the fetal stage of development. The average litter size produced varies from 2.1 to 4.8 individuals per parent. Intrapopulation variations in reproduction are more pronounced in temporary than in permanent aquatic habitats. Interpopulation transplants of* M. securis *indicate that reproductive habits may be adaptively modified.*

The present study was planned to show the extent of intrapopulation and interpopulation variations in several reproductive aspects of *Musculium securis*. The reproductive aspects examined were seasonal gonad activities, number of brood sacs and larvae per sac (brood size), and the number and sizes of litters produced. Four populations of *M. securis* were examined, two from temporary forest ponds, one from a river, and another from a permanent pond.

To distinguish between species of *Musculium* and *Sphaerium*, van Cleave *et al.* (1947) have given data to indicate that *Musculium* species might have larger brood sizes than *Sphaerium* species. Herrington (1962) suggested a need for data on more species before evaluating the significance of differential fecundities. Gale (1969) suggested the use of standardized pro-

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[1] This contribution summarizes a portion of a thesis submitted by the senior author in partial fulfilment of the requirements for the Ph.D. degree, University of Ottawa, 1973.

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cedures and the analysis of seasonal field collections to show the extent of intraspecific variations before evaluating the diagnostic value of differential reproduction.

STUDY AREAS

Detailed descriptions of the study areas have been given in Mackie (1973). Briefly, the two temporary ponds, called Carp Pond and Greely Pond, are located at Carp and Greely, Ontario, and are situated in deciduous forests. The dominant tree species at the ponds are white elm, *(Ulmus americana)*, willows *(Salix* spp.), red maple *(Acer rubrum)*, and trembling aspen *(Populus tremuloides)*. Carp Pond covers an area of approximately 15,000 m^2 with a maximum depth of 1 m and Greely Pond, 90,000 m^2 with a maximum depth of 0.8 m. *Musculium securis* is the most common macroinvertebrate in Carp Pond but *Sphaerium occidentale* is approximately twice as numerous as *M. securis* in Greely Pond. Both ponds are usually dry from August to November. The mean summer temperatures (18°C) of the ponds are usually reached near mid-May.

The permanent aquatic habitats are located in Britannia Bay of the Ottawa River near Ottawa and at Lac Bourgeois in the Gatineau Hills near Hull, Quebec. Fifteen species of sphaeriids are present in Britannia Bay where *M. securis* is the dominant species in the mud of the 3-4 m depths (Mackie and Qadri, 1973). Lac Bourgeois, with an area of approximately 90,000 m^2 appears to contain only one sphaeriid, *M. securis*, which attains its largest densities on the east shore under the shade of several small willow trees. The mean summer temperatures (18°C) of Britannia Bay is reached in mid-June and of Lac Bourgeois in early June. Only Britannia Bay contains fish; catfish *(Ictalurus punctatus)*, walleye *(Stizostedion vitreum)*, and pike *(Esox lucius)* are among the common fish species. Seasonal fluctuations in several physical and chemical characters of the water in each habitat have been given by Mackie (1973).

MATERIALS AND METHODS

The reproductive habits of each population examined were seasonal gonad activities, numbers of brood sacs and larvae per sac (brood size), and numbers and sizes of litters produced. These aspects were determined from seasonal field collections and from adults maintained in the field and in the laboratory.

Seasonal Field Collections—From May 1970 to May 1973, 50-100 clams were collected twice a month in the summer and once a month in the winter from Carp Pond and Britannia Bay. Greely Pond and Lac Bourgeois were visited monthly for one year.

Random quantitative samples were taken from Britannia Bay with a standard Ekman grab (15 x 15 cm, with screen on top) and qualitative samples from the remaining habitats with an ordinary domestic sieve. The sizes of the samples needed to show differences between means of litter sizes at $P = 0.05$ were determined from the sample size formula of Simpson *et al.* (1960, p. 196). The specific dates of collections and the sample sizes may be found in Mackie (1973).

All clams used for reproductive studies were preserved immediately in 70% ethanol. Since some clams often prematurely aborted their young, individuals longer than approximately 3 mm were isolated and put into vials containing 70% ethanol. Clams to be used for histological examination were first narcotized in 10% sodium nembutal (van der Schalie, 1963), fixed in Bouin's fluid, and then preserved in 70% ethanol. For each clam in the seasonal field collections, lengths and heights were measured to two decimal places in millimeters with a Precision Tools and Instruments Co. Ltd. microscope micrometer, model 14.

Seasonal gonad activities were determined from stained sections of gonads from 4 or 5 individuals of most field collections. Only specimens prepared for histological examination were used. The shells of parents and extramarsupial larvae were removed by hand. After dehydrating, clearing and embedding in paraffin, the soft parts were sectioned to a thickness of 8 microns. Sections were stained with Harris' haematoxylin and counterstained in alcoholic eosin.

The numbers of brood sacs and their brood sizes were determined for both the left and right inner demibranchs. Usually the embryos were so small that their numbers could not be determined accurately. Therefore, data were recorded for only fetal, prodissoconch, and extra-marsupial larvae. The lengths of all shelled larvae were also recorded. Since 99% of the extra-marsupial larvae were viable (as shown from growth studies), their numbers were taken as a valid measure of litter sizes produced by *M. securis.* Note that the brood size is the number of larvae per brood sac while the litter size produced is only the number of extra-marsupial larvae per litter or the number of young born at one birth.

The numbers of litters produced by parents were determined by back-calculation of brood sacs; this technique has been described by Mackie, Qadri and Clarke (1974a). Only parents which had completed growth were used to determine the numbers of litters produced. Parents that had completed growth could usually be identified by the formation of a black deposit on the margin of their shells.

Maintenance of *M. securis* in the laboratory and field—Reproductive studies on adults maintained in the laboratory and field were done to complement those in seasonal field collections. Growth tubes, prepared from 45 mm diam. x 70 mm ht. plastic vials (Mackie, 1973), were used to maintain adults in the field. Racks, made from 1 cm thick plexiglass sheet, were constructed to hold twenty growth tubes.

A rack of twenty tubes was put into each of Carp Pond, Britannia Bay, and Lac Bourgeois on May 9, 1972 (Greely Pond was not investigated because it was first examined on June 6, 1972). Each growth tube contained one newborn *M. securis* and substrate (1 cm deep) from the habitat in which the tube was placed. The lengths of adults were measured at approximately two week intervals until their deaths. Newborns were counted and removed as they appeared in each tube. The numbers of litters produced by each parent were also noted.

Interpopulation transplants were performed to determine if the sizes and numbers of litters produced by *M. securis* adults were environmentally or genetically controlled. Newborn *M. securis* from each habitat were isolated and maintained in growth tubes in all habitats (except Greely Pond) including its own. Lengths of clams were measured at approximately two week intervals until their deaths. The litter sizes and the numbers of litters produced were also recorded.

Adults from Carp Pond, Britannia Bay, and Lac Bourgeois were also maintained in the laboratory. Since *M. securis* would grow only in the presence of tree foliage, only substrate and leaves from Carp Pond were used. "Pyrex" dishes 100 mm diam. x 50 mm ht. were used as growth dishes. Five *M. securis* newborns from each habitat were put into each of three dishes. Three replicates were made of each dish containing 5 *M. securis*, 50 g of air dry Carp Pond soil, 2 g of air dry white elm leaves, and chlorine-free tap water. The lengths of adults were recorded at frequent intervals and the total number of young produced in each dish was recorded.

A student's *t* test. (Simpson *et al.*, 1960, p. 176) was used to determine significant differences between population means at P = 0.05.

RESULTS AND DISCUSSION

Seasonal Gonad Activities. The gonads of newborns are small and often difficult to locate. Primary oocytes are often seen in newborns that have estivated and/or hibernated in Carp Pond and Greely Pond but neither oogenesis nor spermatogenesis is strongly apparent (Fig. 1-1) when serial sections of the gonads are examined. Gametogenesis does not appear to begin until growth of adults ensues in the spring. At this time the ovary appears to be in further stages of development than the testis (Fig. 1-2). Throughout May, June, and early July, both fully developed ova and sperms are present but there is no evidence of increased gonad activity with time (Fig. 1, -3, -4, -5, -6). Spermatogonia and spermatocytes are readily visible and usually fill the entire follicular cavity. It is not until late July that spermatogenic activity appears to be maximum (Fig. 1-7). In late-July-specimens the spermatozoa are usually found in the central lumen of the testicular follicles (Fig. 1-7) where the tails of the sperms are clearly visible (Fig. 1-8). Frequently the testis is so large in these late July specimens that the ovary cannot be located.

In specimens over 4 mm in length collected between November and April from Lac

FIG. 1 *Photomicrographs of seasonal gonad activity in* Musculium securis *in Carp Pond. DO developing oogonia, I intestine, PO primary oocytes, ST spermatozoa, STT tails of spermatozoa, SY spermatocytes.*
1. October 10, 1970. Length of parent 1.70 mm. 380×.
2. May 20, 1971. Length of parent 3.35 mm. 380×.
3. May 30, 1971. Length of parent 3.76 mm. 380×.
4. June 14, 1971 Length of parent 4.65 mm 380×
5. June 28, 1971 Length of parent 5.22 mm. 380×
6. July 12, 1971. Length of parent 5.68 mm. 380×
7. July 26, 1971. Length of parent 5.75 mm. 95×.
8. Same as no. 7 but 380×.

Bourgeois, the testicular follicles show evidence of a decided reduction in spermatogenesis and primary oocytes are usually absent in the ovaries. The central lumens of the ovaries and testis are devoid of gametes so that gametogenesis probably does not occur during the winter months.

Although there are variations, gametogenesis is first apparent in adults of lengths 2.00-2.50 mm. The testis greatly dwarfs the ovary in adults larger than 5.50 mm. On the basis of the earliest appearance of primary sacs, eggs are first fertilized in adults of lengths of 2.00-2.50 mm.

Numbers of Brood Sacs and Brood Sizes. Demibranchs within a parent usually contain the same number of brood sacs. A maximum of three brood sacs per demibranch (i.e. six brood sacs per gill) are usually found but four brood sacs also occur, although very rarely. The total number of brood sacs per gill varies with the size and age of the parent (Fig. 2).

During the summers of 1970 and 1971, only parents longer than 4.00-4.50 mm in the Carp Pond population contained 6 brood sacs (Fig. 2a). By late June extra-marsupial larvae are present but 6 brood sacs also occur indicating that a total of 8 brood sacs (i.e. 2 primary, 2 secondary, and 4 tertiary) are produced. This is probably the average maximum number since only four brood sacs per gill (i.e. 2 secondary, and 2 tertiary) are found in parents taken at the end of July. In 1972 when the pond did not dry up, the same phenomena occurred (as exemplified by results from Greely Pond, Fig. 2b) and new sacs were not produced in later summer. Therefore, the extended aquatic season has little effect on the total number of brood sacs

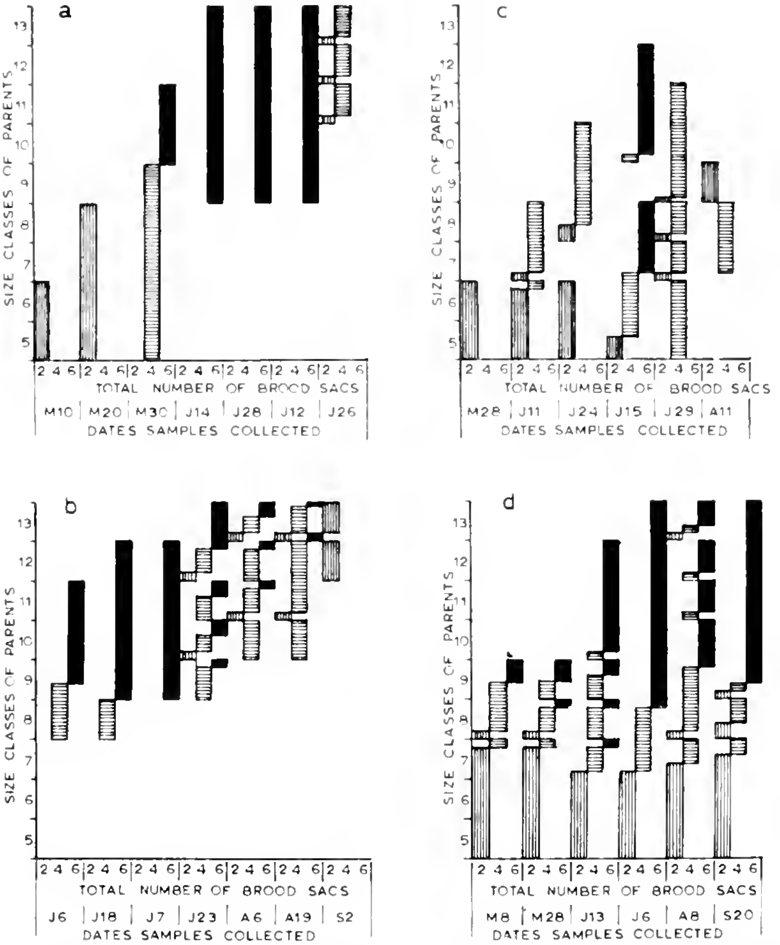

FIG. 2. *Total number of brood sacs per inner gill in parents collected between (a) May 10 and July 26, 1971 from Carp Pond, (b) June 6 and September 2, 1972 from Greely Pond, (c) May 28 and August 11, 1971 from Britannia Bay, (d) May 8 and September 20, 1972 from Lac Bourgeois. Each size class represents a 0.49 mm increment in shell length (i.e. 1 = 0-0.49 mm., 2 = 0.50-0.99 mm, 3 = 1.00-1.49 mm, ... 12 = 5.50-5.99 mm, 13 = lengths greater than 6.00 mm) Each interval on the ordinate axis also represents 100%.*

produced although more brood sacs mature (i.e. 4 brood sacs per gill remained in 1970 and 1971 adults but 2 remained in the 1972 adults).

Six brood sacs are uncommon in individuals from the Britannia Bay population and are found only in July (Fig. 2c). There appear to be no major differences in the total numbers of brood sacs between 1970, 1971 and 1972 populations of Britannia Bay. Usually a total of six brood sacs are produced but only two brood sacs mature and four remain immature at the end of the summer. Clams of lengths 2.00-3.50 mm represent slow-growing adults (Mackie, Qadri, and Clarke, 1974b) which usually produce a total of only four brood sacs (Fig. 2c).

Six brood sacs per gill are most common in adults longer than 4.50 mm in Lac Bourgeois (Fig. 2d). At least 8 brood sacs are produced by many parents since one litter of extra-marsupial larvae is released and 6 brood sacs still remain by mid-September. Some parents release another litter of extra-marsupial larvae in the fall and many still have 6 brood sacs per gill. Therefore, some parents of Lac Bourgeois produce as many as 10 brood sacs per gill.

The number of larvae in brood sacs of parents from each population are given in Table 1. Primary sacs are not included because the embryos were too small to be counted accurately. The total number of larvae increases

TABLE 1. *Sizes of litters in marsupial chamber and brood sizes of* Musculium securis *in four habitats for each year of collection. Only parents in which all larvae were present and from which no extra-marsupial larvae had been released were examined*

	Carp Pond			*Greely Pond*	*Britannia Bay*			*Lac Bourgeois*	
	1970	*1971*	*1972*	*1972*	*1970*	*1971*	*1972*	1971	1972
Extra-marsupial larvae in branchial chamber	3.0[a] (25)[b] 1.10[c]	4.0 (40) 1.61	2.6 (28) 0.90	2.7 (28) 0.81	2.4 (18) 0.83	3.1 (15) 1.44	2.1 (16) 0.90	3.8 (11) 1.48	4.8 (20) 1.56
Prodissoconch larvae in tertiary sacs	4.8 (25) 1.35	5.5 (40) 1.57	5.0 (28) 2.01	5.4 (28) 1.70	3.9 (18) 1.30	4.1 (15) 1.36	3.1 (16) 0.77	5.1 (11) 1.92	6.0 (20) 2.13
Fetal larvae in secondary sacs	6.8 (25) 1.64	7.4 (40) 1.12	7.3 (28) 2.07	6.8 (28) 1.29	5.6 (18) 1.23	6.1 (15) 1.23	5.6 (16) 1.02	7.4 (11) 1.18	7.8 (20) 2.20

[a] Mean litter or brood size.
[b] Number of specimens examined
[c] Standard deviation of the mean

TABLE 2. *Percentage of* Musculium securis *parents producing one, two, and three liters in each of four habitats for each year of collection. The percentages are based on back-calculation of brood sacs in parents that had completed growth.*

	Carp Pond			*Greely Pond*			*Britannia Bay*			*Lac Bourgeois*			
		No. of Litters			*No. of Litters*			*No. of Litters*			*No. of Litters*		
Year of Collection	N[a]	One	Two	N	One	Two	N	One	Two	N	One	Two	Three
1970	(25)	64.0	36.0	No collections			(19)	84.2	15.8	No collections			
1971	(40)	45.0	55.0	No collections			(17)	88.4	11.6	(30)	38.5	53.2	8.3
1972	(30)	6.8	93.2	(31)	13.0	87.0	(16)	81.1	18.9	No collections			

[a] Number of specimens examined.

with age of the parent indicating that the generative performance increases with age.

Numbers of Litters Produced. Table 2 gives the percentages of adults that produced one, two, or three litters in each population for each year of study. A maximum of three litters were produced by a single parent. Variations in the numbers of litters produced within and among populations are discussed later in this paper.

One litter was usually produced in the growth tubes placed in Carp Pond, Britannia Bay, and Lac Bourgeois and in the laboratory growth dishes (Table 3). A maximum number of three litters was produced in all maintenance studies. The results were obtained by noting the presence or absence of newborns in the growth containers at approximately two week intervals. Analyses of parents from seasonal field collections show that in a few instances two litters of extra-marsupial larvae occur together, particularly when the litter sizes are small. Therefore, it is possible that two litters may have been produced within two weeks in the growth containers. If this occurred then a maximum of six litters was produced. However, studies on the numbers of brood sacs produced show that usually four sacs, and rarely five, are formed in each inner demibranch. Therefore, the maximum number of litters most likely produced in the growth containers was four.

Sizes of Litters Produced. Since only extra-marsupial larvae are released, their numbers represent the sizes of litters produced. Table 4 gives the sizes of the first litters in all populations for each year of study and of second litters in populations of which at least 35% of the parents produced two litters. The sizes of the first and second litters of prodissoconch and fetal larvae in sequential parents are also included in Table 4. Sequential parents are those parents that represent a stage in the sequential development of each litter of extra-marsupial larvae. That is, the sizes of the first and second litters of prodissoconch and fetal larvae that

TABLE 3. *Numbers and sizes of litters produced by* Musculium securis *adults maintained in growth containers in three habitats and in the laboratory. Means subscored by the same line are not significantly different at P = 0.05.*

Populations transplanted on Lac Bourgeois from	*Number of Parents Producing*		*Average Sizes of Litters*		*Total Number Born per Av. Parent and Standard Deviation (±)*
	One Litter	*Two Litters*	*first Litter*	*second Litter*	
Lac Bourgeois (control, N = 18)[a]	2	16	3.6	3.9	7.1 (1.8)
Carp Pond (N = 16)	10	6	3.0	3.1	4.3 (2.5)
Britannia Bay (N = 15)	2[c]	0	0.2	0	0.2 (0.4)
Carp Pond from					
Lac Bourgeois (N = 16)	6	10	3.2	5.3	6.5 (2.0)
Carp Pond (Control, N = 17)	5	12	1.2	2.6	6.0 (2.2)
Britannia Bay (N = 11)	1	0	0.1	0	0.1 (0.1)
Britannia Bay from					
Lac Bourgeois (N = 16)	0	16	1.3	3.9	8.2 (1.7)
Carp Pond (N = 17)	0	17	3.7	3.1	6.8 (2.5)
Britannia Bay (Control, N = 18)	10	8	2.8	3.7	1.5 (1.2)
Adults maintained in the Laboratory					
Carp Pond	0	15	3.8	1.2	8.0 (2.1)
Lac Bourgeois	0	15	4.0	5.1	9.1 (2.8)
Britannia Bay	9	6	3.3	4.7	5.5 (1.7)

[a] Twenty specimens were put into each habitat but only N number survived.

[b] Calculated as (Size of first litter × proportion of parents producing only one litter) + (Total number of young born × proportion of parents producing two litters).

[c] Of the adults that survived, one or two produced young.

represent the first and second litters of extra-marsupial larvae were counted in parents from three successive field collections.

The results (Table 4) show that the sizes of the first and second litters of each larval stage are similar ($P > 0.05$) but there are usually significantly larger numbers ($P < 0.01$) of fetal larvae than of prodissoconch larvae which in turn are numerically larger ($P < 0.01$) than extra-marsupial larvae. Clearly, the results in-
population consistently produced fewer ($P <$
tion often differed ($P < 0.05$) among habitats.
the extra-marsupial stage.

Table 3 indicates that there is some genetic control of litter size since the Brittania Bay population consistently produced fewer ($P < 0.05$) young in all transplants than did other populations of the same transplants. However, there also appears to be some environmental control of litter size since the total number of young produced by parents of any one population often differed ($P < 0.05$) among habitats.

Intraspecific variations in reproductive habits of *Musculium securis*. There is some variation in the seasonal gonad activities between slow- and fast-growing adults (Mackie, Qadri, and Clarke, 1974b) in Britannia Bay. In slow-growing adults gametogenesis is first apparent in length classes 2.00-2.50 mm but in fast-growing adults gametogenesis is not apparent until clams are of lengths 3.00-3.50 mm.

Gametogenesis and fertilization appear to continue until the death of the individual in all populations but is most active in the summer months. Similar observations have been reported by Okada (1935) for *M. japonicum*. Okada (op. cit.) also noted that spermatogenesis is most active in clams measuring 3-7 mm in length and oogenesis in those measuring more than 8 mm; protandrous maturation of *M. japonicum* is therefore suggested. The results of the present study indicate that ova and sperm mature at approximately the same time although primary oocytes (ova lying free in the ovarian cavity) are often present before spermatids; therefore,

TABLE 1. *Sizes of first and second litters per gill and the percent viability of larvae in sequential parents (defined in text) of* Musculium securis *in four habitats for each year of collection*

Types of Litters	*Carp Pond*			*Greely Pond*	*Britannia Bay*			*Lac Bourgeois*	
	1970	1971	1972	1972	1970	1971	1972	1971	1972
First Larval litters in sequential parents									
Extra-marsupial larvae	3.0[a] (25)[b]	4.0 (40)	2.6 (28)	2.7 (18)	2.4 (18)	3.1 (15)	2.1 (16)	2.8 (14)	4.8 (20)
	1.10[c]	1.61	0.91	0.81	0.83	1.44	0.90	1.48	1.56
Prodissoconch larvae	4.7 (31)	5.3 (38)	5.5 (36)	5.4 (20)	4.0 (23)	3.9 (22)	3.8 (16)	4.8 (30)	6.0 (34)
	1.26	1.51	1.70	1.30	0.93	1.72	1.29	1.81	1.78
Fetal larvae	7.0 (37)	6.9 (38)	7.4 (37)	7.0 (22)	5.9 (28)	5.8 (12)	6.1 (25)	6.7 (23)	7.6 (34)
	1.67	1.77	2.27	1.91	0.99	1.56	1.20	1.29	2.02
% viability[d]	45	58	37	39	41	58	39	57	63
Second larval litters In sequential parents									
Extra-marsipial larvae	2.1 (9)	3.1 (14)	2.1 (35)	2.1 (34)		Insufficient Size of Sample		4.2 (15)	No Data
	0.11	0.88	0.77	0.74				1.27	
Prodissoconch larvae	4.6 (25)	5.0 (55)	4.8 (50)	6.1 (42)				6.6 (31)	
	1.30	1.44	1.93	1.95				1.99	
Fetal larvae	6.1 (34)	6.6 (50)	7.4 (50)	7.8 (45)				8.0 (32)	
	1.51	1.67	2.11	2.16				2.30	
% viability	34	47	32	31				52	

[a] Mean litter or brood size.

[b] Number of specimens examined.

[c] Standard deviation of the mean.

[d] % viability = (extra-marsupial larvae/fetal larvae) × 100.

protogyny may occur in some individuals. Simultaneous maturation of gametes also seems to occur in *Sphaerium simile* (Zumoff, 1973) and *M. partumeium* (Thomas, 1959).

Intraspecific variations in seasonal gonad activity is also present in other sphaeriids. Foster (1932) suggests that maximum size adults of *S. striatinum* are sterile and reproduction occurs in the winter months; Avolizi's (1971) data indicate that reproduction in this species occurs until the death of the animal with peak reproduction in spring and fall but Monk (1928) found that reproduction of *S. striatinum* is at a peak during the summer months.

There is very little intrapopulation variation in the total number of brood sacs produced per parent from one year to the next. However, interpopulation variations in brood sac production are present. Individuals in Britannia Bay usually produce a total of six brood sacs while those in other populations usually produce eight, and occasionally ten (Lac Bourgeois), brood sacs. Of these totals, only two to four (occasionally six) brood sacs mature. Therefore, the potential total number of litters (six to ten) is probably rarely achieved, although Heard (1974) suggests that *M. securis* can "produce several litters over a life span of several years".

A significantly larger number ($P < 0.05$) of extra-marsupial larvae occurred in 1971 than in 1970 or 1972 in Carp Pond, Britannia Bay, and Lac Bourgeois. There are no significant differences ($P > 0.05$) in the numbers of prodissoconch larvae nor of fetal larvae between the 1970, 1971 and 1972 populations of Carp Pond and Britannia Bay nor between 1971 and 1972 populations of Lac Bourgeois. The numbers of each larval stage in Greely Pond adults are similar to those in Carp Pond adults in 1972. Smaller numbers ($P < 0.05$) of prodissoconch larvae and of fetal larvae are produced in the Britannia Bay population than in other populations. Lac Bourgeois parents produced larger ($P < 0.05$) numbers of extra-marsupial larvae in 1972 than did other populations in the same year and similar numbers ($P < 0.05$) of prodissoconch and of fetal larvae as Carp Pond and Greely Pond in the last two years of study.

Significantly more ($P < 0.005$) parents produced two litters in 1972 than in previous years of study in Carp Pond (Table 2). The 1972 increase is attributable to the extended aquatic season since the data was obtained from parents sampled in August and September when the pond was usually dry. The data for 1970 and 1971 were obtained from parents collected at the end of July, just prior to the disappearance of water from the pond. Parents of Carp and Greely Ponds produced the same proportions of one and two litters in 1972. A larger proportion ($P < 0.005$) of parents produce one litter in Britannia Bay than in other habitats. No differences are observed in the proportion of parents producing one and two litters in Lac Bourgeois, Carp Pond, and Greely Pond although a small percentage of parents produce three litters in Lac Bourgeois. The extended aquatic season had no apparent affect on the numbers of litters produced by individuals in the Britannia Bay and Lac Bourgeois populations.

The results from the transplant studies (Table 3), suggest that the Britannia Bay population may be adaptively modified with respect to the number of litters produced. That is, with two to four weeks lag in rate of temperature increase in Britannia Bay (Mackie, 1973), the population has less time than other populations to produce additional litters. Hence, there is greater survival value to select for one litter than for several litters of which only one can be produced.

Gale (1969) proposes that more discretion is needed in comparing the numbers of embryos in various species since differences may reflect seasonal or parental size class variations; also purported differences between species may be due to differences in procedures used by various investigators. The present study indicates that brood sizes of *M. securis* vary greatly within and among habitats, primarily because of differences in larval mortalities. However, there appears to be less variation in the brood sizes of secondary sacs within and among populations with similar habitats. Therefore, the numbers of fetal larvae alone (and probably embryos) appear to be more valid measurements for determining differential fecundities among species within similar habitats than are numbers of extra-marsupial or prodissoconch larvae.

The data (Table 3 & 4) also indicate that both intrapopulation and interpopulation variations in litter sizes are present. Within the Carp Pond, Britannia Bay, and Lac Bourgeois populations, the sizes of litters released are significantly larger in the second year of study than in the first. These higher values may indicate the response of *M. securis* to replace those individuals that had been removed for life history analyses by the author in the previous year of study. The removal of specimens by the author are interpreted as representing a mortality factor that is not normally present in the populations. If this interpretation is correct, *M. securis* compensated for the high mortality by producing large litters in the following year. This appears to be achieved, not by producing more eggs (since the total number of fetal larvae per parent remained relatively constant), but by maintaining a greater survival rate (reflected in % viability, Table 4) of larvae already produced. In this context, the sampling efforts of the authors apparently had little ultimate effect on the litter sizes produced since the litter sizes in the third year of study are not significantly different from those in the first year (Table 4). This is a valid interpretation if the large amount of rainfall in 1972 did not cause reductions in the litter sizes produced.

The viability of *M. securis* larvae from the fetal stage of development ranges from 37% to 63% in the first litter and 31% to 52% in the second litter, depending on the year of study and the habitat. Since the number of embryos probably exceeds the number of fetal larvae, the percent viability of larvae from point of fertilization of the egg is probably smaller. The data (Table 4) also indicate that *M. securis* produces a certain number of eggs, this number being genetically fixed. This is suggested from the similar numbers of fetal larvae (approximately 7.0) of the first litters in Carp Pond, Greely Pond and Lac Bourgeois. The Britannia Bay population produces significantly smaller numbers ($P < 0.01$) of fetal larvae per secondary brood sacs than other populations. This implies that either a high mortality of embryos occurs in the Britannia Bay population or that the population is genetically distinct with respect to egg production and indicates that the litter size can be modified adaptively. Support for adaptive modification of litter size is seen in the results from the transplant studies (Table 3). The Britannia Bay population produced significantly smaller ($P < 0.05$) litter sizes in all transplants than did other populations of similar transplants.

Avolizi (1971) has also studied larval viabilities but presented his data in terms of "embryonic mortality"; the maximum embryonic mortalities of *S. striatinum* and *S. simile* are 90% and 77-65%, respectively (i.e. larval viabilities of 10% and 23-35%, respectively). Avolizi (op. cit.) suggests that "the dying off of younger stages contributes to the nutrition of... embryos which survived". The litter sizes of *S. striatinum* and *S. simile* at birth range from 1-2 for both species.

The annual ratio of selection of *M. securis* (i.e. number of young born annually per average adult) varies widely within and among populations. For example, the Carp Pond population in 1970 and 1972 and the Greely Pond population in 1972 had an annual ratio of selection of ABOUT 5:1; this ratio increased to about 7:1 in the 1971 Carp Pond population. With only one litter, the Britannia Bay population has a low annual ratio of selection of about 2-3:1 while parents in Lac Bourgeois have the highest annual ratio of selection (8:1).

Analyses of results obtained from seasonal field collections and the maintenance of adults in the field and laboratory (Table 3) indicate that the annual ratio of selection is a function of density dependent and independent factors. This is also suggested from the results obtained by Mackie's (1973) ecological studies on the effects of such factors as intraspecific and interspecific competition, temperature, and pollution on the growth and reproduction of *M. securis.* Similar conclusions are reported by Avolizi (1971) for *S. simile* and *S. striatinum.* Burky (1968) has demonstrated that the annual ratio of selection of *Ferrissia rivularis* varies from 35:1 in an eutrophic habitat to 8:1 in an oligotrophic stream.

Heard (1974) describes five types of reproductive cycles in *Sphaerium* and *Musculium.* The Type II cycle describes reproduction of *M. securis* in the Britannia Bay and Lac Bourgeois populations where there are two or three periods of fertilizations and births every year. However, neither of the five cycles defined by Heard (1974) describe reproduction of *M. securis* in the Carp Pond and Greely Pond populations. In conformity with Heard's (1974, Table 41) criteria, the reproductive cycle of the latter two populations can be described as having a life span of approximately one year, semelparous reproduction with one litter (or two litters in one birth period) per year, rarely a fall and winter incubation period, and only one birth period (summer).

ACKNOWLEDGMENTS

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THE GENUS *FONTIGENS* FROM APPALACHIAN CAVES (HYDROBIIDAE: MESOGASTROPODA)

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ABSTRACT

Fontigens holsingeri *Hubricht from Harman Cave, Randolph Co., West Virginia, and* Fontigens turritella *Hubricht from McClung Cave, Greenbrier Co., West Virginia are described as new species. Additional geographical records are given for* Fontigens orolibas *Hubricht,* Fontigens aldrichi *(Call & Beecher),* Fontigens tartarea *Hubricht,* and Fontigens nickliniana *(Lea).*

Fontigens holsingeri *new species*

Fig. 1A

Description: Shell small, conical, diameter about 65% of height, thin, translucent, dull, pale yellowish-horn; umbilicus open, about 0.1 mm. in diameter; nuclear whorl nearly flat, later whorls regularly increasing in size, well rounded with very deep sutures, each whorl lightly appressed to the preceding whorl; sculpture of numerous inconspicuous growth lines; aperture ovate, vertical, may or may not be appressed to the preceding whorl; lip thin, sharp, with a very slight thickening within. Operculum paucispiral, thin, of about 3.5 whorls, hyaline, the nucleus being located about one-half way between the center and the lower right margin. Animal unpigmented and blind, verge unknown.

Height 1.7 mm., diameter 1.1 mm., aperture height 0.6 mm., aperture width 0.5 mm., umbilicus diameter 0.1 mm., 4.5 whorls. Holotype.

Distribution: West Virginia: Randolph Co.: stream in Harman Cave, 0.5 mile southwest of Harman (Type locality) (J. R. Holsinger & D. C.

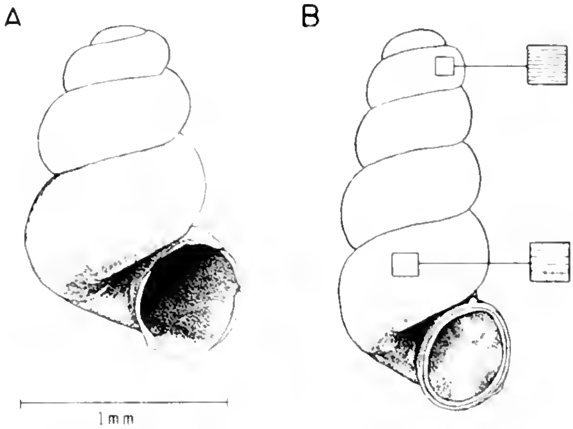

FIG 1A Fontigens holsingeri *Hubricht, holotype Length, 1.7 mm*

FIG 1B Fontigens turritella *Hubricht, holotype Length, 1.9 mm Drawings courtesy Field Museum of Natural History, Chicago, with thanks to Elizabeth Liebman for her skilled efforts*

Culver, colls.), holotype 170893 and paratypes 170392 Field Museum of Natural History, other paratypes 42560 and 43635 collection of the author; stream in Bazzle Cave, 1.0 mile south-southeast of Harman (J. R. Holsinger & D. C. Culver, colls.). Pocahontas Co.: stream in Piddling Pit Cave, 10 miles north-northeast of Marlington (J. R. Holsinger, R. Baroody, & R. Swensson, colls.); stream in Marthas Cave, 0.9 miles southwest of Hillsboro (David Culver & David Newson, colls.).

Remarks: Fontigens holsingeri is most closely related to *F. cryptica* Hubricht; differing in being larger, with more rounded whorls, and a more open umbilicus. *Fontigens tartarea* Hubricht, which is found in the same area differs in its flatter whorls and shallower sutures.

Fontigens turritella *new species*

Fig. 1B

Description: Shell small, conical, turreted, diameter about 48% of height, thin, pale straw colored, translucent, dull; nuclear whorl depressed, giving the shell a truncated appearance, later whorls regularly increasing in size, well rounded with deep sutures; sculpture of very weak growth lines and spiral lines; aperture ovate, vertical, lightly appressed to the preceding whorl; lip thin, sharp, with a very slight thickening within, not reflected in the columellar region. Operculum paucispiral, thin, hyaline, of about 2.5 whorls, the nucleus located left of center. Animal unpigmented and blind.

Verge with three lobes, the upper lobe slender, cylindrical, less than one-third the length of the other two lobes, and attached near the base of the center lobe; the center lobe and the lower lobe are joined together along most of their length, with only their tips separate, they excede in length the diameter of the shell; the center lobe contains the spermathecal duct, the other lobes contain much smaller ducts of unknown function.

Height 1.9 mm., diameter 0.9 mm., aperture height 0.5 mm., aperture width 0.5 mm., 5.5 whorls. Holotype.

Distribution: West Virginia: Greenbrier Co.: stream in McClungs Cave, 2 miles northeast of Maxwelton (Type Locality) (John Rutherford; Leslie Hubricht, colls.), holotype 170891 and paratypes 170890 FMNH, other paratypes 38272 and 40694, collection of the author; stream in The Hole Cave (Gibbs Entrance Section), 2 miles east of Frankford (J. R. Holsinger, D. Culver, P. Starr, S. Peck, & D. Newson, colls.).

Remarks: Fontigens turritella differs from all the species known from Appalachian caves except *F. nickliniana* (Lea) by its elongate shape, its height exceeding twice the diameter. From *F. nickliniana* it differs in its verge, in its smaller size, in its truncated spire, and more slowly increasing whorls.

Fontigens aldrichi (Call & Beecher)

Paludina obtusa Lea. 1841. Proc. Amer. Phil. Soc. **2:** 34. (Not. *P. obtusa* Troschel. 1837).

Bythinella aldrichi Call & Beecher 1886. Bull. Washburn Coll. Lab. Nat. Hist. **1:** 190-192.

Amnicola aldrichi aldrichi (Call & Beecher). Hubricht, L. 1940. Nautilus **53:** 118-119.

Snails found in springs and caves from northwestern Virginia north to Maryland are not distinguishable from snails found in the eastern Ozarks of Missouri. The spring form with eyes and dark gray pigment were collected at the following localities: *Virginia:* Highland Co.: spring, 0.7 mile southwest of Mustoe; spring, 1.3 miles north of Mustoe. Both of these springs are in the headwaters of the Jackson River.

The blind unpigmented cave form was found at the following localities: *Virginia:* Bath Co.: stream in Butler Cave, 1 mile north of Burnsville (J. R. Holsinger, T. Vigour, & L. Vinzant, colls.). Frederick Co.: stream in Ogdens Cave, 3.5 miles west-northwest of Middletown. *Maryland:* Washington Co.: beneath stones, large spring, 0.4 mile south of Little Heiskell Quarry (F. Wayne Grimm, coll.).

It is probable that during the Pliocene, *Fontigens aldrichi* lived in springs in the northern United States but was forced south by the Pleistocene glaciers. Because the kind of springs in which it lived were covered over by till, it was not able to move back into its old range and has survived only in the Appalachians, the eastern Ozarks, and if the type locality for *Paludina obtusa* is correct, in Ohio.

Fontigens orolibas Hubricht

Fontigens orolibas Hubricht. 1957. The Nautilus **71:** 9.

An unpigmented form of this species, which may or may not have eyes, has been collected in the following caves: *Virginia:* Warren Co.: stream in Skyline Caverns, 2 miles south of Front Royal. Giles Co.: stream in Smoke Hole Cave, Newport (J. R. Holsinger & H. R. Steeves, colls.); stream in Tawneys Cave, near Newport; stream in Starnes Cave, 3.5 miles south-southeast of Narrows (J. R. Holsinger & S. Hetrick, colls.). Tazewell Co.: stream in Hugh Young Cave, 1.5 miles southwest of Liberty Hill (J. R. Holsinger, coll.).

Fontigens tartarea Hubricht

Fontigens tartarea Hubricht, 1963. Nautilus **76:** 140

Since this species was described it has been found living in the following caves: *West Virginia:* Tucker Co.: stream in Harpers Cave, 5 miles southeast of Hendricks (J. R. Holsinger & D. C. Culver, colls.). Randolph Co.: stream in Simmons-Mingo Cave, 1.5 miles southwest of Mingo (R. B. Williams, coll.); stream in Bowden Cave, 7 miles east of Elkins (J. R. Holsinger & D. C. Culver, colls.). Monroe Co.: stream in Indian Draft Cave, a few miles south of Wayside (J. R. Holsinger, D. C. Culver, & R. Baroody, colls.); stream in Rock Camp Cave, 1.6 miles south of Rock Camp; stream in McClungs Cave, Zenith.

Specimens from Bowden Cave are very small: height 1.2 mm., diameter 0.7 mm., and are probably the smallest freshwater snails known from the eastern United States.

Fontigens nickliniana (Lea)

Paludina nickliniana Lea, 1839. Trans. Amer. Phil. Soc. n. s. **6:** 92.

Fontigens nickliniana (Lea). Pilsbry, 1933. Nautilus **47:** 12

What appears to represent a blind, white, cave form of this species has been collected at the following localities: *West Virginia:* Monroe Co.: stream in Hunt Cave, near Sinks Grove (J. R. Holsinger, coll.). *Virginia:* Lee Co.: stream in Gallohan Cave No. 1, 6.5 miles southeast of Rose Hill (J. R. Holsinger, coll.); stream in Spangler Cave, 3.5 miles west of Jonesville (J. R. Holsinger, coll.); pool in Smiths Milk Cave, 7 miles southeast of Rose Hill (J. R. Holsinger, D. C. Culver, colls.). The verge has not been examined from any of these lots. It is very difficult to kill cave hydrobiids relaxed.

REPRODUCTION AND EARLY DEVELOPMENT OF THE OCEAN QUAHOG, ARCTICA ISLANDICA, IN THE LABORATORY

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ABSTRACT

The ocean quahog, Arctica islandica, *normally spawns in summer in southern New England. Attempts to ripen these bivalves out of season in the laboratory produced limited success. Clams obtained from the Rhode Island fishery in late winter and kept in seawater ranging from 10°C to 15°C ripened significantly in five weeks, but clams subjected to the same temperatures, plus supplemental feeding with cultured algae in the fall, failed to produce gametes. Ripe clams could not be induced to spawn by rapidly increasing temperature, rapidly decreasing temperature, changing the salinity, or by sperm suspension. Fertilization and the per cent development of stripped eggs to normal larvae were significantly increased when the eggs were exposed to dilute ammonium hydroxide before fertilization was attempted. The eggs developed to the veliger* *larval stage best at a temperature of about 15°C. The larvae were reared to metamorphosis at 12°C ± 2°C. Early straight-hinge stages have an unusually long hinge line. Older larvae have low-profile umbones that barely rise above the hinge line; consequently, the larval outline is always round. Larvae metamorphose most commonly at a length of 190-200μ. The color throughout larval development ranges from colorless to a pale yellow.*

During World War II a modest fishery for *Arctica islandica* (Linné), the ocean quahog, sometimes called the mahogany clam, developed off the coast of Rhode Island, but, because other bivalve species more familiar to the consumer were still plentiful, this fishery did not expand significantly in the post-war years. Recently, a decline in the abundance of the more popular bivalves has spurred the government and industry to explore the possibility of using ocean quahog populations more efficiently (Mendelsohn, Parker, McRae, King and Joyce, 1970). The general distribution and abundance of these clams in the Middle Atlantic Bight have recently been established (Merrill and Ropes, 1969), and it is apparent that these stocks represent a potentially valuable resource. The purpose of this paper is to describe recent attempts at the Milford Laboratory to develop rearing methods for the developmental stages of the ocean quahog as an aid to understanding the dynamics of its natural populations and the response of the clam to its environment.

GAMETOGENESIS

The reproductive cycle of *Arctica* in Rhode Island waters has been described by Loosanoff (1953). Spawning begins in late June or early July, when the bottom water temperature over the clam beds is about 13°C, and continues actively into early October. By late October few animals with ripe sex products are found. After what may be a recovery or "resting" period of about a month, gametogenesis resumes and continues into December. While this activity slows down with the advent of winter water temperatures, both male and female clams can be found with some morphologically mature sex products. The gradual warming of the water in the spring initiates a period of rapid proliferation of sex cells until, by the end of June, many individuals are ready to spawn.

This sequence of reproductive events suggests that it should be easy to ripen ocean quahogs for spawning in the laboratory during much of the year. My attempts to accomplish this, to date, have had only limited success, however. In one instance, clams were obtained from the fishery off Rhode Island in late March 1971. The state of gonad development at this time was as described by Loosanoff (1953); i.e. most animals contained identifiable sex products, including some mature eggs and active sperm, but their numbers were small and the gonads far from being full. These animals were kept in flowing, unfiltered seawater at temperatures that ranged between 10°C and 15°C. By the end of April, the abundance of sex products had increased substantially, and, when the gonad was opened, it produced the runny appearance that is associated with ripeness in field stocks of this bivalve in late June. The clams remained in this environment throughout the spring and summer. Sex products continued to accumulate, producing white, distended gonads. This appearance persisted until late October when a decrease in the volume of sex products became apparent and many of the remaining eggs appeared to be breaking down.

In late November 1971, a new group was obtained from the same fishery. These included a few females with old disintegrating eggs and a few with new, developing eggs. There were also a few males with small numbers of motile sperm. Most clams had empty gonads, however. All were kept in the laboratory at 10°-15°C in unfiltered, flowing seawater. Half of them were additionally fed continuously with cultured algae and the other half were not. Once a month, thereafter, gonads from each batch were examined for sex products.

By mid-March 1972, it was apparent that neither of the treatments had produced any quantity of ripe gametes. Gametogenesis appeared to have been stimulated to some extent in those clams getting the supplemental algae, but with no consistency within the group as a whole, i.e., there were some individuals with little or no identifiable sex products. It appeared from these two trials that gametogenesis in the ocean quahog can be accelerated experimentally in the laboratory by simulating summer temperatures only at certain times of the year.

AVAILABILITY AND DEVELOPMENT OF EGGS

Loosanoff (1953) was unable to spawn ripe ocean quahogs in the laboratory using stimuli that work for many other bivalves. These stimuli included a rapid increase in water temperature, addition of suspensions of sex products, and changes in salinity. He did observe unprovoked spawning in conditioning tanks on two occasions, but could not relate these to any obvious environmental condition. My own attempts at various times, using the same kinds of stimuli during the summer and early fall, when the clams contain the most, and, presumably, the ripest sex products, corroborate Loosanoff's observations. In addition, stimulation with rapidly decreasing temperature, a technique which was described by Posgay (1953) as a dependable way to induce spawning in sea scallops (*Placopecten magellanicus)*, and which we too found to work well with this species, also failed to cause spawning in ocean quahogs, even though these two bivalves live in the same range of water temperature in nature and spawn at about the same time of the year.

Loosanoff (1953) states that the stripped eggs of the ocean quahog cannot be fertilized because the germinal vesicle remains intact even after the eggs are placed in seawater. I found that a few stripped eggs can be fertilized directly with stripped sperm, but that more eggs can be fertilized if they are treated with dilute ammonium hydroxide before the sperm are added. The ammonium hydroxide treatment is one that Loosanoff and Davis (1963) used on certain refractory species, and consists of adding 3 ml of 0.1 NH_4OH for every 100 ml of egg culture, to a clean suspension of stripped eggs. After the required length of exposure, the eggs are washed on a screen repeatedly with filtered, UV-irradiated seawater and resuspended in the same kind of water. The stripped sperm are then added.

Table 1 shows the effects on *Arctica* eggs of exposure to dilute NH_4OH for different lengths of time. The effects are measured in terms of the per cent development of normal eggs to normal straight-hinge, veliger larvae at 12°C ± 2°C. The term "normal eggs" is defined here as those eggs which after being stripped from the gonad have, or quickly assume, the round, solid appearance that characterizes most naturally-spawned bivalve eggs.

In two of the three experiments, there was some fertilization and development of untreated eggs, but the per cent development of treated eggs was almost always higher and, in the best exposure times, about three times higher than in the controls. Exposure times between 5 and 15 minutes appear to give good results.

The ocean quahog is a cold water species. The adults soon die if kept in water of 70°F (Turner, 1949). One might expect, therefore, that their eggs would also be intolerant of high temperature. Table 2, which summarizes the results of two experiments in which the effects of different temperatures on the development of eggs treated with ammonium hydroxide for 15 minutes were observed, shows this to be so.

TABLE 1 *Per cent development to the veliger stage of* Arctica islandica *eggs expose to NH_4OH for different lengths of time prior to fertilization*

Experiment	*Exposure time in minutes*						
number	0	5	10	15	20	30	60
1	1	12	8	10	11		
2	1	12	11	27	6		
3	0	13		13		7	2
Average	5	12	10	17	8	7	2

TABLE 2. *Per cent development to the veliger stage at different temperatures of* Arctica islandica *eggs exposed to NH_4OH for 15 minutes prior to fertilization*

Experiment number	*Water temperature*			
	10°C	15°C	20°C	23°C
1	10	26	2	0
2	27	21	3	0
Average	18	24	2	0

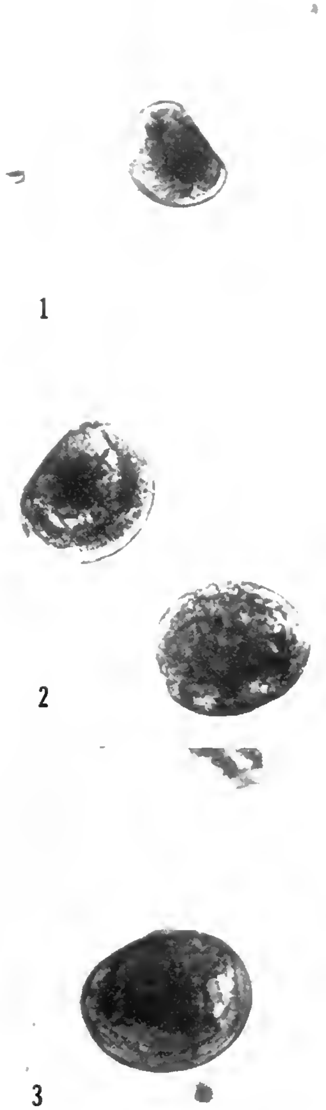
Variations from the prescribed temperatures were about ±1°C in these experiments. At temperatures of 20°C and above development of the eggs to normal larvae is adversely affected. Visual examination showed that fertilization and early cleavage were as successful at the high temperatures tested as at the lower ones, but before the veliger stage was reached, most of the embryos died. Per cent development of eggs at 10°C and 15°C was approximately the same but the *rate* of development was slower at 10°C. At 15°C veliger larvae were present at 48 hours after fertilization but not until about 72 hours at 10°C.

GROWTH OF THE LARVAE

Larvae were grown to metamorphosis twice — once at 10°C and once at 12°C, using the method described by Loosanoff and Davis (1963). A mixture of *Monochrysis* and *Isochrysis* was used as food.

The development of the larvae from straight-hinge to metamorphosis is, in general, undistinguished, with no arresting morphological features which would serve to distinguish the larvae from those of many other bivalves in the plankton. With that in mind, only certain characteristics which appear to be typical of *Arctica* development are described.

The earliest, fully-shelled, straight-hinge larvae average about 110μ long (parallel to the hinge line) and 80μ high (Fig. 1). The hinge line is longer than that of most straight-hinge bivalve larvae and, at this stage, averages slightly more than 80μ. In this respect the larvae are similar to those of the blue mussel, *Mytilus edulis*. The color is light yellow to almost colorless. A noticeable concavity in the hinge line is apparent in some larvae, but in the majority it is straight. In a resting position the larvae appear to be bilaterally symmetrical, with little or no skewness.



FIGS. 1-3. *Larval development in the ocean quahog,* Arctica islandica. FIG. 1. *Early straight-hinge larva, 110 μ long.* FIG. 2. *Late straight-hinge and early umbone larvae, 150 μ long.* FIG. 3. *Mature larva approaching metamorphosis, 180 μ long.*

At a length of 150μ, the straight hinge line is still a prominent feature in many larvae, but has begun to be replaced in others by a convex hinge line (Fig. 2). Umbones are present but are small and of low profile and, consequently, do not impinge on the gradually rounding outline of the shell.

At a length of 175-180μ it is apparent that the larvae have changed only in size and not at all in shape, since the silhouette is still round. In certain perspectives the umbones appear to project very slightly above the hinge, but from most angles they lie about even with the slightly convex hinge line. A few larvae begin to metamorphose at this size and can be seen creeping along the substrate, but the most common larval length at metamorphosis is 190-200μ.

The length of larval life at both 10°C and 12°C in the laboratory was about 60 days. Because the bottom water temperature over the clam beds off Rhode Island does not exceed 15°C during the breeding season (Loosanoff, 1953), the slow growth of the larvae in the laboratory at the experimental temperatures may be accurately reflect the rate of growth of the larvae in the field. This would force the larvae to remain in the plankton for weeks, possibly subjecting them to prolonged predation and widespread dispersal, a consideration in the proper management of the resource if it is ever utilized to its fullest extent.

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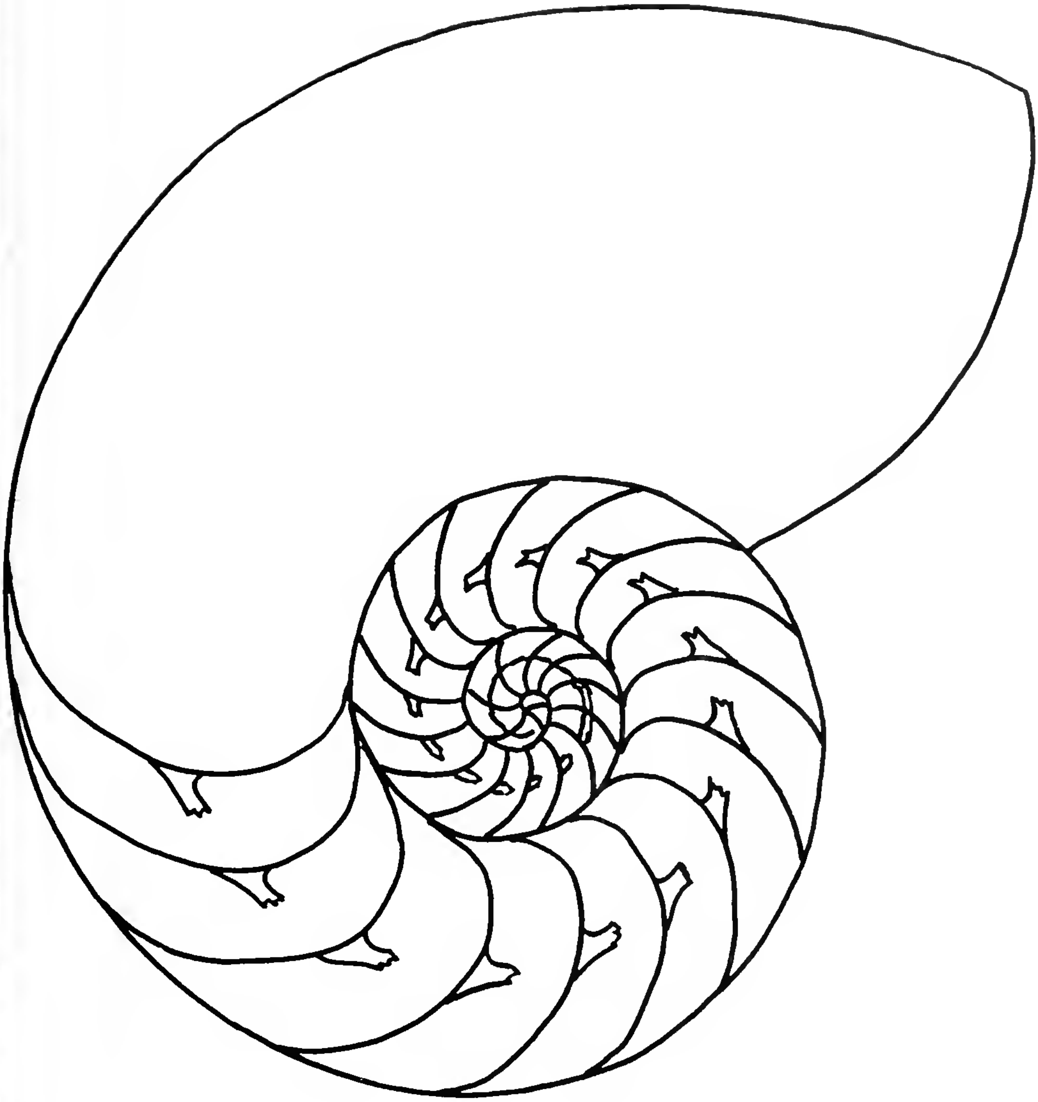

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CONTENTS

BOOK REVIEW

Emerson, William K. and Morris K. Jacobson. 1976. *Guide to Shells: Land, Freshwater, and Marine, from Nova Scotia to Florida.* xviii + 482 pp., 47 pls. (16 in color). Alfred A. Knopf, N. Y. Hardcover, $17.50; paperback, $8.95.

This husky little guide with its attractive illustrations and entertaining, as well as accurate, text should be a popular sheller's reference book to the common shells of the seashore, streams and woods of eastern United States. Numerous keys to all of the species covered in the book, and a wealth of etymological data for the lovers of the origin of names, are outstanding features.

The selection of the 524 species of marine shells, except for a few dozen species requiring a microscope for identification, will help the amateur, although other similar books treat with many more. Most useful under this one cover are several hundred, rather well-illustrated, land and freshwater mollusks.

Somewhat of a drawback created by the book designer is the use of difficult-to-remember roman numerals for the plates (XLII, XXXIX, etc.), and the main species not being put in boldface type. The origin of the scientific names is very well done, but, parenthetically, *Helicina clappi* was named after the venerable land-shell taxonomist, George Hubbard Clapp, and not for the Cape Cod shipworm specialist, William F. Clapp. Amateurs and some professionals will be dismayed over the re-arrangement of the scientific names of the *Busycon* whelks. The illustrated holotype of Linnaeus' *perversum* (The Nautilus, vol. 53, pl. 7) is almost identical to what they label as *kieneri*. Nonetheless, this is a very praiseworthy shell book.

R. Tucker Abbott
Delaware Museum of Natural History

NORTHERN RANGE EXTENSION OF THE FLORIDA MARSH CLAM *CYRENOIDA FLORIDANA* (SUPERFAMILY CYRENOIDACEA)

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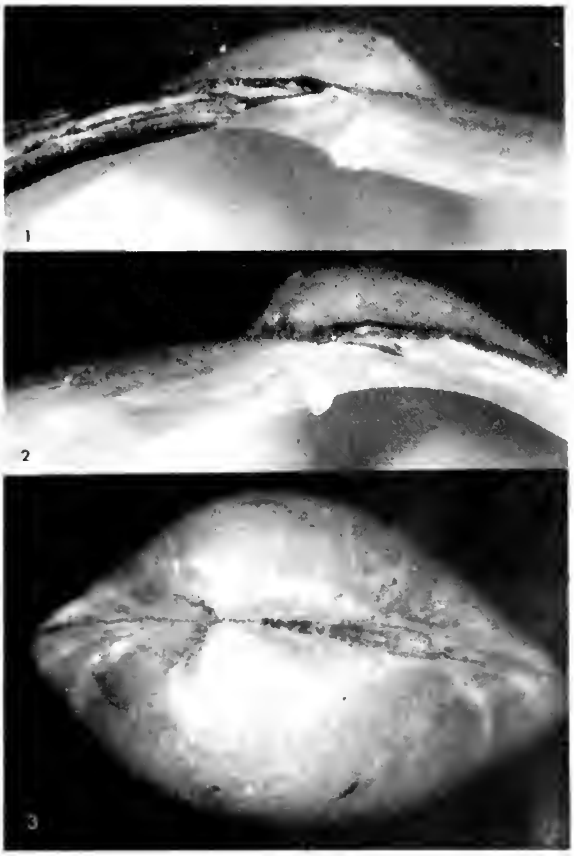
The small bivalve, *Cyrenoida floridana* (Dall, 1896), was collected in the Canary Creek Marsh, Delaware, at 38°48′45″ north latitude and 75°10′ west longitude. In May 1975, 15 samples were collected in connection with a marsh productivity study. On the average, 12 specimens were found in every 1/4 m² sample. The clams attaining a length of 9 mm occurred most abundantly among the layer of detritus at the base of the marsh grasses.



FIGS. 1-3. Cyrenoida floridana *(Dall, 1896) from Canary Creek, Delaware.* **1,** *hinge of left valve.* ×*200.* **2,** *hinge of right valve.* ×*200.* **3,** *dorsal view of bivalve.* ×*100.*

The range for *C. floridana* had previously been reported from Georgia to southern Florida (Dall, 1896). This constitutes a northern range extension of approximately 900 km and crosses a major zoogeographic boundary (Abbott, 1968; Cerame-Vivas and Gray, 1966). The description of these specimens agrees with Abbott (1974, p. 466, fig. 5385).

To ascertain more information about the densities and ecology of *C. floridana*, 15 stations tent and volatiles, sand, silt and clay, Eh, and *alterniflora* (tall and dwarf), *S. patens*, and *Distichlis spicata* zones. The percent of water content and volatiles, sand, silt and clay, Eh, and surface salinity were sampled at each location. A 0.1 m² sample of sediment taken from the base of each of the grasses was sieved over a 1 mm screen and the number of *C. floridana* was recorded.

The area with the highest density of *C. floridana* was the *D. spicata* (15.0/0.1 m²) zone. The dwarf *S. alterniflora* (3.0/0.1 m²) area was the only other area where appreciable numbers of individuals were found. A few specimens were recorded in the *S. patens* and *S. alterniflora* zones.

Of the environmental data collected only the percentage of volatiles and water content showed any association with the observed densities of *C. floridana*. The *D. spicata* and dwarf *S. alterniflora* had mean water contents of 238.4 (± 81.5) and 273.8 (± 104.1), respectively, while the tall *S. alterniflora* value was only 80.7 ± 26.7. The percentage of volatiles was also higher in the *D. spicata* (20.0 ± 7.4) and dwarf *S. alterniflora* (21.8 ± 8.5) areas than in the creekside tall *Spartina* (6.76 ± 2.02).

From this limited evidence it may be speculated that the high water content of the sediments containing *C. floridana* may be important in facilitating the life functions between daily inundations in the marsh areas where it lives. The high volatile content of the sediments inhabited by *C. floridana* should be examined more closely for its possible nutritive role.

The stem densities in the *D. spicata* and dwarf *S. alterniflora* zones are far greater than those in the tall *S. alterniflora*. This may be very important in stabilizing the sediment and lessening the effect of light and temperature on marsh surface containing the clam (Kraeuter and Wolf, 1974).

At the suggestion of Dr. R. Tucker Abbott, who kindly verified the identification (Del. Mus. Nat. Hist., No. 102,538), we offer a figure to supplement the illustration in Abbott (1974). We would like to thank our colleague, Mr. Phil Averill, who collected and brought these specimens to our attention.

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TWO NEW SPECIES OF NON-MARINE MOLLUSCA FROM THE FORT UNION GROUP (PALEOCENE) OF NORTH DAKOTA AND MONTANA

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ABSTRACT

Two new species of fossil freshwater mollusks are described from the Paleocene Tongue River and Sentinel Butte Formations of North Dakota and Montana. Eupera missouriensis *n. sp. is a pisidiid clam related to* E. formosa *(Meek and Hayden).* Bellamya campaniformis *n. sp., a viviparid snail, occurs in the lower and middle Tongue River Formation and possibly in the Paskapoo Formation of Alberta.*

INTRODUCTION

Pioneering work on Fort Union mollusks and stratigraphy was done by F. B. Meek and F. V. Hayden between 1856 and 1860. Meek (1876) summarized the paleontology of the region and listed about 25 non-marine species of mollusks then known to occur in the Paleocene of the Williston Basin. With the exception of studies in the Saskatchewan portion of the basin summarized by Russell (1974) and other, scattered reports, most data on Paleocene mollusks of the Northern Great Plains has come from work in other sedimentary basins.

This report of two new species is part of a study of Williston Basin mollusks initiated in 1971 and due for publication in the near future. The results are based on collections from about 130 localities in eastern Montana and western North Dakota selected to provide the best stratigraphic and geographic coverage of the Fort Union Group.

The Fort Union Group along with the lowest member of the predominantly Eocene Golden Valley Formation includes all the strata of Paleocene age in the Williston Basin. The Ravenscrag Formation is the synonymous lithostratigraphic term for the northern margin of the Fort Union sequence in Saskatchewan (Russell, 1974). In eastern Montana the earliest Paleocene is included in the Tullock Formation which sets on top of dinosaur-bearing beds of the Cretaceous Hell Creek Formation and is overlain by the Lebo Formation. Together, the two reach thicknesses of over 600 ft. In North and South Dakota these two rock units cannot be easily separated and the sequence is termed the Ludlow Formation with possible subdivision into Tullock and Lebo Members in some areas. The Ludlow Formation in North Dakota and southeastern Saskatchewan intertongues with a marine equivalent, the Cannonball Formation, which represents a last resurgence of the Cretaceous epicontinental sea that crossed North America. Up to 700 ft. of the non-marine Tongue River Formation overlays the Lebo-Ludlow formation in Montana and westernmost North and South Dakota, and the Cannonball Formation over much of western North Dakota. The Saskatchewan portion of the basin includes only the lowest part of the Tongue River Formation and older rocks. Over much of North Dakota and parts of eastern Montana up to 650 ft. of the Sentinel Butte Formation overlays the Tongue River Formation and represents the most extensive unit of Upper Paleocene strata in the basin. At scattered localities in western North Dakota remnants of the lower member of the Golden Valley Formation reach maximum thicknesses of 65 ft. The Paleocene-Eocene boundary is placed at the contact of the upper and lower members of this formation based on paleobotanical evidence (Hickey, 1972).

Sediments comprising Fort Union Group strata, with the exception of the Cannonball Formation, were deposited in an alluvial system of numerous streams flowing generally eastward across broad coastal lowlands left from the mid-continent seaway. The sediments occur generally as semi-consolidated silts, clays, fine sandstones, and the lignite beds that command current attention as a source of abundant coal. The strata are often calcareous although true limestone and marlstone units are rather infrequent. Jacob's (1973) discussion of depositional environments of the Tongue River Formation provides a basic insight into the environments responsible for much of the non-marine Fort Union sequence.

Register of localities—The species described here occur at only 8 of the many localities examined, thus both are infrequent or rare in the Williston Basin.

Locality 1.—NW 1/4, SW 1/4, sec. 7, T. 143 N., R. 79 W., Burleigh Co., N. Dak., middle Tongue River Formation. 2.—NW 1/4, sec. 30, T. 142 N., R. 78 W., Burleigh Co., N. Dak., lower Tongue River Formation. 3.—SW 1/4, sec. 12, T. 144 N., R. 84 W., Mc Lean Co., N. Dak., upper Tongue River Formation. 4.—NE 1/4, SW 1/4, sec. 1, T. 140 N., R. 81 W., Burleigh Co., N. Dak., lower Tongue River Formation. 5.—SE 1/4, NW 1/4, sec. 28, T. 148 N., R. 100 W., Mc Kenzie Co., N. Dak., upper Sentinel Butte Formation. 6.—SE 1/4, NE 1/4, sec. 26, T. 148 N., R. 100 W., Mc Kenzie Co., N. Dak., upper Sentinel Butte Formation. 7.—NE 1/4, NW 1/4, sec. 10, T. 12 N., R. 51 E., Prarie Co., Mont., lower Lebo Formation. 8.—sec. 7, T. 135 N., R. 88 W., Grant Co., N. Dak., upper Tongue River Formation.

Family Pisidiidae

Genus *Eupera* Bourguignat

Eupera is represented in the non-marine Paleocene of the Williston Basin by the following taxon and "*Sphaerium*" *formosum* (Meek and Hayden). Yen (1946) referred a Lower Cretaceous species from Alberta and Wyoming to the genus and noted that *Eupera* also occurs in the Eocene of North America.

Eupera missouriensis *new species*

Figs. 1-4

Description—Shell medium size, elongate, inflated, greatest thickness along mid-length; beaks large, raised, umbo extending forward to anterior one-fourth of length; hinge extending over most of shell length; dorsal margin convex, joining posterior margin at a rounded angle; posterior high; posterior margin truncate, joining ventral margin at a prominent but rounded angle; ventral margin convex, merging with rounded anterior margin; anterior margin meeting hinge line to form a rounded angle; anterior end low; posterior outer surface crossed by a rounded and indistinct ridge extending from beak to base of posterior margin; surface above ridge flattened or slightly convex; growth lines fine, irregular, growth cessation intervals marked by coarse lines; right valve (RV) cardinal tooth slender, posterior tip bent slightly ventrad below umbo,

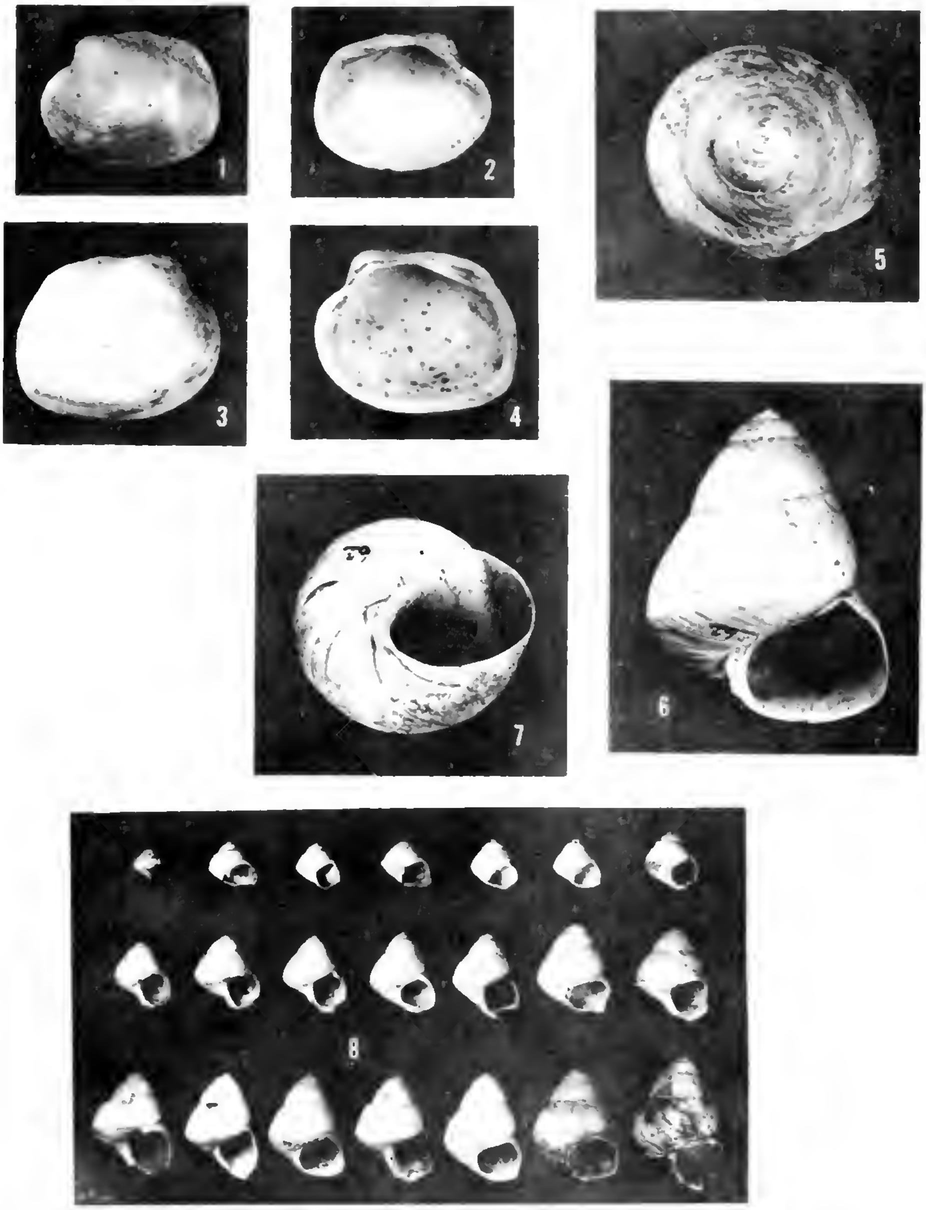

FIG. 1, Eupera missouriensis *n. sp., exterior of Holotype (USNM 220078) ×4;* FIG. 2, *same specimen, interior of Holotype ×4;* FIG. 3, Eupera missouriensis *n. sp. exterior of Paratype (USNM 220079) ×4;* FIG. 4, *same specimen, interior of Paratype ×4;* FIG. 5, Bellamya campaniformis *n. sp., apical view of Holotype (USNM 220080) ×1.5;* FIG. 6, Bellamya campaniformis *n. sp., Holotype ×1.5;* FIG. 7, *same specimen, basal view of Holotype ×1.5;* FIG. 8, Bellamya campaniformis *n. sp., series of 21 paratypes summarized in Table 1, ×½.*

anterior portion merging into hinge; cardinal teeth (LV) two, short, slender, situated below umbo; posterior lateral tooth (RV) slender, length about one-fourth of shell length; anterior lateral teeth (RV) two, short, cusps forming lip-like border for pocket, inner lateral curved, bulging into shell cavity; anterior and posterior laterals (LV) single, thick, raised, cusps prominent and situated near mid-length.

Types and measurements—Holotype USNM 220078 a right valve measuring, length 7.1 mm., height 5.5 mm.; Paratype USNM 220079 a left valve measuring, length 8.1 mm., height 6.4 mm.

Type locality—SE 1/4, NW 1/4, sec. 28, T. 148 N., R. 100 W., Mc Kenzie Co., N. Dak. North Unit of Theodore Roosevelt Memorial Park at 2340 ft. above mean sea level. Sentinel Butte Formation.

Age and range—Middle through late Paleocene age. *Eupera missouriensis* occurs in the Tongue River Formation along its eastern margin and in the Sentinel Butte Formation in the Little Missouri Badlands of western North Dakota. It is a dominant element only in the assemblages from the Sentinel Butte localities. Specimens have been collected at Localities 3, 4, 5, 6, and 8.

Remarks—*Eupera missouriensis* can only be confused with the equally uncommon but smaller species, *Eupera formosa* (Meek and Hayden). It is more elongate than *E. formosa* and possesses a rounded posterior ridge that is flanked by areas that appear flattened relative to the rest of the shell surface. The posterior surface of *E. formosa* is not broken by a ridge and its posterior margin is more rounded and merges with the ventral margin in a gentle curve. *Eupera formosa* appears ovate in outline while *E. missouriensis* appears more triangular. Growth lines on *E. formosa* are more regular than those of *E. missouriensis*. *Eupera formosa* has a slightly more fragile shell, and Williston Basin localities indicate that it inhabited rather heavily vegetated and quiet water in floodbasin areas. *Eupera missouriensis* has been collected from units interpreted as channel, point bar, levee or crevasse splay deposits. It appears that the two species occupied different habitats in the alluvial system, with *E. missouriensis* more closely associated with stream channels, possibly living in quiet reaches along shore. Specimens suited to adequate study of hinge structure are seldom recovered from the fine enclosing matrix, however the hinge structures of *E. formosa* are generally more delicate that those of *E. missouriensis* and the cusp of the posterior lateral (LV) is toward the posterior while on *E. missouriensis* it is central on the tooth.

Family Viviparidae
Subfamily Bellamyinae
Genus *Bellamya* Jousseaume

Examination of numerous lots of living African and Asian Bellamyinae in the U. S. National Museum and Field Museum of Natural History confirms Dwight Taylor's assignment of this and many other Late Cretaceous and Paleocene forms to the Bellamyinae.

Bellamya campaniformis *new species*

Figs. 5–8

Description—Shell medium to large, trochiform, heavy; spiral angle 70°-90° on first five whorls, declining to 50° on later whorls; shell width about three-fourths of height, width and height nearly equal in juveniles; whorls 4 to $6\frac{1}{2}$, juvenile whorls nearly flat to slightly convex, adult whorls slightly to moderately convex; juncture of whorl base and periphery angular, marked by a narrow raised carina on juvenile whorls, whorl base convex; sutures lightly impressed, often slightly to distinctly below keel of preceding whorl; body whorl large, comprising more than two-thirds of shell height; aperture

TABLE 1. *Ranges of measurements and proportions of three size groups of* Bellamya campaniformis *n. sp. Upper, middle, and lower rows of Figure 8 show measured specimens arranged in the respective groups.*

Number of specimens	Height (mm.)	Width (mm.)	Number of whorls	$\frac{\text{Width}}{\text{Height}}$
7	10.8-18.4	12.9-17.0	4.0-4.7	1.19-.92
7	21.0-29.8	18.6-23.7	4.7-5.3	.88-.77
7	31.2-42.6	25.1-28.9	5.1-6.5	.81-.67

ovate to roundly triangular, large, equal to about 60% of shell height in juveniles, about 45% in mature specimens; peristome and growth lines prosocline, forming a 40° angle with spire axis; peristome periphery and base simple, convex, columellar lip attached, thickened, slightly reflected near base; columella imperforate; growth lines prominent, straight or slightly sinuous, and crossed by 1 to 6 or more fine, evenly spaced, spiral ridges.

Types and measurements—Holotype USNM 220080 height 32.7 mm., width 25.1 mm., aperture height 15.5 mm., whorls 6; Paratype USNM 220081 height 25.1 mm., width 20.8 mm., aperture height 12.4 mm., whorls 5. Nineteen other paratypes (Figure 8 and Table 1) are retained in the author's collection.

Type locality—Ball Butte, NE 1/4, SW 1/4, sec. 1, T. 140 N., R. 81 W., Burleigh Co., N. Dak. Gray buff sandstone about 2090 ft. above mean sea level. Tongue River Formation.

Age and range—Mid Paleocene, lower 300 ft. of the Tongue River Formation along its eastern margin in North Dakota (Localities 1, 2, 4, and possibly 7) and the Paskapoo Formation of Alberta.

Remarks—*Bellamya campaniformis* differs from *Bellamya retusa* in having a higher spire, a greater number of whorls, and whorls that are much less convex. *Bellamya retusa* lacks the spiral sculpture and keeled periphery of *B. campaniformis*. Both species have similar peristomes and share the tendency for shoulders to be formed on the first three whorls.

Bellamya campaniformis has a thicker walled and heavier shell than *Paludotrochus trochiformis*. It lacks the two prominent and equally spaced spiral ridges that are consistent features on the spire whorls of *P. trochiformis*. The spiral angle of *P. trochiformis* varies only from 80° to 70° during ontogeny giving the spire a straight-sided, trochoid shape while the spiral angle of *B. campaniformis* decreases during ontogeny producing a spire with convex sides. The number of whorls are about the same for the two species. A distinct shoulder at the top of early whorls persists onto the fourth whorl of *P. trochiformis* while the shoulder on *B. campaniformis* is generally less distinct and fades out on the second or third whorl. *Paludotrochus trochiformis* has a perforate collumella and generally a thinner columellar lip than *B. campaniformis*.

Tozer (1956) referred to *Bellamya retusa* specimens from the Paskapoo Formation (Paleocene) of Alberta that agree with *B. campaniformis*. The description and illustrations give the diagnostic characters of this species, however his material was not examined.

The species has been collected from sand and clayey silt units interpreted as channel, point bar, and floodbasin deposits. Its limited occurrence does not permit a full analysis of its ecology, however it apparently lived in habitats associated with larger streams or at least flowing water as opposed to ponded floodbasin habitats.

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A NEW *HUMBOLDTIANA* (PULMONATA: HELMINTHOGLYPTIDAE) FROM COAHUILA, MEXICO

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ABSTRACT

A new species of land snail, known only from shells, is described and placed provisionally in the genus Humboldtiana *(Pulmonata: Helminthoglyptidae).* Humboldtiana plana *differs from other known species of* Humboldtiana *in its greatly flattened and highly granulose shell. It is presently known only from the Sierra Santa Rosa in north-central Coahuila, Mexico.*

INTRODUCTION

The species of land snail described herein was collected by Riskind from the higher, northern slopes of the Sierra Santa Rosa, north-central Coahuila, Mexico, in 1975. Generic allocation of the species to the genus *Humboldtiana* cannot be done with certainty as living specimens have not been obtained in two collecting trips requiring strenuous climbs. The shell is much more depressed and granulose than in any known species of *Humboldtiana*. However, *Humboldtiana* is the only genus of large, banded helicacean snails known in the region and it seems likely that this species is a conchologically modified representative of the genus or of a new, related genus in the family Helminthoglyptidae.

There are few published records of *Humboldtiana* from Coahuila. However, the genus has been recorded from both the extreme north (*H. taylori* Drake by Drake, 1951: 95 and by Solem, 1954: 6) and the extreme southeast (*H. nuevoleonis* Pilsbry by Pilsbry, 1948b: 192). Thus, it seems likely that the genus also occurs in many of the intervening mountain ranges in the state such as the Sierra Santa Rosa. Drake (1951: 93) assigned shells from archaeological deposits in Frightful Cave in the Cuatro Ciènegas Basin of central Coahuila to *H. montezuma* Pilsbry.

Humboldtiana plana *new species*

Figs. 1-3

Description of Holotype: Shell thin, flattened, with spire rising only slightly above shoulder at an angle of *ca.* 150°; whorls 4.1, with body whorl expanding greatly and angular peripherally; aperture elongate-lunate, its height 1.4 times its width; columellar peristome reflected, covering half of umbilicus; outer lip thin, broken; embryonic whorl smooth; second whorl with small granules in center; remainder of shell, both above and below (including umbilical area) with numerous large, whitish granules, irregularly distributed, smaller on older whorls and ranging from 0.3-0.9 mm in length (averaging *ca.* 0.5 mm) on the body whorl, some arranged in irregular rows of two to twelve granules; dark reddish-brown color of first 1½ whorls continues on as a

FIGS. 1-3. *Holotype of* Humboldtiana plana *new species (43.6 mm diameter) in lateral, dorsal and ventral views.*

band in central dorsal part of whorls $1\frac{1}{2}$ to $2\frac{1}{2}$, greatly expanding thereafter to cover inner half of whorl 4, this band 10.8 mm wide at lip; two additional bands arise on first part of whorl 4, one above and one below peripheral angularity; remaining surface of shell brownish-gray except for the numerous whitish granules; internal surface of aperture dark reddish-brown, slightly iridescent. Etymology: From *planus* (L.), flat, in relation to morphology of shell.

Variation and Measurements: Only four relatively complete shells of *H. plana* have been obtained (numerous fragmentary specimens were observed). Part of the thin-shelled body whorl has been broken away in one paratype and some breakage has damaged the lip of the holotype, which is, otherwise, the best-preserved of the four shells. In two specimens with undamaged peristomes, the outer lip is slightly thickened and recurved and columellar peristome extends over most of the umbilicus. Probably the type died shortly before forming the thickened peristome seen in these paratypes. In one paratype the nuclear whorls are slightly more elevated than in the type. Measurements for the type (listed first) and two paratypes are as follows: Diameter of shell, 43.6, 40.1, 40.5; Height of shell, 19.8, 21.0, 18.8; Aperture width, 25.1, 25.4, 25.1; Aperture height, 17.8, 16.0, 15.5; Number of whorls, 4.1, 4.3, 4.2.

Types: Holotype, Delaware Museum of Natural History 106681; Paratypes: University of Arizona 6220 and University of Texas at El Paso 4651 and 4653.

Localities of Collections: Holotype and two paratypes (UA 6220, UTEP 4651): Mexico, Coahuila, Mcpo. de Muzquiz, Sierra Santa Rosa near the summit of the Rincon de Maria (28°28′ N; 102°04′ W). *Ca.* 2207 m elevation in sheltered, mesic cleft with northern exposure in a massive limestone cliff. Associated plants include such mesophytic species as the ferns *Woodsia* sp., *Polypodium erythrolepis*, the fir, *Abies coahuilensis*, and species of *Tilia*, *Philadelphus* and *Heuchera*. Collected on 23 August 1975 by Riskind, T. Wendt and E. Lott. On 24 April 1975 a paratype (UTEP 4653) was collected by Riskind and T. Wendt on the north slope of the same mountain at an elevation of 1700 m in an area of extensive stabilized limestone talus in oak woodland (predominantly *Quercus glaucoides*).

COMPARISONS AND DISCUSSION

The flatness and angularity of the shell of *H. plana* is much greater than in any *Humboldtiana* known to us. The degree of granulation is extreme for the genus but may be approached by that of *H. pergranulosa* Solem from Durango. Solem (1955: 42) noted granules 0.05-0.75 mm long in *H. pergranulosa*. Illustrations (Solem, 1955: Figs. 1-3) show these to be more uniformly distributed over the surface than in *H. plana*.

Some members of the polygyrid snail genus *Ashmunella* living in talus of limestone rocks have become greatly flattened and carinate. Pilsbry (1948a: 587) quoted notes (A. G. Wetherby) indicating that the greatly flattened and carinate *Anguispira cumberlandiana* (Lea) inhabited crevices between layers of limestone rocks. Perhaps flattened shells are of adaptive value in such habitats.

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ANOMALOUS LAND GASTROPODS FROM TEXAS (POLYGYRIDAE AND UROCOPTIDAE)

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ABSTRACT

Anomalous shells of several land gastropod species from Texas include scalariform Mesodon thyroidus thyroidus, Mesodon roemeri *and faulty shell regeneration in* Holospira oritis, Holospira mesolia, *and* Polygyra texasiana texasiana.

SCALARIFORM MONSTROSITIES

A loosely-spired *Mesodon thyroidus thyroidus* (Say), (Fig. 1) was collected in deep woodlands near White Rock Creek, Dallas Co., on 22 June 1974, by Bruce Boardman. The whorls are acutely raised with the spiral lines deeply incised. The shell wall from the embryonic whorl through the antepenultimate whorl is quite thin. The general appearance is that of a highly turreted shell. The shell measures 16.5 mm in height and 19.6 mm at greatest diameter, giving a H/D ratio of 0.84. Average figures previously reported for this species (Cheatum & Fullington, 1971: 29) are 20 mm and 12-13 mm for an average H/D ratio of 0.60-0.65.

A turreted *Mesodon roemeri* Pfeiffer (Fig. 3) was given to one of us (RWN) on 24 May 1972 by Don W. Kaufman, who collected it in an open woodland floodplain along Barton Creek within Austin, Travis Co. The specimen was alive and appeared normal; it was later found dead in the labortory in early August. Death is believed to be the result of improper care rather than associated effects of the anomalous shell form. The shell measures 18.8 mm in height and 23.0 mm greatest diameter (H/D ratio = 0.82); normal height for a shell of that diameter is about 12 mm (Cheatum & Fullington, 1971: 20-21), resulting in a H/D ratio of 0.52. The shell wall of this specimen of *M. roemeri* does not appear to be thinner than in normal specimens of this species.

These similar anomalies of two species of *Mesodon* were found independently from widely spearated localities. The only shell anomaly reported for these two species previously involved several specimens for *thyroidus* (Bland in Tryon, 1867; Wetherby, 1895; Archer, 1934) and a single sinistral specimen for *roemeri* (Pratt, 1965).

These two specimens, representing two species which are most easily distinguished by differing H/D ratios, appear to be very similar. However, they are referrable to their respective taxa by application of other differences between these two species (Neck, upub. data). The Dallas Co. specimen exhibits the following characteristics of *thyroidus*: 1) almost immediate expansion of upper lip, 2) the erect nature of the lip as it approaches the umbilicus, 3) coarse growth lines and 4) ochre band behind the lip. The Travis Co. specimen exhibits the following characteristics of *roemeri*: 1) delay of peristome expansion until upper lip merges into palatal lip, 2) lip flattened as it approaches umbilicus, 3) fine growth lines and 4) yellowish band behind lip. Additionally, each site contains only individuals of the respecive species of *Mesodon*.

The high-spired *roemeri* is noticeably larger than the high-spired *thyroidus*. In eastern Travis Co. and Bastrop Co. (central Texas) where these two species occur sympatrically, *throidus* is slightly larger than *roemeri*. The smaller size of the Dallas Co. *throidus* may be the result of marginal habitat near the edge of its geographical range.

Without detailed breeding and controlled experiments, we can only speculate as to the cause of these two anomalous shell conditions. A similar anomaly was reported in *Helix aspersa* Muller from a California garden (Herzberg, 1966); breeding of this individual failed to pro-


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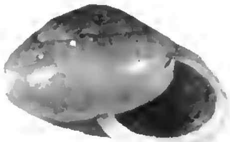
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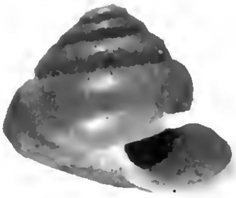
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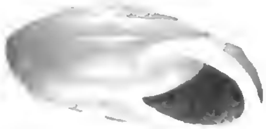
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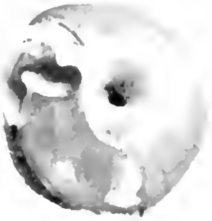
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duce the anomaly in either F_1 or F_2 generations. Similar turreting has been reported for at least two species of *Littorina* (Davis, 1972; Rosewater, 1972). The effect in thsee two species, however, did not involve an increase in shell height, only a turreting effect.

In the two *Mesodon* individuals reported herein, the cause, whether genetic or environmental, affected shell growth from the time of hatching, possibly before. The small size of the protoconch makes it impossible to determine if the turreting effect began in the earliest stages of embryogenesis although this would *a priori* appear to be most likely as all post-nuclear whorls are affected. Rosewater (1972) reported specimens of *Littorina scabra angulifera* Lamarck with both immediate and late turreting, i.e. changes involving all whorls and only the last two. Oldham (1931) attributed the occurrence of high-spired *Arianta arbustorum* (L.) to injuries by parasitic mites; neither *Mesodon* shell appears to have the deformed shell structure which accompanies such a malformation.

M. thyroidus (Fig. 2) and *M. roemeri* (Fig. 4) are members of the same subgenus *(Mesodon s. str.)* but are placed in different species groups (Pilsbry 1940: 704 *et seq.*). As these two species undoubtedly share considerable common genetic material, the turreted anomalies could be genetic in origin, either through similar mutations or through similar rare recombinations of certain alleles. The possibility of some environmental factor affecting expression of normally buffered (non-expressed) genes cannot be ruled out but is considered unlikely. Both shells have the normal number of whorls ($5\frac{1}{4}$-$5\frac{1}{2}$).

FAULTY SHELL REGENERATION

Gastropods are effectively protected from environmental perturbations by their calcreous shells. When an injury cracks or destroys a part of the shell, regeneration of the injured portion must occur. Terrestrial gastropods are

FIGS. 1-2. Mesodon thyroidus *(Scalariform, Normal)*
FIGS. 3-4. Mesodon roemeri *(Scalariform, Normal)*
FIGS. 5-7. *Abnormal* Holospira oritis
FIGS. 8-9. *Abnormal* Holospira mesolia
FIGS. 10-11. *Abnormal* Polygyra t. texasiana

particularly effective in rapid regeneration of shell material (Wagge and Mittler, 1953). Sometimes regeneration of an injured shell results in oddly-formed shells.

A dead shell of *Holospira oritis* (Fig. 5-7) Pilsbry & Cheatum with two complete apertures (Fig. 3) was collected 26 July 1974, deep in South McKittrick Canyon, Guadalupe Mountains National Park, Culberson Co., by Ray Garza. The shell measures 14.6 mm in height and 4.8 mm at greatest diameter. The shell contains nine whorls but several apical whorls have been lost. Entire shells of this species measure 13½-15½ whorls and 15-20 mm in length (Cheatum & Fullington, 1973: 40). The breakage may have occured some time following death as the shell material is not weathered to the same degree as the rest of the shell. The body whorl of the snail was filled with soil and debris when found.

The entire body whorl except for the original aperture and 2.5-3.0 mm behind it had been torn away. A new body whorl and partial peristome were secreted with the original neck cavity being filled by the columellar lip of the new aperture. The new shell secretions were rough and irregular; now new ribs were formed on the new basal whorl. The basal lip of the new aperture was split by the presence of remnants of the original whorl; thus, the animal emerged between the palatal wall of the second aperture and the jagged edge of part of the original body whorl. A similar double-aperture example of *Cylindrella agnesiana* C. B. Adams is illustrated by Cooke (1895: 252, Fig. 160A). In this case, the body whorl was undamaged with destruction restricted to previous whorls. The second aperture was constructed completely separate from the first. The most likely source of the original shell injury was attempted predation by some unknown animal (most likely rodent). Apparently, the shell was dropped and the animal was unharmed or only slightly injured as it survived to produce the illustrated repair work.

On 19 October 1974, several living and dead shells of *Holospira mesolia* Pilsbry (Fig. 8-9), were collected (by RWN) 4.6 km west of Sanderson, Terrell Co., on the north side of U.S. 90. Attention was drawn to one shell due to its shorter height (17.0 mm vs. 23.7 for normal shell). The smaller size was due to the loss of several whorls as a resullt of an injury similar to that suffered by the above individual reconstructed about 1¾ whorls before producing the extremely flat expansion of the peristome which is characteristic of this species. The final ¾ whorl is moderately ribbed in the manner typical of the body whorl of this species. The first reconstructed whorl which is partially underneath the remnant apical portion of the original whorl is unsculptured and much thinner than normal. The injury, however, either occured before the snail matured and constructed an aperture or was so massive that the original aperure was also destroyed. Comparison of the shortened shell with a normal shell revealed the loss of four complete whorls (if the injured individual matured previous to injury).

An additional example of shell repair was collected (by RWN) on 30 August 1974, at the Brackenridge Field Laboratory of the University of Texas at Austin within the Austin city limits. The shell involved is a *Polygyra texasiana texasiana* (Moricand) (Fig. 10-11) which had lost about ⅓ of its body whorl. The site of the original aperture was discernable by the presence of the parietal tooth which was apparently not totally built up at the time of the injury. The snail, however, did not reconstruct any of the body whorl. It simply constructed a new reflected lip complete with two teeth, one basal and one palatal. A new parietal tooth was also constructed. The diameter of the shell as found measured 8.1 mm; before injury, the original shell measured about 9.5 mm.

These three shells exhibit three responses to somewhat similar injuries. The differential responses of the two *Holospira* resulted from differential injuries. The response of the *P. t. texasiana* may indicate a basic difference between the Polygyridae and the Urocoptidae in the physiological response to shell regeneration.

All specimens described herein are deposited in the Dallas Museum of Natural History Mollusca collection. Reprint requests are directed to the Museum.

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NOTES ON SOME LAND SNAILS OF THE EASTERN UNITED STATES

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ABSTRACT

The examination of type and other material has made it necessary to change the status of a number of specific and subspecific names: Polygyra septemvolva volvoxis *and* P. s. febigeri *are synonyms of* P. cereolus; Polygyra latispira *is a synonym of* Triodopsis vultuosa; Guppya miamiensis *is a form of* G. gundlachi; Glyphyalinia burringtoni *is a synonym of* G. wheatleyi; G. roanensis *is a synonym of* G. cumberlandiana; G. umbilicata *is a valid species;* Paravitrea walkeri *is a synonym of* P. umbilicaris; P. smithi *is a synonym of* P. petrophila; Anguispira alternata paucicostata *is a synonym of* A. mordax; Helicodiscus enneodon *is a synonym of* H. multidens; Megapallifera *is raised to genus; and* Gastrocopta tappaniana *is a valid species.*

The examination of material in the Academy of Natural Sciences of Philadelphia (ANSP), the Museum of Comparative Zoology (MCZ), the University of Michigan Museum of Zoology (UMMZ), the Carnegie Museum (CM), and material in the author's collection has made it necessary to change the status of a number of specific and subspecific names.

Polygyra cereolus (Mühlfeld)

Helix cereolus J. C. Megerle von Mühlfeld, 1818, Gesellschaft naturforschender Freunde zu Berlin, Magazin etc., **8:** 11, pl. 2, fig. 18a, b.

Helix volvoxis "Parreyss" Pfeiffer, 1846, Symbolae ad Hist. Heliceorum, **3:** 80.

Helix carpenteriana Bland, 1860, Ann. Lyc. Nat. Hist. N. Y. **7:** 138.

Helix febigeri Bland, 1866, Amer. Journ. Conch., **2:** 373, pl. 21, fig. 10.

Polygyra septemvolva var. *floridana* Hemphill, in W. G. Binney, 1892, 4th suppl., Bull. Mus. Comp. Zool. **22:** 184.

Polygyra cereolus (Mühlfeld), Pilsbry, 1940, Acad. Nat. Sci. Philadelphia Mono. 3, 1: 582.

Polygyra cereolus form *carpenteriana* (Bland), Pilsbry, *ibid.* **1:** 585.

Polygyra cereolus floridana Hemphill, Pilsbry, *ibid.* **1:** 586.

Polygyra septemvolva volvoxis (Pfeiffer), Pilsbry, *ibid.* **1:** 590.

Polygyra septemvolva febigeri (Bland), Pilsbry, *ibid.* **1:** 591.

The presence of an internal lamella which Pilsbry used to distinguish *P. cereolus* from *P. septemvolva* Say is not a valid specific character. *P. cereolus* has larger caliber whorls and a smaller umbilicus than *P. septemvolva.* Very depauperate specimens less than 7 mm in diameter are very difficult to identify, but such specimens are rare. When the two species occur together, as they sometimes do, they can be sorted without too much difficulty. Very large lots will usually contain the complete range of variation in size, sculpture, and degree of angulation of the periphery; so that it does not seem wise to attempt to recognize subspecies.

Triodopsis vultuosa (Gould)

Helix vultuosa Gould, 1848, Proc. Boston Soc. Nat. Hist., **3:** 39.

Triodopsis vultuosa (Gould), Pilsbry, 1940. Acad. Nat. Sci. Philadelphia Mono. 3, **1:** 818.

Polygyra latispira Pilsbry, 1896, Proc. Acad. Nat. Sci. Phila., p. 16; 1940, **1:** 622.

The holotype and paratype (ANSP) of *Polygyra latispira* are immature *Triodopsis vultuosa.* An immature specimen of *T. vultuosa* in lot ANSP 172794, from 2 miles northeast of Neches, Anderson Co., Texas, Wheeler & Archer, colls. agrees with the types of *P. latispira.*

Guppya gundlachi form **miamiensis** Pilsbry

Helix gundlachi Pfeiffer, 1840, Archiv. f. Naturg., **1:** 250.

Guppya miamiensis Pilsbry, 1903, *The Nautilus* **17:** 77.

Guppya gundlachi (Pfeiffer), Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mono. 3, **2:** 244.

Guppya miamiensis Pilsbry, Pilsbry, *ibid.* **2:** 244.

Guppya miamiensis differs from *G. gundlachi* only in the absence of spiral sculpture. I believe it to be only a form of *G. gundlachi.*

Glyphyalinia wheatleyi (Bland)

Zonites wheatleyi Bland, 1883, Ann. N. Y. Acad. Sci. **2:** 368, fig. 1.

Glyphyalinia burringtoni Pilsbry, 1928, *The Nautilus,* **41:** 83.

Retinella wheatleyi (Bland), Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mono. 3, **2:** 272.

Retinella burringtoni (Pilsbry), Pilsbry, *ibid.* **2:** 266.

Glyphyalinia wheatleyi (Bland), Hubricht, 1964, Sterkiana **13:** 12.

There is no difference in the shells between *G. wheatleyi* and *G. burringtoni,* and recent studies show that the anatomical differences are not constant. Both types of penis may occur in the same lot and intermediates are sometimes found.

Glyphyalinia cumberlandiana (Clapp)

Polita cumberlandiana Clapp, 1919, *The Nautilus,* **33:** 8.

Retinella (*Glyphyalus*) *cumberlandiana roanensis* H. B. Baker, 1930, Proc. Acad. Nat. Sci. Philadelphia, **82:** 203, pl. 9, figs. 7-9; Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mono. 3, **2:** 271.

Retinella cumberlandiana (Clapp), Pilsbry, 1946, *ibid.* **2:** 269.

Glyphyalinia cumberlandiana (Clapp), Hubricht, 1964, Sterkiana **16:** 7.

Glyphyalinia roanensis (H. B. Baker), Hubricht, 1965, *The Nautilus* **78:** 133.

By going on my collecting trip through the Southern Appalachians in May instead of June, I discovered that *G. cumberlandiana,* which I had considered to be a rare species, was rather common. As a result, I was able to collect a good series which enabled me to better understand the species. H. B. Baker's treatment of *R. cumberlandiana* was based on small specimens of *G. wheatleyi* and *R. cumberlandiana roanensis* which I consider a synonym of *cumberlandiana.*

Glyphyalinia umbilicata (Singley)

Zonites indentatus var. *umbilicatus* Singley, in Cocherell, T. D. A. 1893, Brit. Nat., **3:** 81. 1899; *The Nautilus* **12:** 120.

Specimens collected in Dallas, Texas, were dissected and found to be more closely related to

G. luticola Hubricht than to *G. indentata* (Say), although the shell looks like a rather large *G. indentata* with a more open umbilicus. Judging by the shells I have seen, *umbilicata* appears to be widely distributed in Texas, but more anatomical studies of Texas material are needed. This species has been called *Retinella indentata paucilirata* (Morelet) by H. B. Baker and H. A. Pilsbry. But *paucilirata* was described from Guatemala and its anatomy is unknown. For this reason it seems unwise to use the name of a species so geographically distant in a group with such deceptive shells.

Paravitrea umbilicaris (Ancey)

Gastrodonta multidentata umbilicaris Ancey, 1887, Conch. Exch., **1:** 55.
Gastrodonta walkeri Pilsbry, 1900, Proc. Acad. Nat. Sci. Philadelphia, p. 146.
Paravitrea (*Paravitreops*) *walkeri dentata* H. B. Baker, 1929, *The Nautilus*, **42:** 88.
Paravitrea walkeri (Pilsbry), Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mono. 3, **2:** 362.
Paravitrea walkeri form *dentata* H. B. Baker, Pilsbry, 1946, *ibid.* **2:** 363.

The three specimens in the type lot (UMMZ), and a good series of topotypes which I collected, show that this species is not related to *P. multidentata* (Binney) but is identical with *P. walkeri* form *dentata*. Thus *P. umbilicaris* will replace *P. walkeri* form *dentata* and the lamellate form will become *P. umbilicaris* form *walkeri*. The type locality for *P. umbilicaris* is Alleghany Springs, Blount Co., Tenn., which is a former Spa at a sulfur spring on the side of Chilhowee Mtn., about 11 miles southwest of Maryville.

Paravitrea petrophila (Bland)

Zonites petrophila Bland, 1883, Ann. N. Y. Acad. Sci. **2:** 369, fig. 2.
Vitrea (*Paravitrea*) *smithi* Walker, 1928, Terr. Moll. Ala., p. 88, fig. 120.
Paravitrea petrophila (Bland), Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mono. 3, **2:** 385.
Paravitrea smithi (Walker), Pilsbry, *ibid.* **2:** 384.

The holotype (UMMZ) and paratype (CM) could not be found; but specimens which I collected at what I believe to be the type locality, and which agree with the original description, are depauperate *P. petrophila*. *P. smithi* should be placed in the synonomy of *P. petrophila*.

Anguispira mordax (Shuttleworth)

Helix mordax Shuttleworth, 1852, Mittheil. Naturforsch. Ges. Bern, Nr. 248-9, p. 195.
Anguispira alternata paucicostata Kutchka, 1938, *The Nautilus* **52:** 12, pl. 2, fig. 2. Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mono. 3, **2:** 581.
Anguispira alternata mordax (Shuttleworth), Pilsbry, *ibid.* **2:** 581.
Anguispira mordax (Shuttleworth), Hubricht, L., 1968, Sterkiana **32:** 5.

The holotype and two paratypes (CM) of *A. alternata paucicostata* were examined. The paratypes are typical *A. mordax*, and the holotype is an aberrant specimen of the same species.

Helicodiscus multidens Hubricht

Helicodiscus multidens Hubricht, 1962, *The Nautilus* **75:** 102.
Helicodiscus enneodon Hubricht, 1965, *The Nautilus* **79:** 6.

Recent collecting has shown that *H. multidens* and *H. enneodon* intergrade and therefore *H. enneodon* should be placed in the synonomy of *H. multidens*.

Genus **Megapallifera** Hubricht

Megapallifera new subgenus, Hubricht, 1956, *Nautilus* **69:** 126.

Megapallifera was originally described as a subgenus of *Pallifera* to contain *Pallifera mutabilis* Hubricht (type species), *P. wetherbyi* W. G. Binney, and *P. ragsdalei* (Webb). Much collecting has been done in the Philomycidae since this subgenus was described and no intergradation with *Pallifera s.s.* has been found. The large size and basic chevron color pattern of all species causes them to be confused with *Philomycus*. I feel that *Megapallifera* should be raised to the status of genus.

Gastrocopta tappaniana (C. B. Adams)

Pupa tappaniana "Ward" C. B. Adams, 1842, in Thompson's History of Vermont, p. 158.
Gastrocopta tappaniana (C. B. Adams), Pilsbry,

1948, Acad. Nat. Sci. Philadelphia Mono. 3, **2**: 889.

Joseph C. Bequaert & Walter B. Miller, 1973, Moll. Arid Southwest, Univ. Arizona Press, Tucson, Ariz., p. 89) state that the holotype (MCZ) of *Gastrocopta tappaniana* is a typical *G. pentodon* (Say) and that there is only one species. I have examined this specimen and can state that it is not *G. pentodon*, but represents *G. tappaniana* as understood by Pilsbry and others. I have examined a good many lots of *G. pentodon* and *G. tappaniana* and have had no difficulty in separating them. Large series in river drift have sorted readily.

H. A. Pilsbry (1939-1948, Acad. Nat. Sci. Philadelphia Mono. 3) reported a number of species, notably *Sterkia eyriesi rhoadsi* (Pilsbry), from Dismal Key, Lee Co., Florida. However, Dismal Key is not in Lee Co., but in Collier Co. It is one of the Ten Thousand Islands and is located several miles southeast of Goodland.

STATUS OF *SUCCINEA OVALIS CHITTENANGOENSIS* PILSBRY, 1908

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ABSTRACT

Dissection and SEM radular study of the morph described as Succinea ovalis chittenangoensis *Pilsbry, 1908, suggest that this is a marked genetic mutation of* Succinea ovalis *Say, 1817, characterized by one shell feature and an apparent specialization in ecology. A summary of its varying abundance and ecology is presented. Comparisons of genital and radular structure are made with the sympatric* Oxyloma decampi gouldi *Pilsbry, 1948 and* S. ovalis *from Illinois.*

INTRODUCTION

Pilsbry (1908) determined the identity of *Succinea ovalis* Say, 1817, and described a population from Chittenango Falls, Madison County, New York, as a new subspecies, *Succinea ovalis chittenangoensis* Pilsbry, 1908. The differentiating features were the elongated shell spire and larger size in comparison with typical populations. The original data essentially were republished in Pilsbry (1948). Subsequently Hubricht (1972) and Wayne Grimm (letters) have suggested that *chittenangoensis* is a distinct species.

As part of a survey of rare and potentially endangered land snail species of Eastern North America for the Office of Endangered Species (hereafter OES), the status of this taxon was investigated. The field work by Alan Solem and Glenn Goodfriend was supported by OES Contract 14-16-0008-764, which also provided for the illustrations by Ms. Claire Kryczka. OES Contract 14-16-0008-965 covered the page and illustration charges. The scanning electron microscope photographs were taken from Cambridge S4-10 Stereoscans during cooperative research with the American Dental Association and an instrument provided the Field Museum through NSF Grant BMS72-02149. I am indebted to Glenn Goodfriend, Arthur Clarke, Leslie Hubricht, Wayne Grimm, George Najarian, Fred Huysmans, Dorothy Karall, Elizabeth Liebman, and Sharon Bacoyanis for assistance with various phases of this project. The financial support given by the

Office of Endangered Species and the National Science Foundation is gratefully acknowledged.

ECOLOGY AND ABUNDANCE

The initial collection of *S. o. chittenangoensis* occurred August 27, 1905, and was "on a sloping weedy talus near the foot of the falls." According to Pilsbry (1908:49), "A very large series was taken, associated with a few *S. ovalis.*" Subsequently, Pilsbry (1948:807) indicated that "It occurred in great abundance. A few typical *S. ovalis* were found with them, but no intergradation was seen." Hubricht (personal communication) collected at Chittenango Falls on May 31, 1954, finding *ovalis* and *chittenangoensis* about equally abundant, but again without intergradation. Wayne Grimm, in 1964, 1965 and 1973 (personal communication) reported *S. ovalis* as fairly abundant, but found only a few *chittenangoensis.* In June 1973, Glenn Goodfriend found one live *chittenangoensis,* but no live *ovalis.* On August 3 and 8, 1974, I found freshly dead *chittenangoensis* in talus, fresh dead shells of *Oxyloma,* live *Oxyloma decampi gouldi* Pilsbry, 1948, and one live juvenile *ovalis.*

In 1905, *chittenangoensis* was common and *ovalis* scarce; in 1954 they were equally abundant; in the mid-1960's *ovalis* was common and *chittenangoensis* scarce; and in the early 1970's, both morphs were scarce. The above anecdotal statements of abundance are not sufficient to indicate a trend. Natural fluctuations in numbers seem more probable than a linear trend, but the data do establish that *ovalis* and *chittenangoensis* have been taken sympatrically on several occasions. Whether the current low population numbers are the result of habitat changes cannot be established with certainty. Arthur Clarke (personal communication) has noted a drastic decline in downstream unionid clam abundance during the 1950's and 1960's. This change correlated with increased upstream water pollution.

Specimens of *chittenangoensis* have been taken from talus on both sides of the foot of the falls, from talus halfway up the falls, and even from rock surfaces behind the falls itself. The sightings all involve actual spray zone or seepage areas of the falls. No specimens have been found elsewhere along Chittenango Creek, although typical *S. ovalis* has, at times, been abundant downstream. Despite intensive collecting efforts in other areas of New York and adjacent states, no additional colonies with the features of *chittenangoensis* have been discovered. The colony probably is unique. The shaded ravine habitat, constant cool water flow, and spray zone talus or rock face situation combine to produce a very stable and cool habitat. Wayne Grimm (personal communication) tried to transfer live specimens to establish a refrigerated colony, but even only four hours in an ice chest resulted in their demise. The range of conditions in which specimens of *chittenangoensis* live is far more restricted and less variable than that encountered by most succineids.

COMPARATIVE STRUCTURE

Since *ovalis* and *chittenangoensis* are sympatric and at least occasionally equally abundant, their structures should show "species recognition differences" if they were distinct species. The shell difference (figs. 1, *a-c*) is larger size, which frequently results from dwelling in more favorable conditions, and a more elongated spire. Conceivably the spire change could result from a single mutation. Pilsbry (1908, 1948) reported no anatomical or color differences between *ovalis* and *chittenangoensis.*

Dissection of several populations of *Succinea ovalis* from various parts of Eastern North America and of the adult *S. o. chittenangoensis* (figs. 1, *g-h*) collected in June 1973 (FMNH 175425) revealed no significant anatomical differences. Specimens of typical *S. ovalis* collected August 31, 1965, from Dresden Id., Illinois River, Grundy Co., Illinois (FMNH 169132) are illustrated for comparison (fig. 1, *f*). A shell (fig. 1, *d*) and genitalia (fig. 1, *e*) of Chittenango Falls *Oxyloma decampi gouldi* (FMNH 175394) also are figured for convenient identification by others. Radular illustrations are given of all three taxa (figs. 11-17). The much smalier sized shell with flatter sided whorls and reduced callus in *Oxyloma* (fig. 1, *d*) easily separate it from the two *Succinea.* The differences between *S. ovalis* and form *chittenangoensis* (figs. 1, *a-c*) involve only increase in whorl count and spire height.

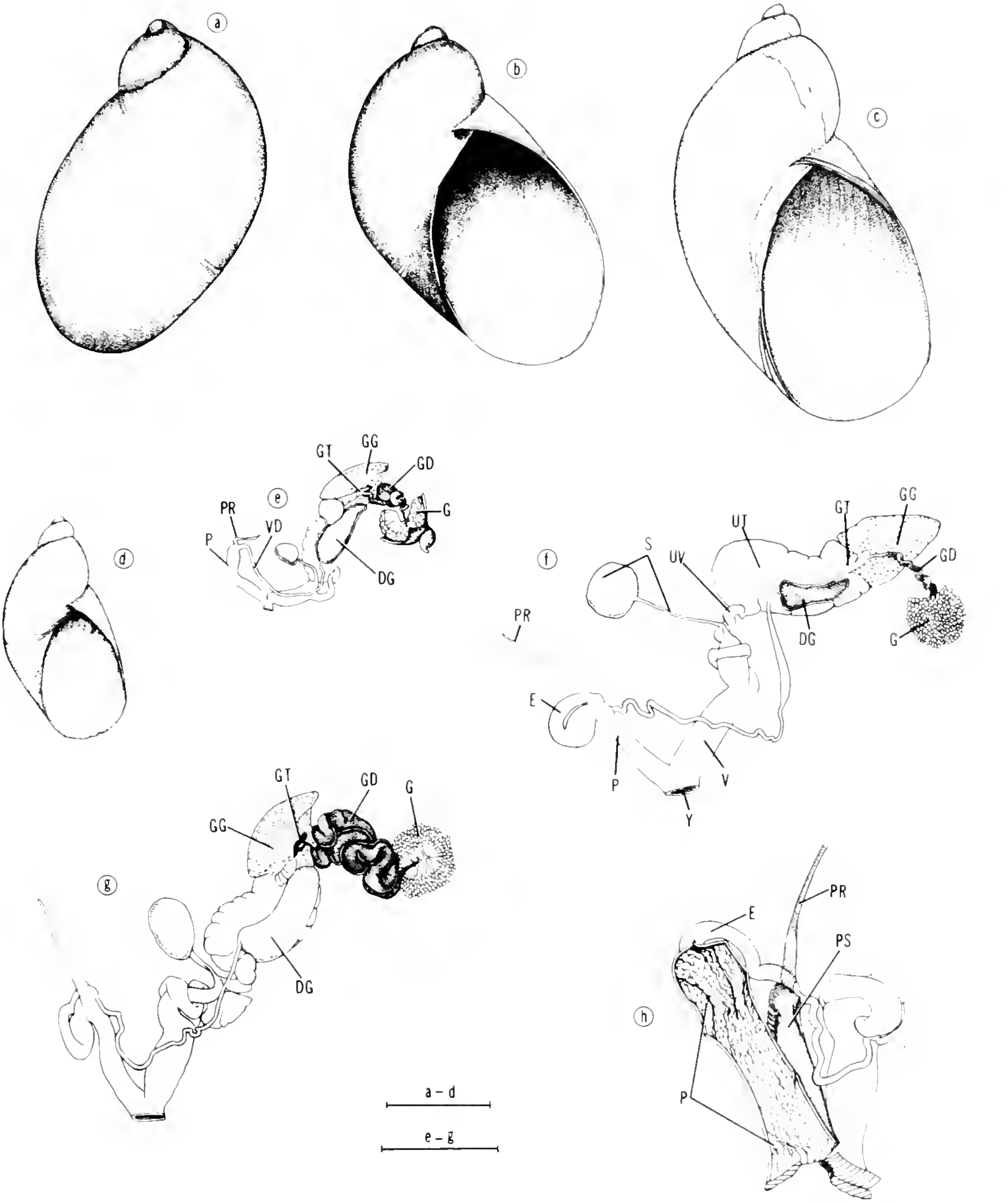
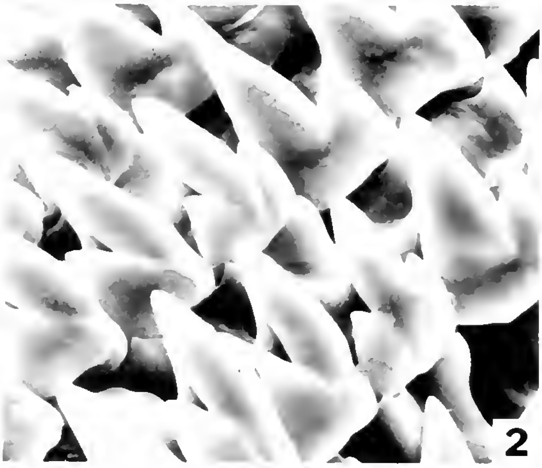


FIG. 1. **Shells and anatomy. a-b,** Succinea ovalis *Say, 1817. Dresden Island, Illinois River, Gurney Co., Illinois. FMNH 169132;* **c,** Succinea ovalis *form* chittenangoensis *Pilsbry, 1908. Chittenango Falls, Madison Co., New York. FMNH 175425;* **d-e,** Oxyloma decampi gouldi *Pilsbry, 1948. Chittenango Falls, Madison Co., New York. FMNH 175394.* **d,** *shell,* **e,** *genitalia,* **f,** S. ovalis. *genitalia;* **g-h,** S. ovalis *form* chittenangoensis. **g,** *genitalia,* **h,** *interior of penis. Scale lines equal 5 mm.*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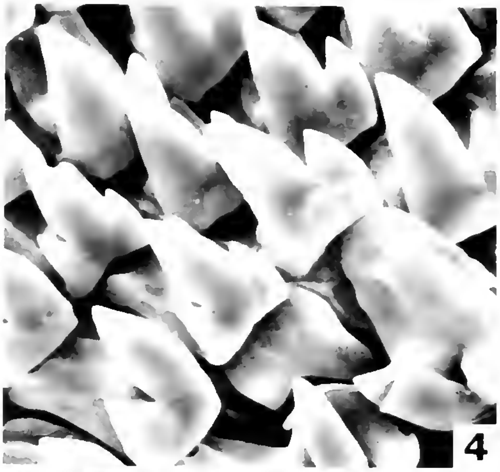
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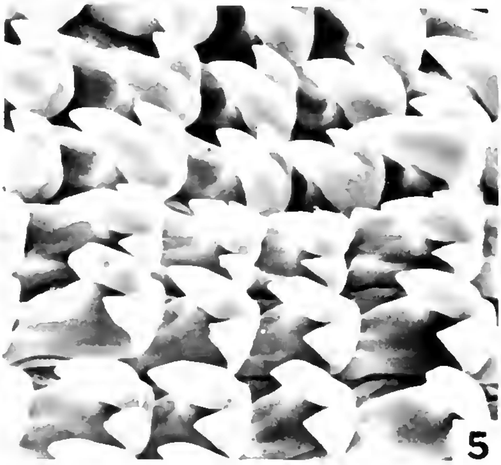
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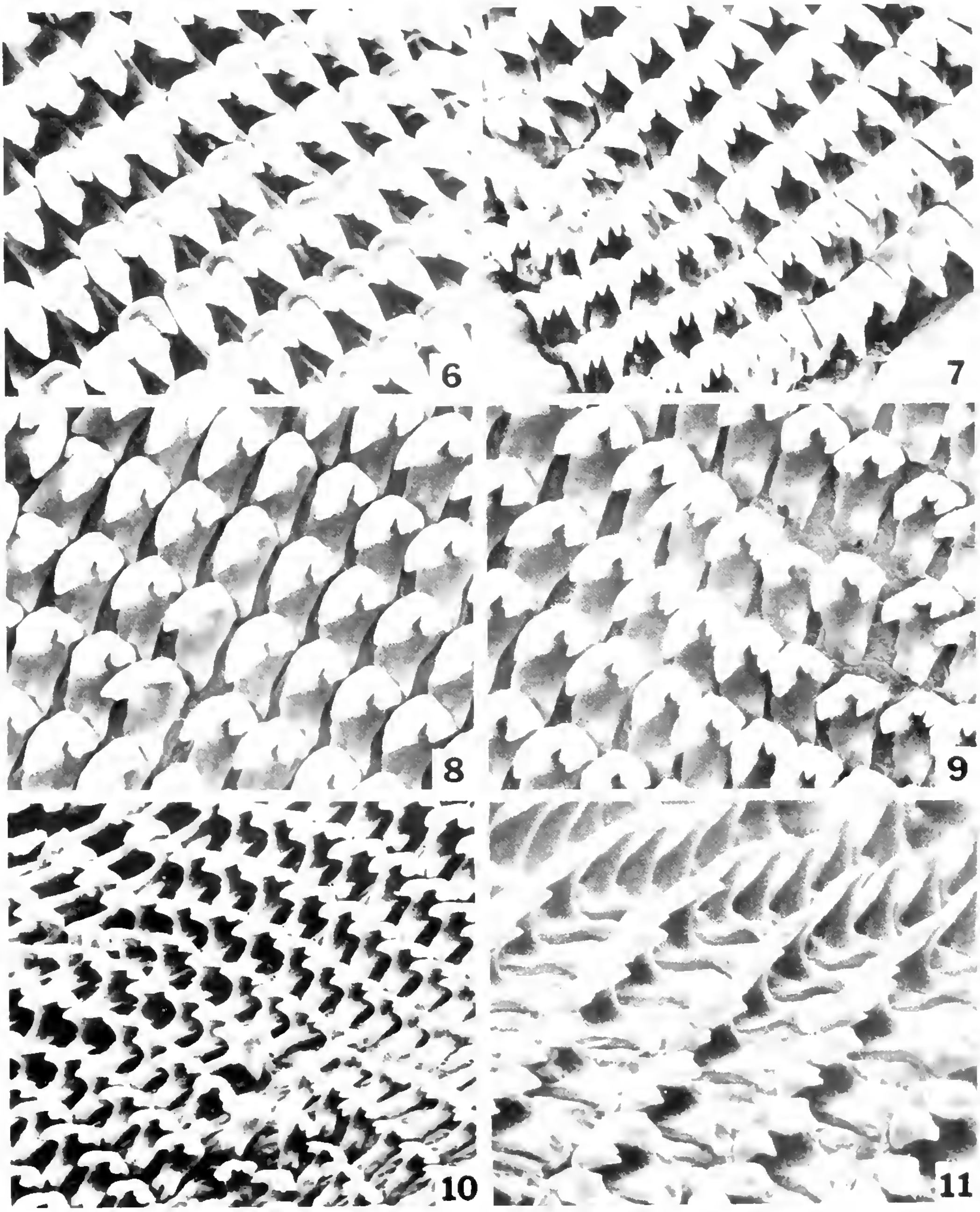
FIGS. 2-5. **Radular teeth.** *Fig* **2**, *Central and early lateral teeth of* Succinea ovalis *form* chittenangoensis *Pilsbry. FMNH 175425. 905 ×. Fig.* **3**, *Central and first lateral teeth of* Oxyloma decampi gouldi *Pilsbry FMNH 175394. 890 ×*

Figs. **4-5**, Succinea ovalis *Say. FMNH 169132. Fig.* **4**, *Central and first lateral teeth. 865 ×. Fig.* **5**, *Low angle views of central and early lateral teeth. 645 ×.*

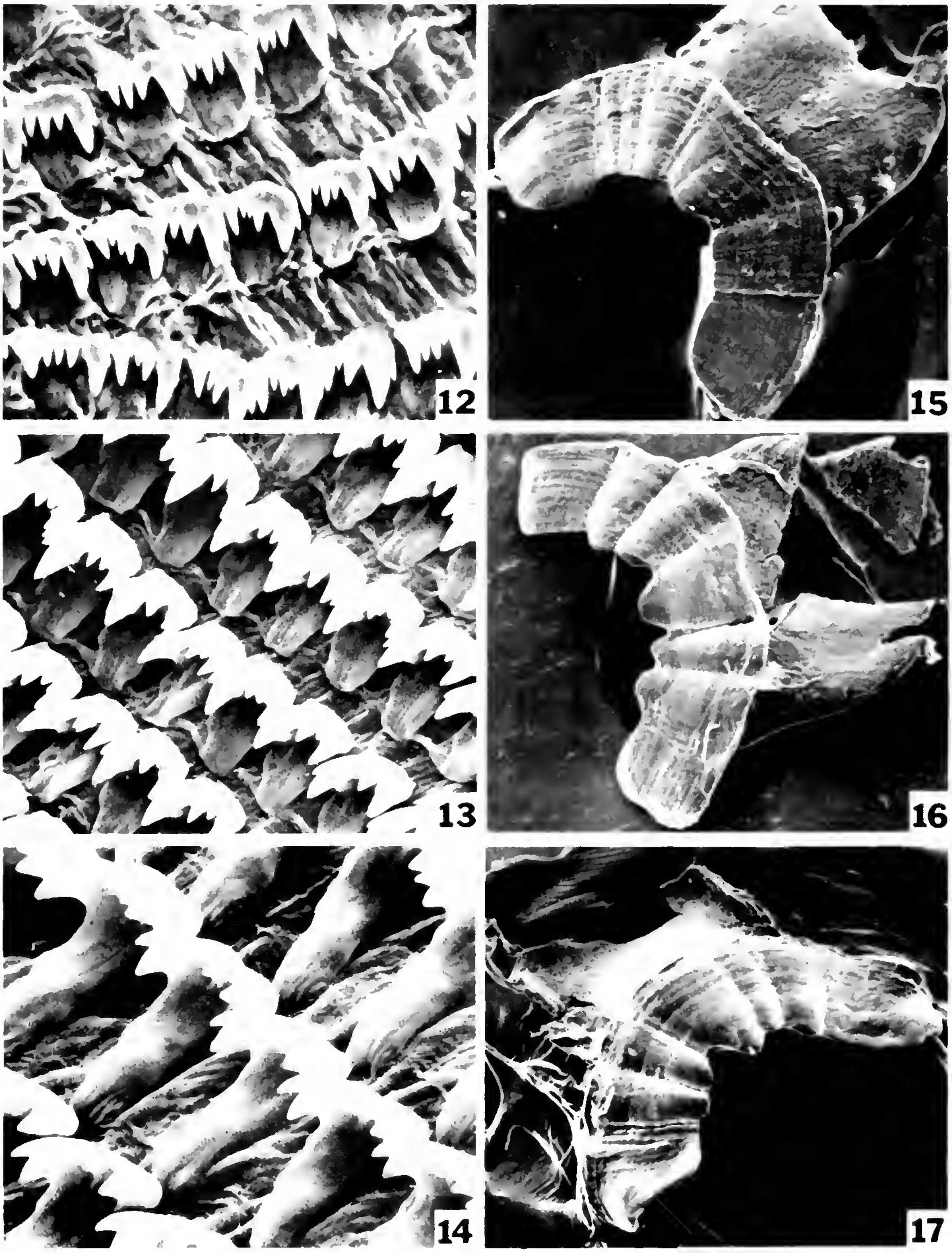
Anatomically, specimens of *Oxyloma* (fig. 1, *e*) are most easily separable from *Succinea* (figs. 1, *f-g*) on the basis of penis structure. The characteristic protruding epiphallic loop (E) in *Succinea* is very different from the simple penis (P), penis retractor (PR), and vas deferens (VD) junction found in *Oxyloma*. More fundamental internal penial differences exist, but this feature is readily observable in early stages of dissection. When the penial difference is combined with the obvious shell size change, separating these taxa presents no problems.

Species of *Succinea* differ greatly in shell form, pattern of the epiphallic loop protrusion, oviduct and vaginal length, and also in the degree to which the free oviduct and spermatheca are coiled around each other (see Pilsbry, 1948). The genitalia of *S. ovalis* (fig. 1, *g*) and form *chittenangoensis* (fig. 1, *g*) have no significant differences. The enlarged prostate (DG) and hermaphroditic duct (GD) in *chittenangoensis* (and in *Oxyloma*, fig. 1, *e*) relate to the June collecting (normally wet period) compared with the dry August conditions in Illinois for the *S. ovalis* sample. The samples were in different reproductive phases when collected. In terms of penis (P) and epiphallus (E), vagina (V) and free oviduct (UV) length, coiling of the spermathecal shaft (S) and free oviduct, length of uterus (UT), form of albumen gland (GG), talon (GT) and ovotestis (G), there are no differences between the two *Succinea*. The slight difference in shape of the spermathecal head is probably an artifact of preservation. The basic similarities hold for all populations compared.

The radular structure of the succineids has been used for many years to distinguish species and some higher taxa (see Quick, 1933, 1934;



FIGS. 6-11. **Radular teeth.** *Figs.* **6–7,** Succinea ovalis *form* chittenangoensis *Pilsbry FMNH 175425. Fig.* **6,** *Central and lateral teeth. 435* ×. *Fig.* **7,** *Lateromarginal transition. 435* ×. *Figs* **8, 9, 11,** Succinea ovalis *Say. FMNH 169132. Fig.* **8,** *Central and lateral teeth. 440* ×. *Fig.* **9,** *Lateromarginal transition. 540* ×. *Fig* **11,** *Low angle view of lateromarginal transition. 875* ×. *Fig.* **10,** *Part row of* Oxyloma decampi gouldi *Pilsbry FMNH 175394 411* ×



FIGS. 12-17. **Radular teeth and jaws.** *Figs.* **12, 13, 15, 16.** Succinea ovalis *Say FMNH 169132. Fig.* **12,** *Outermost marginals. 1,195* ×. *Fig.* **13,** *Inner marginals. 805* × *Figs.* **15-16,** *Jaws at 41.5* × *showing variation in ridging. Fig.* **14,** *Midmarginal teeth of* Oxyloma decampi gouldi *Pilsbry FMNH 175394. 1,675* × *Fig.* **17,** *Jaw of* Succinea ovalis *form* chittenangoensis *Pilsbry FMNH 175425. 38.2* ×.

Pilsbry, 1948), but no report has been presented on the functioning interrow teeth reactions. The illustrations presented here thus serve a dual purpose.

The central and early lateral teeth of *S. ovalis* (figs. 4, 5, 8) are identical in form, size and elevation angle to those of *chittenangoensis* (figs. 2, 6). The observation angle of fig. 8 is more posterior than that of fig. 6, which somewhat deemphasizes the anterior flare on the individual teeth, but also permits seeing the anterior basal support ridge on the outer side of the plate. The presence of two such ridges on the tricuspid rachidian tooth and the functioning on the interrow support can be seen clearly in the right portion of fig. 5. The rachidian tooth also lacks the anterior flare that is characteristic of the bicuspid laterals (figs. 2, 4-6, 8). The central tooth of *Oxyloma* (fig. 3) has somewhat smaller ectocones and is a little larger in relation to the laterals than in *Succinea*.

The transition from laterals to marginals is essentially identical in pattern for *Succinea* and *Oxyloma*. The first ten or more laterals remain constant in size and shape (figs. 6, 8), but then in the course of perhaps three teeth (figs. 7, 9) make a rather abrupt transition to the marginal pattern. The ectocone enlarges and splits, the mesocone becomes narrower, smaller in size, and perhaps one tooth after the splitting of the ectocone, a small endocone appears on the mesocone. At the same time, the basal plate shortens and the interrow support ridge is greatly reduced and then lost. Not visible from the top view, but clearly seen in side view (fig. 11), is a change in angle of cusp elevation. The laterals (top third of fig. 11) point up at nearly a 60° angle, while the marginals curve to point almost directly backward into the mouth. The reduction of the support ridge and the shortening of the basal plate can be followed quite easily along the row. The "cutting" nature of the laterals is evident and contrasts with the "catching" nature of the marginals. The latter pull food into the mouth that has been scraped or torn loose by the laterals. The comparable view of *Oxyloma* (fig. 10) shows that the lateral teeth are not elevated as much, that the marginal teeth basal plates are longer and narrower, and that the cusps of the marginal teeth seem to be different in pattern.

The variation in cusps on the marginal teeth is very large both within and between radulae of the same species, so that the large endocone seen on the marginals of *Oxyloma* (fig. 14) may not be a constant difference, although the elongated and narrower basal plate does seem to be a species level, if not generic level, difference (see Quick, 1933, 1934). The short, broad basal plate (figs. 12, 13) and multiple small cusps between the mesocone and ectocone characterize the two *Succinea*, but cusp splitting varies from tooth to tooth (fig. 13).

Oxyloma has long and slender marginal basal plates, compared with the short and broad basal plates in *Succinea*, as was cited in Pilsbry (1948). The different pattern of cusp elevation in the two genera, and the shared pattern of interrow central and lateral tooth supports have not been reported previously. This same interrow support system—a basic anterior flare interlocking with a raised projection on the outer margin of the basal plate in the laterals, and the two support ridges on the basal plate of the central tooth—is found in many families of the Stylommatophora and may well prove to be the generalized pattern of radular structure in the higher land mollusks.

Ribbing of the jaw in *Succinea ovalis* is highly variable (figs. 15-17). The two specimens from Dresden Island (figs. 15, 16) bracket the example of *chittenangoensis* in terms of rib prominence. There is thus no difference.

To summarize the above observations, in radula, jaw, and genitalia, *Succinea ovalis* and *chittenangoensis* show no differences that cannot be regarded as seasonal (swollen hermaphroditic duct and enlarged prostate) or individual variation (cusping on radular marginal teeth). The only morphological difference is the longer spire and slightly higher whorl count in the shell of *chittenangoensis*.

DISCUSSION

Succinea ovalis chittenangoensis Pilsbry, 1908 differs from *S. ovalis ovalis* only in spire height of the shell, larger size, and in being restricted to the very moist splash or seepage areas around Chittenango Falls. At times this morph has occurred abundantly with typical *S. ovalis*. In the absence of any differences in radular (feeding specialization) or genital (species recognition phenomena) structure, despite the known sympatry, I cannot accept *chittenangoensis* as being a distinct species. The lack of intergradation in shell form, the only known difference, could be the result of a simple dominant genetic change. To what extent this shell difference is linked to physiological and/or biochemical changes that aid adaptation to the somewhat unusual environment is unknown, but should be investigated. The hypothesis of *chittenangoensis* representing a mutant strain of *S. ovalis* raises far fewer problems than attempts to call it a distinct species, in view of its anatomical identity to typical *S. ovalis*.

The entire range of the mutant form lies within Chittenango Falls State Park and, provided collecting is prevented, this variation has every chance of continuing its normal span of existence. In time, fluctuations in abundance, caused either by man's pollution or the unknown factors that resulted in the great change in abundance of both *S. ovalis* and *chittenangoensis* since 1905, will lead to extinction by natural causes. Collecting during periods of low abundance, such as the 1970's, could easily hasten this extinction, but the protection provided by the Park rules plus the cooperation of malacologists, can prevent our hastening the departure of this interesting variation. Monitoring of changes in its population level and biochemical comparisons between *ovalis* and *chittenangoensis* are highly desirable future activities.

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GROWTH RATE OF FOUR SPECIES OF EUTHECOSOMATOUS PTEROPODS OCCURRING OFF BARBADOS, WEST INDIES

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ABSTRACT

Growth rates of the four most common species of euthecosomatous pteropods occurring off Barbados were measured using the probability paper method. Average growth rates were: Limacina trochiformis *0.10 mm/month,* L. inflata *0.12 mm/month,* L. bulimoides *0.15 mm/month, and* Creseis virgula conica *0.30 mm/month. The species reach metamorphosis in* $1\frac{1}{2}$ *to 3 months and sexual maturity in 7 to* $9\frac{1}{2}$ *months. The maximum life spans of all four species are estimated to be about one year.*

INTRODUCTION

Euthecosomatous pteropods are a small group of holoplanktonic gastropod molluscs occurring throughout the world oceans (van der Spoel, 1967). Most are tropical though *Limacina retroversa* (Fleming) is a boreal species and *L.*

TABLE 1. *Growth rates of euthecosomatous pteropods off Barbados, West Indies.*

Species	Rate (mm month)
Creseis virgula conica	0.30
Limacina bulimoides	0.15
Limacina inflata	0.12
Limacina trochiformis	0.10

helicina (Phipps) occurs in the Arctic and Antarctic Oceans. Information on many of the basic aspects of the biology of euthecosomes is lacking because the animals, especially the tropical species, survive for only a limited time in the laboratory. Paranjape (1968) was able to maintain *L. helicina* hatched from eggs for 30 days in the laboratory, but no other species has been cultured for even this long, and growth rates from controlled studies are nonexistent. Examination of growth in field populations has been done in only a few species. The present paper reports the growth rates and life spans of the four most common euthecosomes in the tropical waters off Barbados, West Indies.

MATERIALS AND METHODS

Collections were made twice monthly at a station 5 km west of the Bellairs Research Institute, St. James, Barbados, West Indies (13°11'N; 59°41'W), from June 1971 to May 1973 using a 1 m diameter open plankton net equipped with a flowmeter and No. 20 (76 μm) nylon mesh. On each cruise 3 oblique tows were made from 300 m to the surface. Samples were preserved in 10% formalin buffered with hexamethylene tetramine. Every month the maximum shell diameter of 300 *Limacina inflata* (d'Orbigny) and the maximum shell length of 200 *Creseis virgula conica* (Rang) were measured with a dissecting microscope equipped with an ocular micrometer. Maximum shell length of all available individuals of *L. bulimoides* (d'Orbigny) and *L. trochiformis* (d'Orbigny) were also measured.

RESULTS

Nineteen species and subspecies of euthecosomes were collected during the two years of the study. *Limacina inflata* constituted 61.5% of all individuals collected, *Creseis virgula conica* 23.0%, *L. trochiformis* 6.7%, and *L. bulimoides* 2.2%. Together the 4 species accounted for 93.4% of all euthecosomes. All 4 reproduced continuously at high levels off Barbados (Wells, 1976), so changes in the size-frequency curves could not be used to estimate growth rates. Instead, the size-frequency data was plotted on probability paper as described by Harding (1949) and Cassie (1954). The method utilizes fluctuations in the numbers of individuals in the various size classes to determine growth rates over short periods of time such as 1 month. Cassie (1954) demonstrated a technique to estimate mortality in species with discrete reproductive periods, but the continuous breeding of the 4 species off Barbados precluded estimation of mortality.

Table 1 shows the growth rates of the 4 euthecosome species examined. They ranged from 0.10 mm per month for *Limacina trochiformis*, the smallest species, to 0.30 mm per month for *Creseis virgula conica*, the largest. There are no apparent stages in the life cycle during which growth is temporarily halted as occurs in some other thecosomes. The animals begin enlarging the embryonic shell immediately after hatching. In euthecosomes metamorphosis is a gradual process involving primarily the loss of the velum and the development of parapodia, and in the present species there is no substantial change in shell morphology associated with the onset of the juvenile state. One would expect juveniles to grow rapidly and the growth rate to decline as the animal ages. The data for each species was divided into two groups at half of the maximum shell size. A t-test showed there was no significant difference between the growth rates of the small and large groups of any species at the .05 level. It should be noted that most individuals of a species were small, making the growth rates calculated for larger individuals less reliable.

If the growth rate is assumed to be relatively constant during the growth portion of the life of an individual, an idea of the lifespan can be obtained. Table 2 shows the sizes at which the maturational stages were reached off Barbados (Wells, 1976) and the time required to reach the various stages. *Limacina inflata* releases veligers 67 μm in shell diameter (Lalli and Wells, 1973). The other 3 species deposit freefloating egg masses in the water column (Wells, 1976) but the sizes at which veligers hatch are unknown. The

TABLE 2. *Times required to reach maturational stages of euthecosomatous pteropods off Barbados, West Indies.*

	Species			
Stage	*C. virgula conica* Size (mm)-Months	*L. bulimoides* Size (mm)-Months	*L. inflata* Size (mm)-Months	*L. trochiformis* Size (mm)-Months
Minimum	0.15	0.10	0.067	0.10
Metamorphosis	0.6 - 1½	0.40-2	0.4 -3	0.25-1½
Maturity	3.0 - 9½	1.1 -7	1.0 -8	0.8 -7
Maximum	4.2 -13½	1.4 -9	1.4 -8	1.0 -9

minimum size collected off Barbados is included in Table 2. Veligers required from 1½ to 3 months to reach metamorphosis and a total of 7 to 9½ months to reach sexual maturity. Maximum sizes of the various species would be attained in 9-13 months, indicating that all 4 can complete their life cycles in 7-9 months off Barbados and live a maximum of about a year.

DISCUSSION

Redfield (1939) studied the movement of a population of *Limacina retroversa* in the Gulf of Maine. An influx of juveniles into the Gulf in December 1933 was traced for several months. Growth rates calculated from the histograms presented by Redfield averaged 0.21 mm per month. Similarly growth rates of 0.18 mm per month can be obtained from the data published by Kobayashi (1974) for *L. helicina* in the Central Arctic Ocean. Both figures are somewhat higher than those of the tropical *Limacina*, but because of the larger sizes involved the lifespan of *L. helicina* in the Central Arctic was about 18-24 months and that of *L. retroversa* in boreal waters was one year. The 3 tropical *Limacina* studied here reproduced 7 to 8 months after hatching. This follows the pattern described by Dunbar (1968) in which planktonic species in the Arctic have a two year life cycle, related boreal species live one year, and tropical forms less than a year.

All of the above species are members of the Limacinidae, except *Creseis virgula conica*, which is in the Cavoliniidae. This species also had a continuous growth pattern with a life span of up to 13 months off Barbados. The only other cavoliniids in which growth had been studied are *Clio pyramidata* Linné, *Cuvierina columella* (Rang), *Cavolinia gibbosa* (Orbigny), and *Diacria trispinosa* (Blainville). The growth pattern of these species consists of a gradual enlargement of the embryonic shell during the veliger and juvenile stages followed by a period of rapid growth during which the adult shells are laid down. Little subsequent growth occurs after the adult shell is complete. Van der Spoel (1973) found all 4 species had a one year life cycle off Bermuda, similar to that of *Creseis virgula conica* off Barbados.

ACKNOWLEDGMENTS

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THE INVASION OF THE ASIATIC CLAM *(CORBICULA MANILENSIS* PHILIPPI) IN THE ALTAMAHA RIVER, GEORGIA

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ABSTRACT

The population of Corbicula manilensis *Philippi in the Altamaha River, Georgia, increased considerably from October 1971 to November 1975. Density of* Corbicula *generally reached a maximum in late summer or fall and was at a minimum during winter and spring, a relation which was inversely related to river discharge. Generally, densities of older age classes were greater in areas of low current velocity, whereas densities of younger age classes were greater in areas of high velocity. Average* Corbicula *densities increased from a minimum of* $0/m^2$ *in 1971 to a maximum of* $10{,}000/m^2$ *in 1974. The invasion of* Corbicula *has been accompanied by a drastic decline in the populations of other bivalves. Several species of Unionidae endemic to the Altamaha River may be affected by* Corbicula *and are considered endangered.*

INTRODUCTION

The Asiatic clam (*Corbicula manilensis* Philippi) has continued to spread in southeastern rivers since their discovery in the Tennessee River in 1959 (Sinclair and Ingram, 1961). Sickel (1969) studied mussel populations in the Altamaha River (Georgia) between river miles 113 and 118 and found nine species of unionids, three of them in great abundance, but no *Corbicula*. In 1971 Scott and Schindler, University of Georgia (personal communication) observed *Corbicula* in the Altamaha River near river mile 116. Sickel (1973) proposed that *Corbicula* was introduced into the Ocmulgee River, a tributary to the Altamaha River, by overland transfer from the Flint River (Apalachicola drainage) in 1968 or 1969.

Biologists at the Georgia Power Company have been sampling the Altamaha River between river miles 113 and 118 (Figure 1) since October 1971 as part of a comprehensive program to assess and monitor the biota near E. I. Hatch Nuclear Plant (Georgia Power Company, 1974). The purpose of

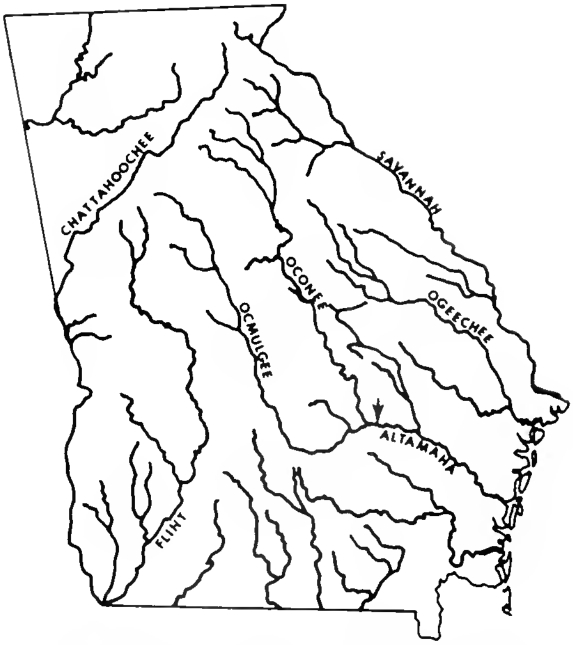

FIG. 1: *Major rivers of Georgia. Arrow indicates study area.*

this paper is to discuss changes in the populations of *Corbicula manilensis* and other bivalves that have occurred from October 1971 through November 1975.

MATERIALS AND METHODS

Samples were collected at approximately six-week intervals from several stations between river miles 113 and 118 during the period of study. A modified Petersen dredge which sampled an area of .025 m² was used. In October 1971 stations were established at RM 113.4 and 117.8. Five to ten samples were obtained at each station. In May 1973 two new stations were added to the sampling program at RM 115.9 and 116.6. In 1974 the station at RM 113.4 was discontinued, and a new station was added at RM 115.5. In February 1975, the present method of sampling was adopted in which six samples were taken in a transect at each station (RM 117.8, 116.6, 115.9 and 115.5).

Samples were washed immediately in a field screen having ten meshes/cm and preserved with 10% formalin (4% formaldehyde). In the laboratory, bivalves from each sample were sorted and *Corbicula*, were separated into size classes by washing them through a series of five U. S. standard soil sieves with openings of 2.00 mm, 4.75 mm, 9.50 mm, 12.50 mm and 19.00 mm. The number of *Corbicula* retained by each sieve was recorded, empty shells were excluded. Bivalves other than *Corbicula* were counted together but not identified. These were mainly Sphaeriidae, but included some Unionidae: *Lampsilis dolabraeformis* Lea, *Canthyria spinosa* Lea, and *Elliptio hopetonensis* Lea (Sickel, 1969).

RESULTS AND DISCUSSION

Water temperature and discharge of the Altamaha River reported from a United States Geologic Survey station near Baxley are shown in Figure 2 (U. S. Department of the Interior, 1972, 1973, 1974, 1975). Water temperature ranged from 6.5°C (winter minimum) to 30°C (summer maximum) during the period of study. Mean annual water temperature for the Altamaha is about

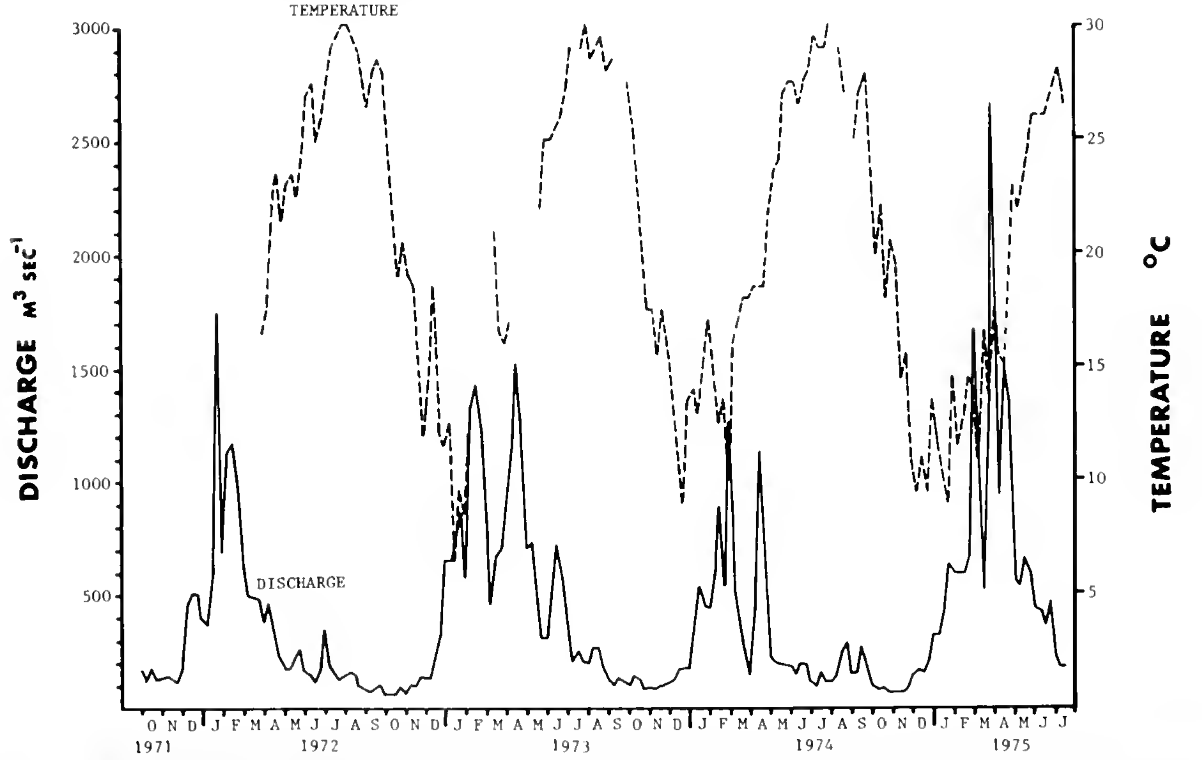

FIG. 2: *Mean daily discharge and temperature of Altamaha River near Baxley, Georgia (U. S. Geological Survey Data). Gaps in data indicate equipment malfunction.*

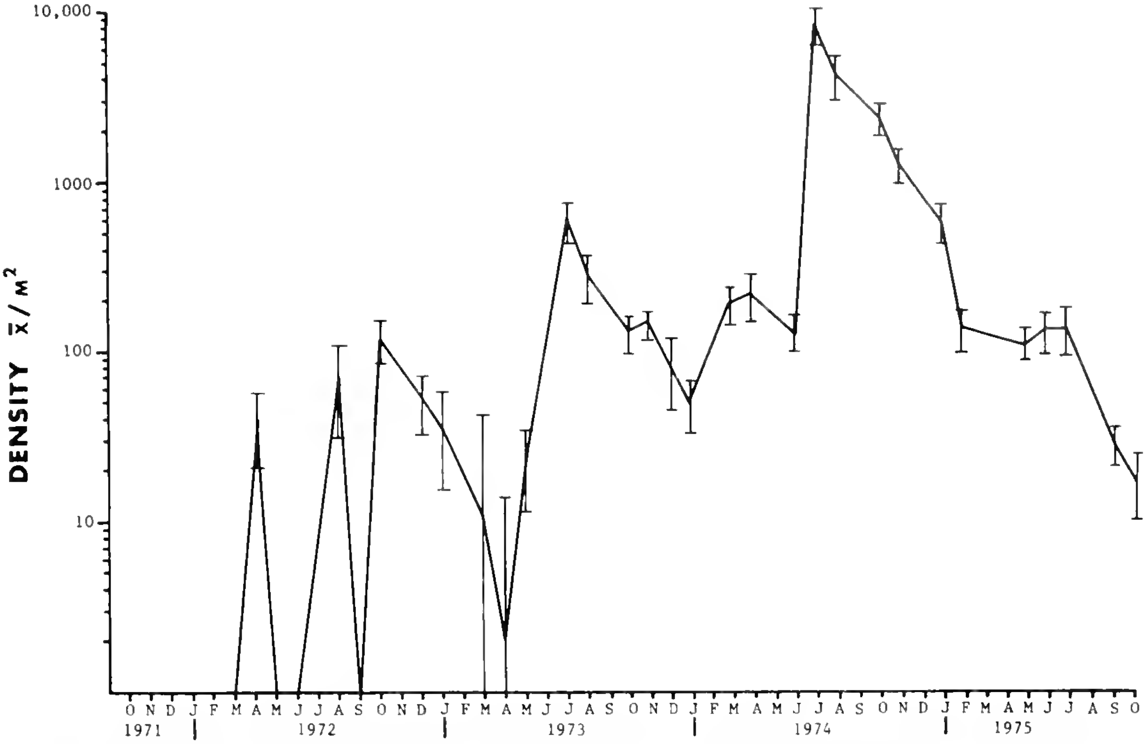

FIG. 3: *Mean (± SE) density of first year, sexually immature* Corbicula *in Altamaha River, October 1971 through October 1975.*

20°C. Mean annual discharge is 340 m³/sec and ranged during the period of study from 80 m³/sec (fall low) to a maximum of about 2,650 m³/sec (spring 1975). Maximum discharges decreased each spring during the period 1971-1974, but reached a maximum of 2,650 m³/sec in 1975. Total discharge for spring flood season was greater in 1973 and 1975 than in 1972 and 1974. The *Corbicula* spawning season begins when the water temperature reaches approximately 16-17°C (J. B. Sickel, personal communication) and continues until temperature falls below this, thus allowing a spawning season in the Altamaha River usually from April through November.

Shell lengths of *Corbicula* have been used to approximate age (Sinclair and Isom, 1963; Keup, Horning, and Ingram, 1963). The method used in this study to determine size and age classes was based on shell width and depth since these parameters determined the maximum cross sectional area that would pass through the sieve openings. Joy and McCoy (1975) found a strong correlation (r = 0.99) between *Corbicula* shell length and width. Thus, the authors believe the sieve system to be a fairly accurate method for rapidly determining size and age classes, particularly when a large number of samples are involved. Size classes and their approximate year class (J. B. Sickel, personal communication) are shown in Table 1.

The population of *Corbicula* in the Altamaha River increased considerably during the period of

TABLE 1. Shell lengths retained by sieves and approximate age classes (J. B. Sickel, *personal communication*).

Sieve Size (mm)	*Shell Length Retained (mm)*	*Approximate Age*
2.00	<7.5	1 yr. (sexually immature)
4.75	7.5-13.5	1 yr. (sexually mature)
9.50	13.4-18.5	2 yr.
12.50	18.5-28.0	3 yr.
19.00	>28.0	4 + yr.

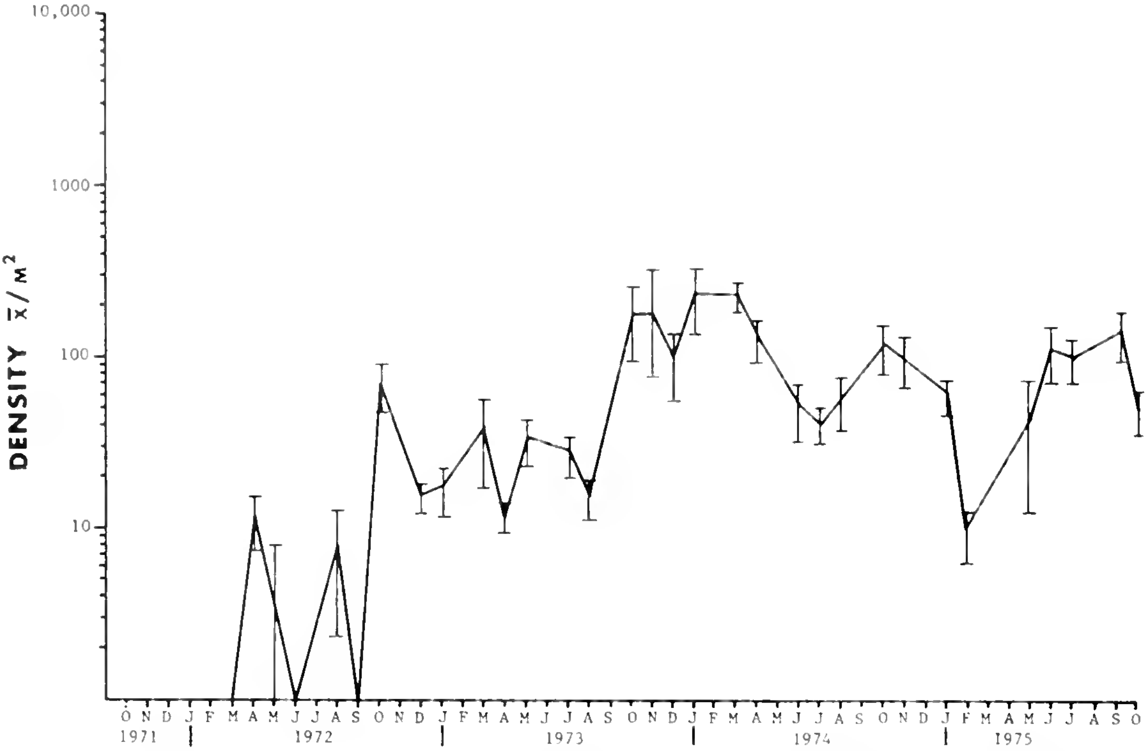

FIG. 4 *Mean (± SE) density of first year, sexually mature* Corbicula *in Altamaha River, October 1971 through October 1975*

study. Mean densities of *Corbicula* for all year classes are shown in Figures 3-6. Density of *Corbicula* generally reached a maximum in late summer or fall and was at a minimum during winter and spring. In contrast, Villadolid and Rosario (1930), Bickel (1966), Fast (1971), and Taylor (1975) found *Corbicula* to be at maximum in winter and minimum in summer. One explanation for the high density in the Altamaha during the late summer low water periods is that less substrate is available at these times, thereby concentrating the organisms. The width of the river ranges from 100-200 m during the low water period and is often greater than 2 km during flood stage. The available substrate surface area is about ten times greater at high water than at low water. This could account, in part, for the differences in *Corbicula* density, which is roughly a change of the same magnitude. Maximum discharge (Figure 2) occurred simultaneously with low densities in *Corbicula* (Figures 3-6). Seasonal variations in density diminished with increasing size of the clams. Apparently the smaller clams were probably picked up and swept by the current during flood season more readily than were the larger ones. Small *Corbicula* shells were found deposited in the flood plain and along exposed sand bars indicating their presence during high water.

Sexually immature *Corbicula* (Figure 3) usually were found in greatest density in summer. Maximum density of this group increased by a factor of 10 each year during the summers 1972-1974, reaching an average density of 9,257/m² in July 1974. The largest sample collected on this date contained 1,527 *Corbicula* or 61,080/m². Winter and spring densities were about 100/m² each year since 1973. First year sexually mature clams (Figure 4) fluctuated greatly since 1972, but generally reached maximum density in fall. Recruitment into this size class from sexually immature *Corbicula* is evident in 1973 and 1974, occurring 4-6 months after the maximum density of immature clams. Average density of sexually mature first year *Corbicula* was about 70/m² for 1974 and 1975.

Density of second year *Corbicula* (Figure 5) fluctuated irregularly in 1971-1972, probably because of sampling bias and clumped distribution, but rose steadily in 1973 and 1974. Density of this size clam reached a maximum of 40/m² in summer 1973, and a maximum of 100/m² in summer 1974. Average density for second year *Corbicula* was approximately 70/m² for 1974 and 1975. Figure 6 shows average densities of third and fourth year class *Corbicula*. Third year clams were first collected in October 1972, but were not consistently present until spring 1973. Maximum density reached 100/m² in fall 1974. Average density for three year clams was about 70/m² in 1974 and 1975. *Corbicula* in the fourth year class were not collected until summer 1974. Very few four year clams were collected in dredge samples, however larger clams were collected in qualitative samples.

Corbicula have been reported occurring in a wide variety of substrates. Sinclair and Isom (1963) found *Corbicula* common in rock-gravel substrates and black clay substrates in the Tennessee River. Fast (1971) found a positive correlation between *Corbicula* density and sediment particle size in a Southern California reservoir. Fuller and Powell (1973) reported *Corbicula* living in a shifting sand bar in the Savannah River, Georgia, and in a variety of substrates including mud and fine gravel in the Delaware River. Rhinne (1974) found greatest densities on rock and rubble substrates in an Arizona reservoir. Diaz (1974) found *Corbicula* in a variety of substrates in the James River, Virginia, but mainly in silt-clay sediment. Sickel and Burbank (1974) in a substrate preference experiment, found that larval *Corbicula* settled on fine sand, coarse sand, and mud in decreasing order of preference. In the present study, Altamaha River *Corbicula* were found on a variety of substrates. A substrate preference was not clearly determined by our sampling. In general, more *Corbicula* were found on substrates consisting of sand in combination with mud or detritus than on substrates which were predominantly mud or detritus.

Analysis of variance of 1974 and 1975 data was used to compare densities of *Corbicula* from high

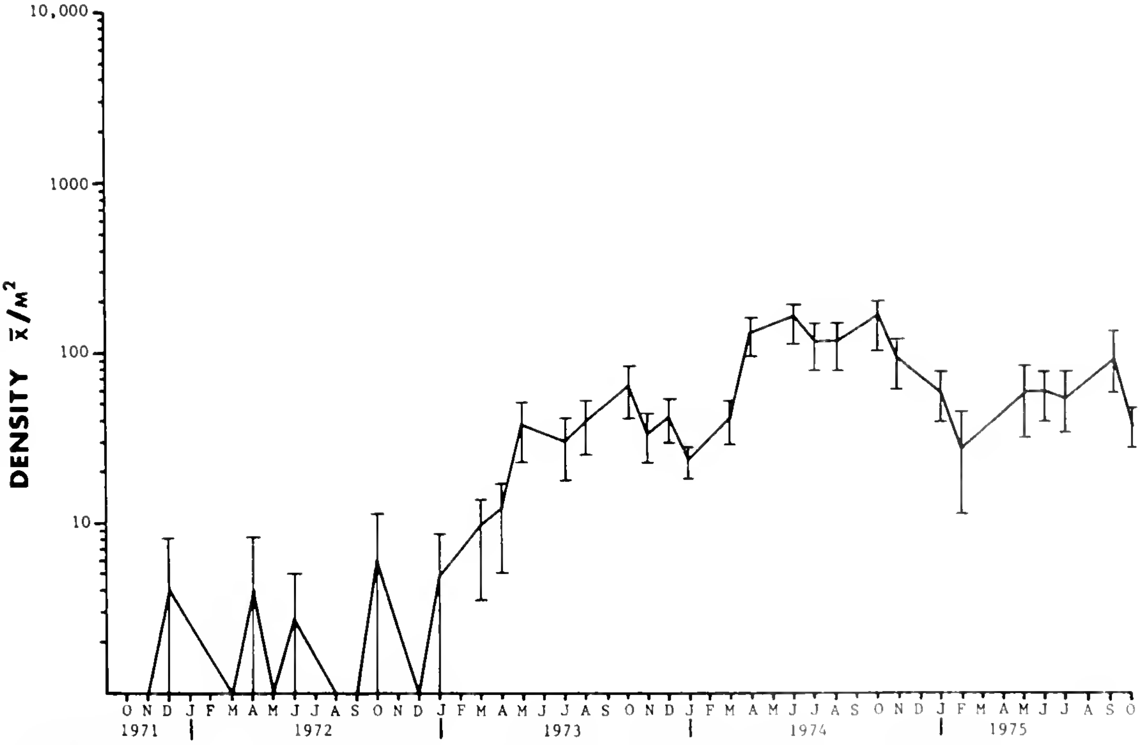

FIG. 5: *Mean (± SE) density of second year* Corbicula *in Altamaha River, October 1971 through October 1975.*

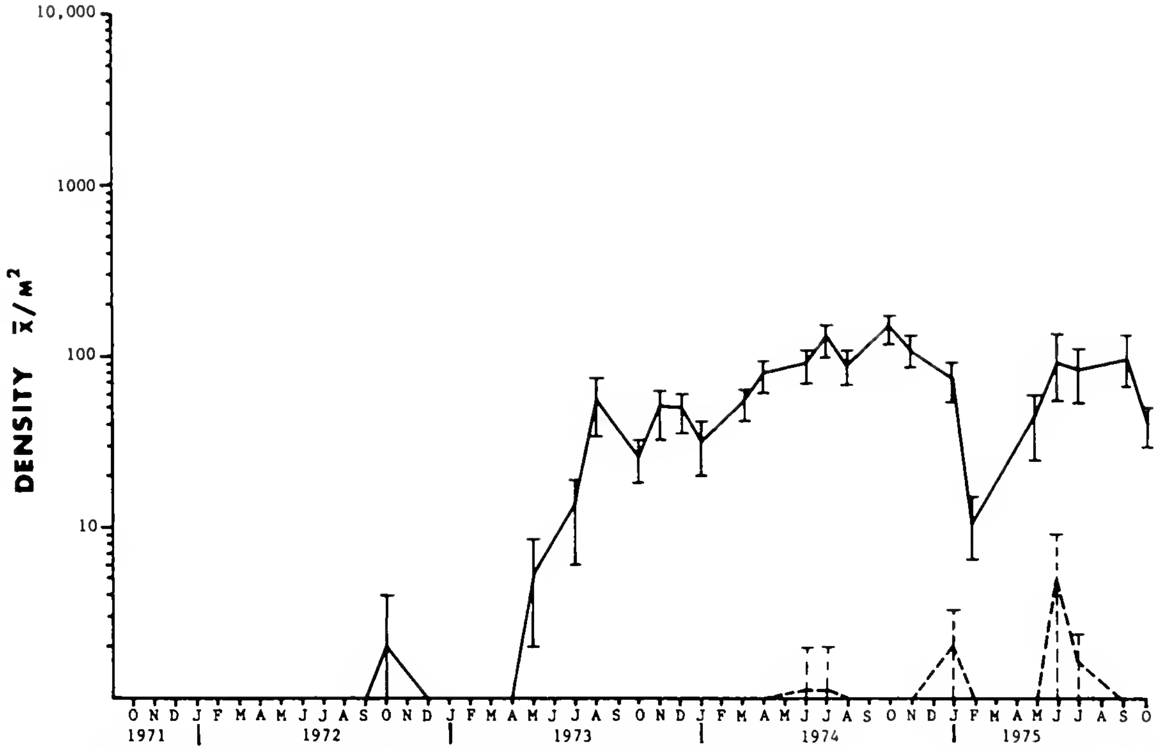

FIG. 6: *Mean (± SE) density of third year (solid line) and fourth year (dashed line)* Corbicula *in Altamaha River, October 1971 through October 1975.*

and low current velocity habitats. To meet criteria for homogeneity of variances the densities were transformed by $\log_{10}$ (X + 1). The results indicated that first year *Corbicula* showed no preference for either habitat, but older *Corbicula* (two to three years) were found in greater numbers in low velocity areas. Mean densities of immature and mature first year *Corbicula* were greater in high velocity areas than in low velocity areas, but the differences between the means were not significant at the .05 level. Second year clams were slightly more abundant in low velocity areas, but the difference between the means was not significant at the .05 level. Mean densities of third and fourth year *Corbicula* were both significantly greater in low velocity habitats at the .001 and .05 levels respectively.

In October 1975 several shells from dead *Corbicula* were found deposited on a sand bar at river mile 113.4. Some of these were as large as 38 mm, and were probably six years old. It is possible that the older clams prefer habitats away from the main channel, such as sand bars and sloughs. None of the sampling stations were placed so that they were over sand bars or sloughs on high water because these habitats could not be sampled during low water. Another possibility is that the larger clams were imported from an older population upstream during the unusually high water in spring 1975. If the clams were established first upstream by overland transport as Sickel (1973) speculates, one would expect to find larger individuals upstream.

The invasion of *Corbicula* in the Altamaha River since 1971 has been accompanied by a drastic decline in populations of other bivalves (Figure 7). *Corbicula* density fluctuated greatly from late 1971 through summer 1972, indicating their aggregated distribution. By late fall 1972 *Corbicula* were collected consistently. Other bivalves (Sphaeriidae and some Unionidae) maintained average densities of approximately $200/m^2$ during late 1971 and 1972. In October 1972 average *Corbicula* density in areas sampled increased to almost $200/m^2$ and the density of other bivalves fell sharply. During winter and spring of 1973 densities of *Corbicula* fell to 60/m² and the density of other bivalves rose to 80-90/m². Concurrently, much dead *Corbicula* tissue was collected in drift samples (unpublished data), indicating a large die-off. This phenomenon has been reported by Sinclair and Isom (1963) and Bickel (1966). In August 1973 *Corbicula* density rose above the peak for the previous year reaching nearly 700/m², while the density of other bivalves again fell sharply. In summer 1974 *Corbicula* reached a density of almost 10,000, and other bivalves disappeared from our samples. These inverse fluctuations in 1972 and 1973 may be due to sampling bias as a result of clumped distribution of both *Corbicula* and other bivalves but may also indicate some form of competition. In the Flint River, Sickel (1973) observed that "where *Corbicula* were most dense there were no unionids, even though the habitat appeared suitable." He further suggested that "this indicated some form of competition, which was unlikely to be simply spatial competition since the size of *Corbicula* and its density did not appear to be great enough to exclude the much larger unionids."

Canthyria spinosa and *L. dolabraeformis* were collected commonly as late as October, 1974 but have rarely been found since then by the authors or by local fishermen who use the mussels for bait. In November 1975 a survey was made of sandbars and sloughs once described (Sickel, 1969) as having an abundant population of *L. dolabraeformis*, *E. hopetonensis*, and *C. spinosa*. No *L. dolabraeformis* or *C. spinosa* were found. A single *E. hopetonensis* was found near an area from which Sickel (1969) observed densities up to 16/m². *Corbicula* was found in abundance in these areas and in one slough the density was 710/m². Scattered along the sandbars and in shallow waters nearby were empty shells of *E. shepardianus*, *E. hopetonensis*, *L. dolabraeformis*, *L. splendida*, and *C. spinosa*. Most of the shells were found with both halves intact, and some had bits of dried mantle attached, indicating relatively recent death. In December 1975 one of our coworkers discovered a small bed of *L. dolabraefor-*

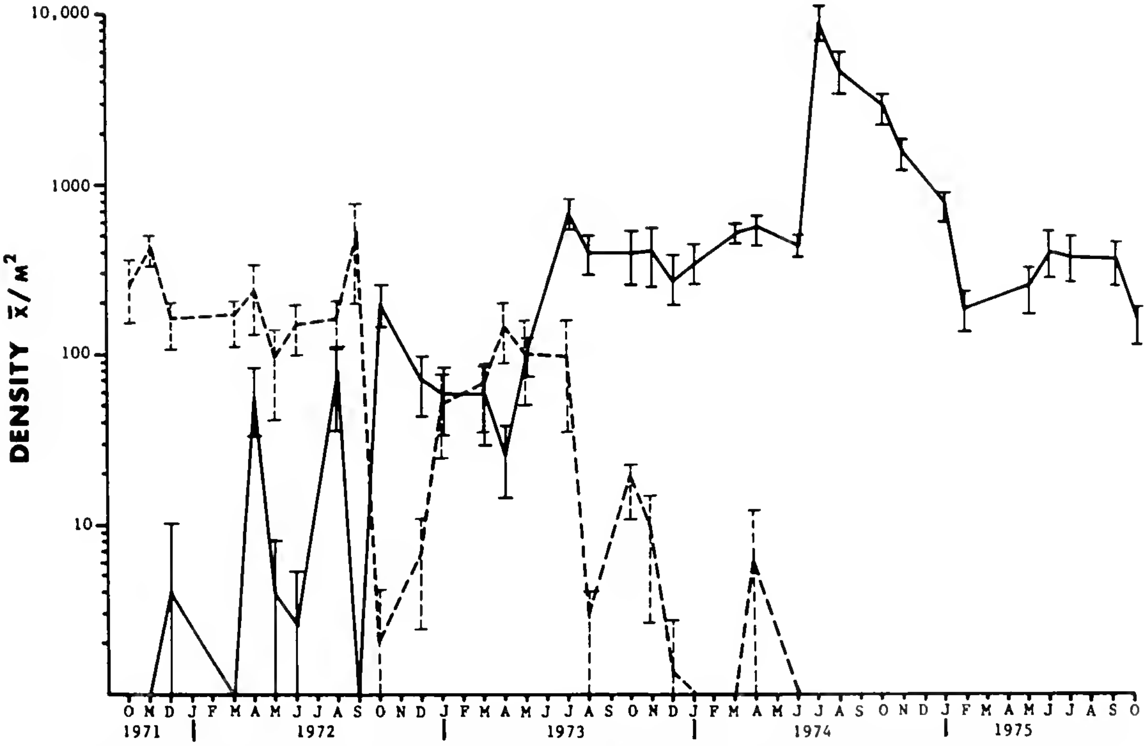

FIG. 7: *Mean (± SE) density of total* Corbicula *(solid line) and other bivalves (dashed line) in Altamaha River, October 1971 through October 1975.*

mis on the north bank just above a sand bar (RM 111). Most of the shells examined were empty. A few live *L. dolabraeformis* were found but were observed to be extremely emaciated. It is interesting to note that all of the above species except *L. splendida* are endemic to the Altamaha River and are listed as endangered species by the Georgia Department of Natural Resources (1974). Additional endemic species listed as endangered but not collected during this study include *Alasmidonta arcula* Lea, *Elliptio dariensis* Lea, and *Anodonta gibbosa* Lea.

It is possible that *Corbicula* may have a higher rate of filtration than mussels. Mattice and Dye (1975) reported a filtration rate for *Corbicula* of 1 liter/hr. Stanczykowska, Lawacz, and Mattice (1973) found that filtration rates ranged from 10-100 ml/hr for *Dreissena polymorpha* Pallas and from 60-490 ml/hr for Unionidae. However, Habel (1970) found a lower filtration rate of 11 ml/hr for *Corbicula*. *Corbicula* have been found to be tolerant of a variety of adverse conditions. Mattice and Dye (1975) found *Corbicula* tolerant of high and low extremes in water temperature. Sinclair and Isom (1963) reported *Corbicula* tolerant of intense water level fluctuations in the Tennessee River. Habel (1970) found *Corbicula* strongly resistant to low DO. Diaz (1974) found a high density of *Corbicula* in the James River below an area receiving 90,000 lbs BOD/day.

Several features of the *Corbicula* reproductive cycle (Sinclair and Isom, 1963) give them a definite competitive advantage. *Corbicula* are monoecious, incubatory and attain sexual maturity in less than one year. Unionidae, most of which are dioecious, have a weakness in that larval parasitism of fish is required for development to maturity. Although many glochidia may be produced, very few are able to find a suitable host, and the period of development to sexual maturity is often extended more than one season (Storer and Usinger, 1957). Although sphaeriids, like *Corbicula*, are monoecious and incubatory, they may have a definite disadvantage of fragility. The authors have observed, especially in young individuals, that the sphaeriid shells appear to be thinner and may not withstand scouring caused by extreme river discharge as well as *Corbicula*.

Density of sexually immature *Corbicula* (Figure 3) did not reach a maximum in fall 1975 of the magnitude reached in 1973 and 1974. The extreme river discharge in spring 1975 may have exerted a flushing or diluting effect on the *Corbicula*. Another possibility is the attainment of *Corbicula* carrying capacity in the river after an initial overshoot. It is evident from Figure 7 that the average density of *Corbicula* in 1974 and 1975 was about the same as the density that other bivalves were prior to fall 1972, which indicates the replacement of other bivalves with *Corbicula*.

A combination of factors probably was responsible for the success of *Corbicula* and the decline of other bivalves in the Altamaha River. Clearly, more investigation is necessary to determine the magnitude and extent of the invasion in the upper and lower reaches of the Altamaha drainage system. Additional research, such as determinations of relative filtration rates, food particle size preference, and spatial interactions is needed to elucidate the nature of competition between *Corbicula* and other bivalves.

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SUCCINEA RAOI NEW NAME FOR *SUCCINEA ARBORICOLA* RAO, 1925 (STYLOMMATOPHORA : SUCCINEIDAE)

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Mousson (1887) described a new species, *Succinea arborea* from Kalaruri (=Kalahari), Southeast Africa. As the name was preoccupied by *Succinea arborea* Adams and Angas (1863) from South Australia, Connolly (1912) proposed the new name, *Succinea arboricola* for the South African species.

During the course of our studies on molluscs from Poona District, Maharashtra, we have come across a species of succineid, *Succinea arboricola* Rao, the type specimens of which were collected by Dr. S. L. Hora, during August, 1924, on. the bark of mango trees in the compound of Hamilton Hotel at Lonavla, Poona District. Signifying its peculiar habitat, Rao (1925) named the new species as *Succinea arboricola* which, however, is distinct from the South African and South Australian succineids. Since *Succinea arboricola* Rao is a junior homonym of *Succinea arboricola* Connolly, it is necessary to propose a new name for the Indian species. We take this opportunity to propose the new name *Succinea raoi,* for *Succinea arboricola* Rao, in honour of late Dr. H. S. Rao, who made significant contributions to Indian malacology.

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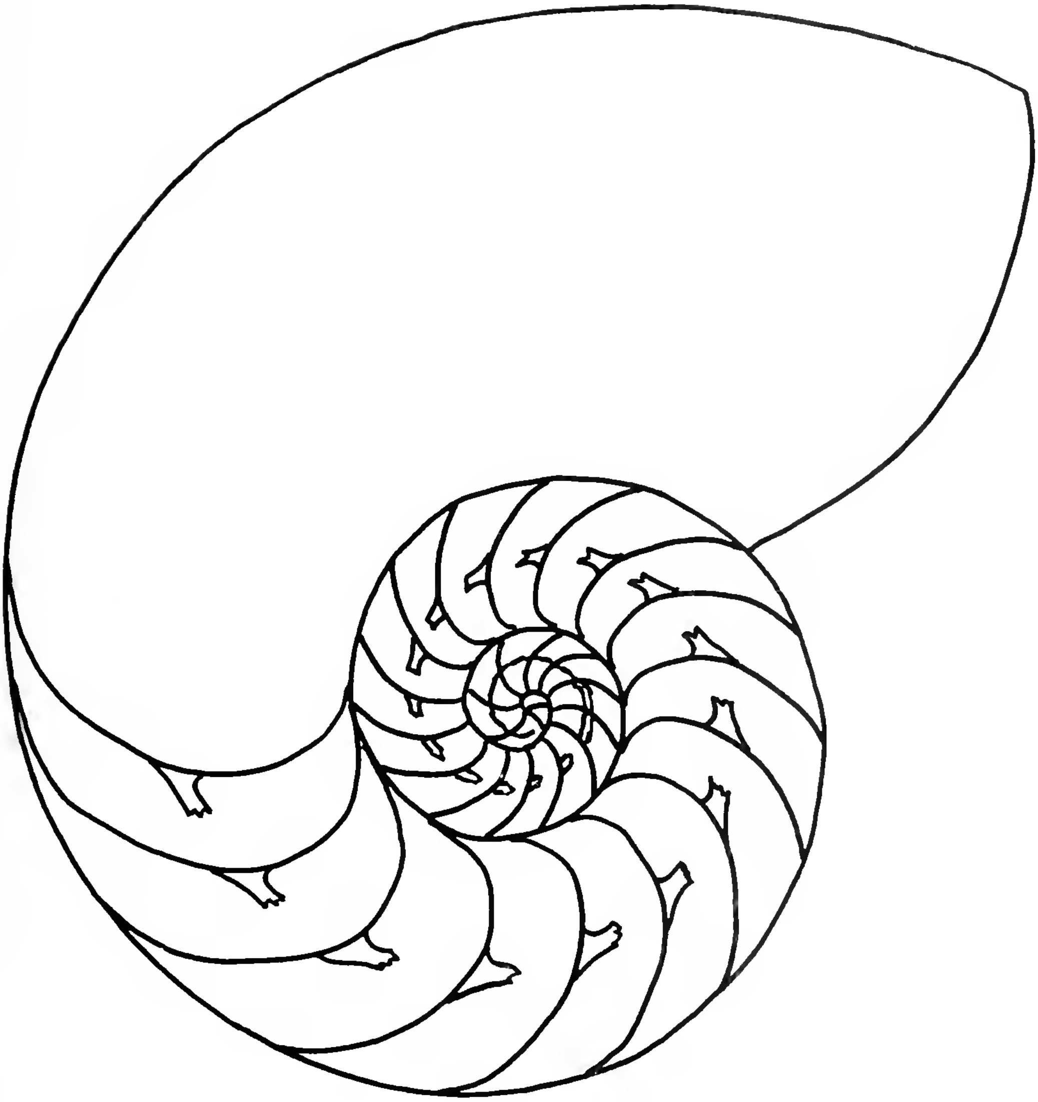

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CONTENTS

NEW PLEISTOCENE NEOGASTROPODA FROM THE NEW HEBRIDES

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ABSTRACT

One new genus and eleven new species, representing six families of neogastropod mollusks, are described from the highly fossiliferous beds of the Navaka sands on the island of Santo. Also included is a highly decorated cone, possibly identical with a living species. The fossiliferous sediments were deposited at moderate depths in an off-reef environment.

INTRODUCTION

Several recent publications have cited the occurrence on the island of Santo, New Hebrides, of richly fossiliferous Pleistocene sediments (Mallick, 1971, 1973, 1974, 1975; Mallick and Greenbaum, 1975; Greenbaum, 1974, 1975). Collections of fossils made by Messrs. Mallick and Greenbaum of the New Hebrides Condominium Geological Survey were sent to the U.S. National Museum for identification starting in 1970. They proved of such interest that Thomas Waller of that institution and Warren Blow of the U.S. Geological Survey visited the island in 1974 to collect bulk samples. As work on all of these collections proceeds, it becomes apparent that the Santo sediments contain perhaps the richest and most diversified and certainly the best preserved fauna of fossil mollusks yet discovered in the islands of the Pacific, possibly in all of the Indo-Pacific region. Recently I described two new volutes from the area (Ladd, 1975). Since that time eleven other new species of mollusks have appeared, a surprisingly large number in view of the demonstrated Pleistocene age of the beds. The entire molluscan assemblage is being studied, but it will necessarily be years before a comprehensive report is published. The purpose of the present paper is to describe the additional new forms that have appeared.

LOCATION

Localities where fossils were collected are shown on Fig. 1. SM242 on the Kere River is 166° 55.74′E, 15°34′S at an altitude of 70 meters. U.S. Geological Survey Cenozoic locality numbers 25715 and 25718 cover the same spot. SM43 on the Navaka River is 166°51.04′E, 15°36.08′S at an altitude of 50 meters. U.S. Geological Survey Cenozoic locality numbers 25731, 25736 and 25742 are in the same outcrop area. All are on the island of Santo, New Hebrides.

A collecting locality SG79 is mentioned in the text but does not appear on the map. It includes float from a tributary to the Sarakata River 20 km. northeast of SM242.

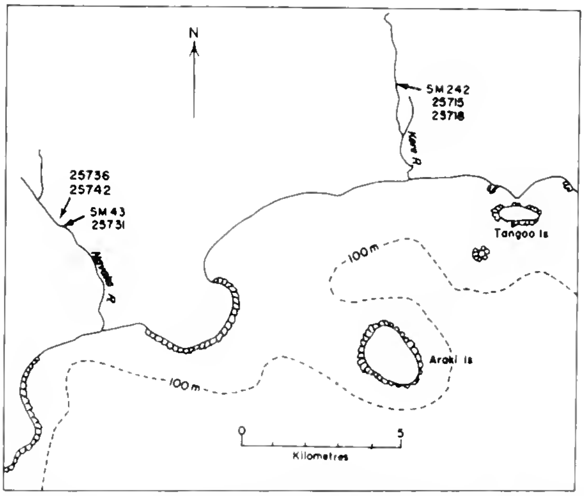

FIG. 1 *Part of south Santo, New Hebrides, showing the location of fossil sites on the Navaka and Kere Rivers (after Mallick and Greenbaum, 1975). Numbers without prefix are USGS Cenozoic locality numbers.*

STRATIGRAPHY

When Mawson studied the geology of the New Hebrides some seventy years ago he collected a large number of fossil mollusks from beds outcropping near Tasiriki on the southwest coast of Santo. He referred to these beds as the Tasiriki foundation-beds (1905, p. 448, 451). Mallick and Greenbaum (1975, p. 8) identify them with the Navaka Sands. Mawson pointed out that the beds at Tasiriki were intermediate in character between the soft "soapstone" (calcareous clay) and fossiliferous cinder beds. Mallick noted that the typical beds were soft unlithified sands and silts with some gravel. Mallick and Greenbaum mapped the geology of a part of south Santo, the area covered including the fossiliferous beds on the Navaka and Kere Rivers. Ladd (1975) referred to the fossiliferous sediments as marls, using the term rather loosely. In their 1975 discussion, Mallick and Greenbaum refer to the SM242 outcrops on the Kere River as the Kere Shell Bed—a sediment composed of 50-70% calcareous skeletons and fragments in a gray silt. The unit had an observed thickness of at least 1 meter and its base appeared to dip SSE at about 5 degrees.

PALEOECOLOGY

A brief summary on this subject was included in a paper describing two new fossil volutes from Santo (Ladd, 1975). At present there is little to be added to that account. I still favor the view that the fossiliferous beds were accumulated on an off-shore shelf at depths in excess of 50 meters. In this connection it may be noted that Hedley, who examined the numerous fossil mollusks collected by Mawson from Tasiriki on Santo, was reminded of an assemblage collected elsewhere in 15 fathoms (27 meters) (Hedley, 1905, p. 477).

The high percentage of new species of mollusks contained in the beds may reflect present lack of knowledge of the existing fauna rather than great age. Very little dredging has been done in the New Hebrides at depths comparable to those postulated for the Navaka Sands. Some of the fossil species here described as new may eventually be found living in the existing seas. The cone, *Kenyonia*, here described, may be identical with a species that lives today at depths of 150-190 meters in Japanese waters.

AGE

In 1970 Miss Ruth Todd of the U.S. Geological Survey reported on the rich and beautifully preserved Foraminifera contained in the sands found on the Navaka River at SM43. She noted at least 150 species of benthonics and about 18 species of planktonics. Among the latter was *Globorotalia truncatulinoides* (d'Orbigny), indicating an age no older than Pleistocene. (R. Todd, written communication August 10, 1970).

As noted in 1975 (Ladd, p. 136) a Uranium-Thorium age determination on well-preserved coral from SM242 by Barney Szabo of the U.S. Geological Survey gave a figure of 14,000 years, a date at approximately the Pleistocene-Holocene boundary. This figure seemed small in view of the field relations and the occurrence of undescribed species of mollusks and, at Mr. Szabo's suggestion, a carbon 14 test of the same coral was made. This determination, by Dr. Robert Stukenrath of the Radiation Biology Laboratory of the Smithsonian Institution, gave a figure of 25,280 ± 460 years—a place clearly in the Pleistocene.

SYSTEMATICS

Order **Neogastropoda**

Family **Coralliophilidae**

Genus **Coralliophila** H. and A. Adams

Adams, H. and A. 1853, Genera of Recent mollusca, vol. 1, p. 135.

Type (by subsequent designation, Iredale, 1912. Mal. Soc. London, Proc. Vol. 10, p. 221): *Murex neritoideus* Chemnitz = *Purpura violacea* Kiener. Holocene, Pacific.

Coralliophila mallicki *new species*

Figs. 5-7

Shell small and thin with a low, flattened spire and widely expanded body whorl. Non-umbilicate, aperture broadly triangular, outer lip thin, inner lip wide with a concave columellar callus that extends the full length of the aperture. Sculpture consisting of about 30 shallow spiral grooves that produce low-flat-topped spiral ribs. Measurements of the holotype, USNM 214348, SM242-444A: height 11.9 mm, diameter 10.0 mm.

The single small New Hebrides fossil may be immature. It resembles the variable living type species, *Coralliophila violacea* Kiener, but has a flatter spire, a thinner and more expanded outer lip. In overall shape and sculpture *C. mallicki* resembles some of the fossil species assigned to *Concholepas* (Beu, 1970; Vokes, 1972), but the excavated columellar area of the New Hebrides shell seems to place it clearly in *Coralliophila*.

The species is named for Dr. D. I. J. Mallick, formerly Senior Geologist of the New Hebrides

FIGS. 2-4. Latiaxis (Tolema) blowi *new species. Holotype, USNM 214250.* X *2.* **5-7** Coralliophila mallicki *new species. Holotype.* × *6.* **8–9** Phos bakeri *new species. Holotype. USNM 214307.* × *3.* **10** Metula kerensis *new species. Holotype, USNM 214288.* × *3* **11** Metula santoensis *new species. Holotype.* × *2.*

Geological Survey, who discovered the fossil beds on the Kere River, and collected this and many other unique shells.

Occurrence: A single specimen from SM242 on the Kere River.

Genus **Latiaxis** Swainson

Swainson, 1840, Treatise on malacology, p. 306.

Type (by subsequent designation, Gray, 1847, Proc. Zool. Soc. London, pt. 15, p. 135): *Pyrula mawae* Gray. Holocene, Indo-Pacific.

Subgenus **Tolema** Iredale

Iredale, 1929, Records Australian Mus., v. 17, no. 4, p. 186.

Type (ICZN Op. 911, 1970): *Purpura sertata* Iredale (= *Tolema australis* Laseron). Holocene, Australia.

Latiaxis (Tolema) blowi *new species*

Figs. 2-4

Shell biconic, strongly turreted. Protoconch consisting of about two whorls, coiled at a slight angle to the axis of the spire, followed by six sculptured whorls. Surface of shell covered by close-set scaly spiral cords; shoulder sharply elevated with triangular open scales that are more prominent on early whorls than on the body whorl; axial ribs, about 9 on penultimate whorl, are broadly rounded. Body whorl constricted anteriorly; aperture, triangular outer lip thin, made lirate within by the exterior spirals; inner lip thinly callused; umbilicus a shallow chink.

Measurements of the holotype (only specimen), USNM 214250: height 28.0 mm, diameter 18.3 mm.

L. blowi seems most closely related to *L. filaregis*, a Holocene species described by Kurohara (1959), but that species is more slender, more coarsely sculptured and less constricted anteriorly.

This species is named for Warren Blow of the U.S. Geological Survey who collected the only specimen from USGS locality 25715 on the Kere River outcrops, Santo, New Hebrides.

Occurrence: U.S. Geological Survey station 25715 on the Kere River. *L. filaregis* Kurohara, the related form mentioned above, occurs at depths of 50-100 meters off Shikoku, Japan (Habe, 1964, p. 86).

Family **Buccinidae**

Genus **Phos** Montfort

Montfort, 1810, Conchyl. Syst. p. 495.

Type (by original designation): *Murex senticosus* Linnaeus. Holocene, southwest Pacific.

Phos bakeri *new species*

Figs. 8, 9

Medium in size, biconic. Protoconch consisting of four whorls, each of the lowest three with two fine spiral ribs on its lower half. Aperture broadly lenticular with a short and slightly twisted canal anteriorly; outer lip with a thin edge, thickened within and bearing short denticles; columella with two plaits, the anterior one larger. Sculpture consisting of strong smooth axial ribs, fourteen on the penultimate whorl, and many fine spirals that become coarse near the base. Measurements of the holotype, USNM 214307: height 18.4 mm, diameter 9.0 mm.

P. bakeri seems most closely related to *P. dingsi* described by MacNeil (1960, p. 74, pl. 3, fig. 21) from the Miocene Yonobara Clay, Shimajiri Formation, of Okinawa. That species, however, has more numerous axial ribs, some of which are clearly formed varices. *P. bakeri* is also related to a Japanese Holocene species, *P. hirasei* Sowerby (see Habe, 1964, p. 95, pl. 31, fig. 7) but that species is much larger, has well developed spiral cords and occasional varices.

This species is named for Mr. F. E. Baker, British District Agent on Santo, who assisted Thomas Waller and Warren Blow in many ways during their visit to the area in 1974.

Occurrence: Three shells from the Kere River outcrops at USGS locality 25715.

Genus **Metula** H. and A. Adams

H. and A. Adams, 1853, Genera of Recent Mollusca, v. 1, p. 84.

Type (by hidden tautonymy): *Buccinum hindsii* H. and A. Adams (= *Buccinum metula* Hinds). Holocene, Pacific coast of Panama.

Metula kerensis *new species*

Fig. 10

Shell small and slender; protoconch consisting of 2½ glassy convex whorls, followed by 5½ sculptured whorls. Sculpture consisting of fine, irregularly-spaced axials and close-set flattened spirals. Sculpture on some specimens uniform over entire shell, on others the spiral immediately below the suture is more prominent than the others; there are occasional low varices. Aperture elongate, truncated anteriorly; outer lip thickened both anteriorly and posteriorly, smooth within save for a broad node posteriorly; columella concave, inner lip heavily callused.

Measurements of the holotype, USNM 214288: height 24.3 mm, diameter 7.3 mm.

M. kerensis differs from described species of *Metula* by the subdued nature of its sculpture. The pattern of axials and spirals are clearly seen only with the aid of a lens.

Occurrence: Represented by eight shells from the USGS localities 52715 and 52718 Kere River, Santo.

Metula santoensis *new species*

Fig. 11

Small to medium in size, slender, whorls gently convex, suture lightly impressed; protoconch not preserved. Sculpture consisting of close-set, slightly curved axial ribs that are stronger than the over-riding spirals, especially on the whorls of the spire; immediately below the suture and on the base the spirals are more widely spaced than elsewhere. Aperture elongate, outer lip thickened, crenulate within; inner lip smooth, heavily callused. Measurements of the holotype, BM (NH) GG19763: height 30 mm, diameter 9.8 mm.

M. santoensis closely resembles *M. elongata* Dall dredged off Japan in 57 fathoms of water (Dall, 1957, p. 166) but that species is longer and more slender.

Occurrence: Represented by two specimens, the holotype from station SM242 on the Kere River, and a smaller shell from river debris on the Sarakata River (SG79), Santo.

Family **Nassariidae**

Genus **Nassarius** Duméril

Duméril, 1806, Zoologie analytique, p. 167 (genus without species).

Type (by monotypy) Froriep, 1806, C. Duméril's Zoologie analytique, p. 167: *fide* Iredale, 1916, Proc. Mal. Soc. London, v. 12, p. 83): *Buccinum arcularis* Linnaeus. Holocene, western Pacific.

Subgenus **Alectrion** Montfort

Montfort, 1810, Conch. Syst. v. 2, p. 566.

Type (by original designation): *Buccinum papillosum* Linnaeus. Holocene, Indo-Pacific.

Nassarius (Alectrion) barsdelli *new species*

Figs. 12-15

Medium in size, thin, body whorl greatly inflated. Early whorls with rounded axial ribs crossed by fine spiral grooves: subsequent whorls may be slightly crenulated at the deeply channeled suture and may have a faint subsutural spiral groove; late whorls mostly smooth except for spiral grooves over the base of the body whorl. On some shells weak spirals can be seen over the entire body whorl (Figure 15). Aperture broadly lenticular, outer lip thin, columella smooth except for obscure corrugations near its base.

Measurements of the types: Holotype, USNM 214274 (Figs. 12-14) height 23.8 mm, diameter 14.0 mm; paratype, USNM 214278 (Fig. 15 height) 23.8 mm, diameter 15.0 mm.

The new species is smaller than *N. glans* (Linnaeus) and is proportionately shorter and more inflated. None of the nearly 40 fossils has a denticle on the parietal wall and none shows a trace of color pattern. I first considered the fossil form as a new subspecies of *N. glans* (Linnaeus) but the later recovery of two incomplete but typically banded shells of *N. glans* from the outcrop on the Kere that yielded the fossils indicates that the two are distinct.

This species is named for Mark Barsdell, formerly of the New Hebrides Geological Survey, who, in 1974, aided Messrs. Waller and Blow in collecting on the rivers and in dredging.

Occurrence: Abundant in the Kere River outcrops, USGS locality 25715. *N. glans* (Linnaeus) lives today in many parts of the tropical Pacific (Cernohorsky, 1972, p. 180).

Bathynassa Ladd, *new genus*

Type: *Bathynassa bolangoi* Ladd, new species. Pleistocene, Santo, New Hebrides.

Small, slender. Protoconch of three convex whorls, the middle one faintly keeled, the last more strongly keeled. Early whorls of teleoconch with sharply elevated axial ribs that are overridden by weaker spirals; on later whorls axials and spirals become subequal; uppermost spirals on each whorl forming a rim that bounds a deeply excavated subsutural furrow. Aperture broadly lenticular; inner lip callused, with a low denticle posteriorly; outer lip faintly lirate within, backed by a strong varix.

The genus is characterized particularly by its


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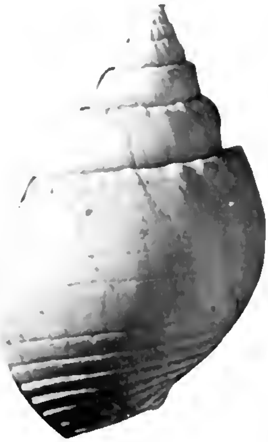
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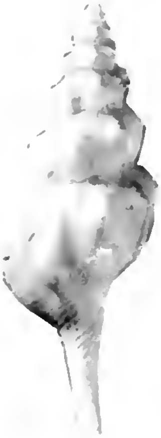
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FIGS. 12-15 Nassarius (Alectrion) barsdelli *new species.* **12, 13** *Holotype, USNM 214274.* × *2.5.* **14** *Apex of holotype.* × *5.* **15** *Paratype, USNM 214278.* × *2.5.* **16-20** Fasciolaria (Pleuroploca) walleri *new species* **16, 17** *Holotype, USNM 214260.* × *1. (uncoated to show original color pattern)* **18-20** *Paratype, USNM 214261.* X *1.* **21-22** Kenyonia *cf* chiangi *(Azuma) USNM 214291.* X *6.*

deeply excavated, nearly flat-bottomed subsutural furrow.

Bathynassa bolangoi *new species*

Figs. 34-40

Shell small, slender. Protoconch consisting of three gently convex glassy whorls; middle whorl with a trace of a median keel, the lowest whorl with a stronger keel. Teleoconch of six whorls; on early whorls strong axial ribs are overridden by weak spirals but on later whorls the axials and spirals are subequal in strength; on the base the spirals are sharply elevated and more widely spaced. A deep subsutural furrow has a gently concave floor that is crossed by the axial ribs. Under low magnification the furrow appears deeper than in Figs. 38 and 39 which are SEM photographs. Aperture broadly lenticular, inner lip thinly callused, the callus edge slightly elevated; columella smooth except for a low denticle posteriorly; outer lip weakly lirate within, backed by a strong varix. Siphonal canal short and broad.

Measurements of the types:

Holotype	USNM	214343	length 13.9 mm.	diameter 5.2 mm.
Paratype	A	214344	12.8	5.2
	B	214345	13.6	5.2
	C	214346	(incomplete)	about 5

The fossils are more slender than the average nassarid but the protoconch of the fossil seems typically nassarid, likewise its aperture and outer lip varix. Its excavated, nearly flat-bottomed subsutural furrow separates it from other members of the family. I have not found a living or fossil species with a furrow of this type. Superficially, the new species resembles *Nassarius caelatus* A. Adams from Southeast Asia, but the latter is much larger, more obese and with weaker spiral threads.

This species is named for John Bolango of the New Hebrides Condominium Geological Survey who collected with Thomas Waller and Warren Blow when they visited Santo in 1974.

Occurrence: Seven shells from the Navaka River beds, all from the northern end of the outcrop area, stations 25736 and 25742. It may be that the beds in this area accumulated at somewhat greater depth than those farther south on the Navaka or the beds on the Kere River to the east.

Family **Fasciolariidae**

Genus **Fasciolaria** Lamarck

Lamarck, 1799, Prodrome d'une nouvelle classification des coquilles... Mém. Soc. Hist. nat., Paris **1**, p. 73.

Type (by monotypy): *Murex tulipa* Linnaeus. Holocene, Caribbean.

Subgenus **Pleuroploca** P. Fischer

Fischer, P., 1884, Jour. de Conchyl, vol. 32, p. 169.

Type (by monotypy): *Murex trapezium* Linnaeus. Holocene, Indo-Pacific.

Fasciolaria (Pleuroploca) walleri *new species*

Figs. 16-20

Shell small, slender, fusiform. Protoconch consisting of 2½ smooth, convex whorls, followed by 8 sculptured whorls. Sutures appressed; aperture broadly lenticular, extended anteriorly into a long and strongly recurved siphonal canal; outer lip lirate within; columella callused with a low broad fold, the callus with a detached outer edge. Sculpture consisting of broad, rounded axial folds, 8-10 on the penultimate whorl; folds becoming less well developed on the latter half of the body whorl; all whorls covered by close-set weak spirals that are a little stronger on the folds than in the intervening valleys; spirals much stronger at the base of the body whorl. Crest of each axial fold with a band of reddish-brown color, the color deeper between the fine spirals than on their crests.

Measurements of the types: Holotype, USNM 214260: length 66.6 mm, diameter 22.6 mm. Paratype, USNM 214261: length 58.7 mm, diameter 21.3 mm. A specimen in the Mallick collection (SM242-63A) is 71.4 mm in length.

F. walleri resembles *F. filamentosa* (Röding), a common and widely distributed species in existing Indo-Pacific seas, but is smaller, has finer spiral sculpture and a much longer and more strongly recurved siphonal canal.

This species is named for Dr. Thomas R. Waller of the Smithsonian Institution who organized a collecting trip to Santo, during the course of which the types of this species and many other fossils were collected.

Occurrence: Four specimens from the Kere River, (USGS locality 257115 and SM242).

Family **Turridae**

Genus **Epidirona** Iredale

Iredale, 1931, Records Australian Mus., v. 18, no. 4, p. 225.

Type (by original designation): *Epidirona hedleyi* Iredale. Holocene, Australia.

Epidirona greenbaumi *new species*

Figs. 23-26

Shell medium in size, stout, biconic. Protoconch of two glassy convex whorls followed by eight and one-half sculptured whorls. Aperture lenticular, outer lip thin, lirate within; inner lip callused; sinus moderately deep; anterior canal short, wide, slightly flaring. Sculpture consisting of strong primary spirals that alternate with weaker secondaries; primary ribs beaded by axials (about 25 on penultimate whorl); upper two spirals set off by a groove to form a distinct subsutural band; on the whorls of the spire the axials are nearly straight but become slightly sinuous on the body whorl.

Measurements of the holotype, USNM 214306 from USGS locality 25715: length 20.8 mm, diameter 8.3 mm. Paratype, BM(NH)GG19762 from SM242: length 20.0 mm, diameter 8.1 mm.

E. greenbaumi is closely related to *E. perksi* (Verco), a species that lives off South Australia (Verco, 1896, p. 224, pl. 17, figs. 3, 3a-c). I have not seen shells of *E. perksi* but, judging by Verco's detailed account, it appears that the New Hebrides fossil has coarser sculpture, particularly on the body whorl, a more prominent collar and straighter axials on the whorls of the spire.

This species is named for Dr. David Greenbaum of the New Hebrides Condominium Geological Survey who mapped the geology of parts of Santo and made large collections of fossils from outcrops on the Kere River and on other streams.

Occurrence: Two shells from USGS locality 25715 and three from SM242 on the Kere River. Verco's closely related species, *E. perksi*, was dredged alive in 15 fathoms (27 meters) off South Australia.

Genus **Euclathurella** Woodring

Woodring, 1928, Carnegie Inst. Washington, Pub. 385, p. 187.

Type (by original designation): *Clathurella vendryesianus* Dall. Miocene, Jamaica.

Euclathurella santoensis *new species*

Figs. 27-30

Small, slender, fusiform, high spired. Protoconch consisting of about four convex whorls, the first three smooth, the last bearing curved, close-set axials; teleoconch of 6 whorls with thin, widely spaced axials, about a dozen on penultimate whorl. Axials extend from suture to suture and are slightly sigmoid with a sharp peripheral angulation more than one-third of the distance below the suture; below the angulation the rib is convex in profile, above it is flat; surface of whorl between axials is smooth; a few spiral threads are discernible on the base under magnification. Aperture long and narrow, its length exceeding that of the spire; sinus deep and broadly rounded; outer lip with a thin edge but callused posteriorly and backed throughout its length by a prominent varix; columellar area thinly callused except for a pad below the anal sinus; anterior canal long, wide and rather abruptly truncated. Measurements of the holotype, USNM 214337: height 14.0 mm, diameter 4.9 mm.

I could find no close relative of *E. santoensis*. Its axial ribs are more widely spaced than those of the Caribbean type species, *E. vendryesianus*, and the spiral sculpture of the new species is mostly absent. The protoconchs of the two are similar but that of the New Hebrides shell has more whorls. Our new species superficially resembles *Eucythara funiculata* (Reeve), but lacks the small teeth in the columellar wall and outer lip. We are provisionally placing *santoensis* in *Euclathurella*.

Occurrence: Four shells from USGS locality 25718 on the Kere River.

Family **Conidae**

Genus **Kenyonia** Brazier

Brazier, 1896, Linnean Soc. New South Wales, vol. 21, p. 346.

Type (by monotypy): *Kenyonia pulcherrium* Brazier, Holocene, New Hebrides.

Kenyonia cf. **chiangi** *(Azuma)*

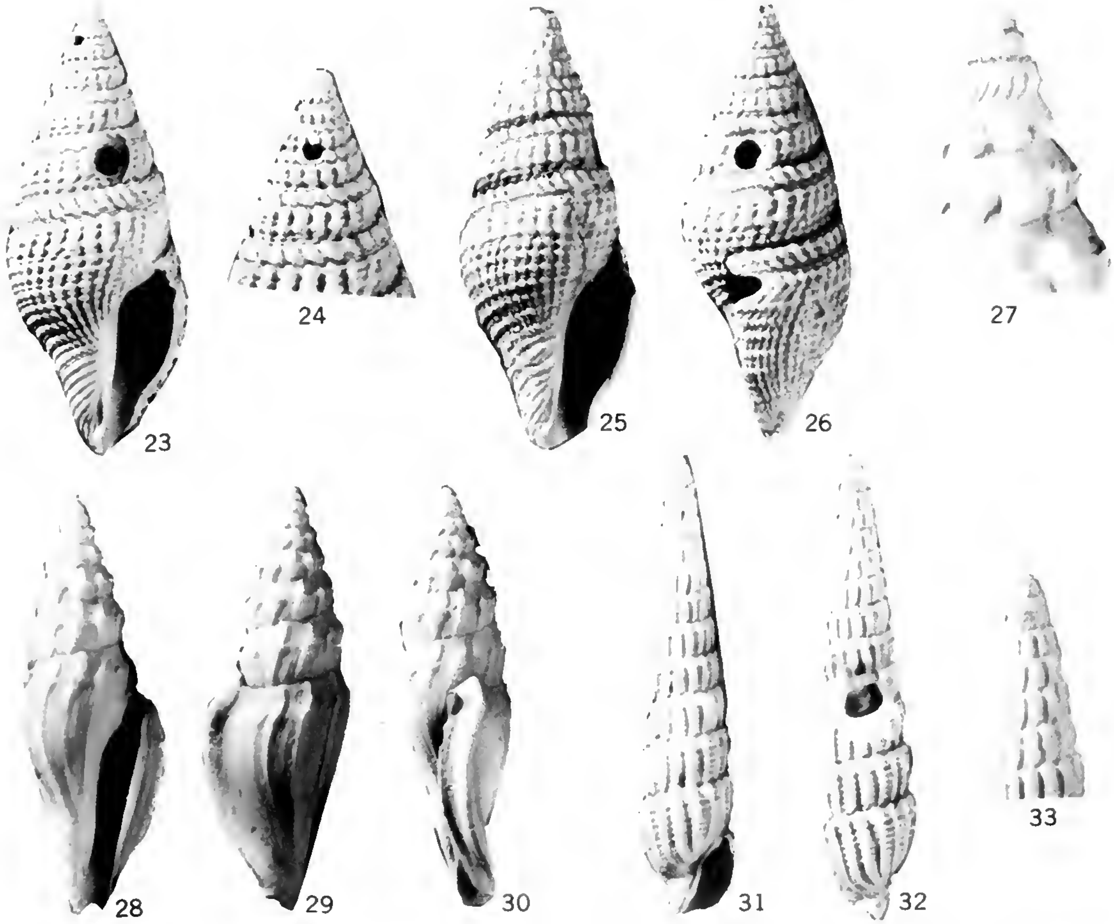
Figs. 21-22

Shell, small, conical, with a low spire culminating in a protoconch of at least two slightly convex glassy whorls. Shoulder sharply angled, bearing a series of elevated triangular plates that form cup-like structures opening inward and forward; fifteen cups on body whorl; cups give shell a stellate appearance when viewed apically. Whorls of spire with close-set spiral grooves that are overridden by finer, curved, axial threads. Body whorl with shallow wavy grooves and finer irregularly spaced axial lines. Aperture elongate; columella slightly concave near base; outer lip thin, straight. Much of the lower third of the body whorl is faintly tinged with brown color.

Measurements of the figured specimen, USNM 214291: length 10.4 mm, diameter 5.9 mm.

The fossil may be conspecific with the species described by Azuma as *Taranteconus chiangi* (1972, p. 59, figs. 5, 6) and recently figured by Okutani (1975, p. 194, pl. 10, fig. 27) but the fossil is more slender anteriorly and may have stronger spiral sculpture.

The fossil has many of the unusual features described for the type species, *K. pulcherrima*, but



FIGS. 23-26 Epidirona greenbaumi *new species* **23** *Holotype, USNM 214306.* × *3.* **24** *Apex of holotype.* × *5.* **25, 26** *Paratype.* × *3.* 27-30 Euclathurella santoensis *new species* **27** *Apex of holotype. (slightly retouched).* × *14.* **28-29** *Holotype, USNM 214337.* × *4.* 31-33 Terebra (Microtrypetes) kerensis *new species* **31, 32** *Holotype, USNM 214340.* × *6.* **33** *Apex of holotype. (slightly retouched)* × *10.*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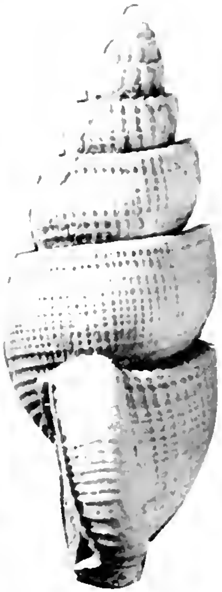
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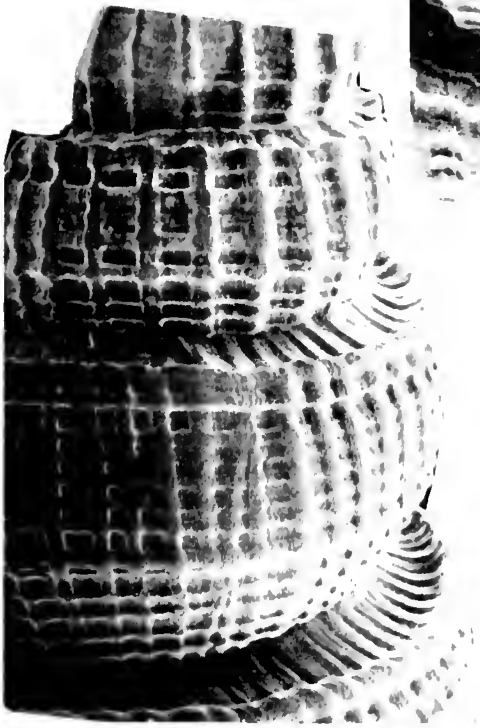
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the fossil is smaller by one-third, is proportionately wider, has a lower spire, fewer peripheral plates and a straight outer lip. These two New Hebrides shells differ greatly from other cones and from most turrids. The fossil here described may be ancestral to the Holocene shell described by Brazier (1896, p. 346); unfortunately, Brazier's single shell has apparently been lost.

Occurrence: A single specimen from USGS locality 25731 on the Navaka River. Azuma's type was collected on the South China Sea at a depth of 200 fathoms (365 meters) Okutani found living specimens fairly common on banks at depth of 150-190 meters in Japanese waters.

Family **Terebridae**

Genus **Terebra** Bruguière

Bruguière, 1789, Ency. méthodique, Histoire naturelle des Vers, vol. 1, p. 15 (genus without species).

Type (by monotypy): Lamarck, 1799, Soc. Histoire Nat. Paris, Mém. p. 79: *Buccinum subulatum* Linnaeus. Holocene, western Pacific.

Subgenus **Microtrypetes** Pilsbry and Lowe

Pilsbry and Lowe, 1932, Proc. Acad. Nat. Sci. Phil., vol. 84, p. 43.

Type (by original designation): *Terebra iola* Pilsbry and Lowe. Holocene, west coast of America.

Terebra (Microtrypetes) kerensis *new species*

Figs. 31-33

Small, very slender; a protoconch of about three smooth whorls is followed by eleven sculptured whorls that are flat-sided but slightly shouldered. Sculpture consisting of sharp, straight axial ribs, sixteen present on penultimate whorl, and narrow spiral grooves, 4-5 on each whorl; one groove close to the suture is larger than the others, suggesting the boundary of a subsutural band. Aperture lenticular, drawn out to form the anterior canal; columella with a single low fold.

Measurements of the holotype, USNM 214340: height 10.0 mm, diameter 2.0 mm.

This little species resembles *T. spei* described by Brown and Pilsbry (1913, p. 497, fig. 1) from the Pleistocene of Panama but is more slender, has less curvature in its axials and its whorls are slightly shouldered; also, the subsutural groove on the species here described is less developed than on the shells of the Panama species. *T. kerensis* is more slender than *T. iola*, type of the subgenus and has fewer spiral grooves than that species.

Occurrence: Many specimens from USGS locality 25715 on the Kere River.

ACKNOWLEDGMENTS

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FIGS. 34-40 Bathynassa bolangoi *new genus and new species. Figures 38-40 taken by Scanning Electron Microscope.* **34, 35** *Holotype, USNM 214343.* × *6.* **36, 37** *Paratype A. USNM 214344* × *6* **38** *Paratype B. USNM 214345* × *21* **39** *Paratype B. USNM 214345.* × *26.* **40** *Paratype C. USNM 214346.* × *72*

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THE TYPE-SPECIES OF *NEPTUNEA* RÖDING, 1798 (GASTROPODA: BUCCINACEA)

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ABSTRACT

Fridolin Sandberger's subsequent designation in 1861 of Fusus antiquus *(Linnaeus) as the type-species of* Neptunea *Röding, 1798, ex Bolten MS, replaces the often-cited, although unavailable, selections by Monterosato (1872) and Kobelt (1876).*

Peter Friedrich Röding (1798, 115-116), in his sale catalogue[2] of the Bolten Museum collections, established, without diagnosis or type-species designation, genus *Neptunea* for a mélange of caenogastropods centered on *Murex antiquus* Linnaeus, 1758. *M. despectus* L., 1758, *M. antiquus* L., 1758 and *M. contrarius* L., 1771, the first, fourth and fifth, respectively, of 17 species-group taxa listed therein, presently remain valid *Neptunea.* Two of the remaining species included by Röding may tentatively be synonomized with *M. antiquus* L. *Buccinum liratum* Martyn, 1784 and *B. saturum* M., 1784, both *Murex* sensu Gmelin (1791, 3498, 3531) and now valid *Neptunea,* are not among species assigned by Röding to *Neptunea, Buccinum, Colus, Fusus, Murex* or *Tritonium.*

Present neptuneids were subsequently so often included in *Fusus, Tritonium* or *Trophon,* that Swainson (1840, 90, 308), in describing *F. antiquus* (L.) and the other North Atlantic species, established *Chrysodomus* for them. *C. argyrostoma,* Swainson's type-species, is a *species inquirenda.* Later designations of type-species by Hermannsen (1847, *I,* 234: "Typus: *Fusus despectus* Linn." of *Chrysodomus*) and Gray (1847, 137: "Type of *Chrysodomus* Swainson, 1840: *Murex antiquus*") remain unavailable. Jeffreys' (1867, 328) selection "Bolten founded his genus *Neptunea,* and Swainson his genus *Chrysodomus* on the present species." *Fusus antiquus,* [discussion pp. 323-328] is invalid under provisions of Article 67(c) of the International Code of Zoological Nomenclature. Subsequent to Bernardi's (1858, 183) equation of Röding's and Swainson's names, Gabb (1869, 3, 71) also synonomized *Chrysodomus* with *Neptunea* and emphasized the priority of the Bolten Catalogue names over those of Lamarck (1799).

Heinrich Link and Fridolin Sandberger were the only European investigators to employ consistently Röding's names prior to the publications of Wilhelm Kobelt. Sandberger (1861, 216), in describing species of "Fusus Bruguière 1791" [1789] in his conchology of the Mainz Tertiary basin, selected "..., für das Pliocän und den Crag des Erscheinen der jüngsten aller Fusus-Gruppen, Neptunea Bolt. (Typus F antiquus)... ." No previous discussion of type-species selections for *Neptunea* Röding has cited Sandberger's subsequent designation.[3]

Tommaso, Marquis di Monterosato's (1872, 17) designation of "... il genere *Fusus* solanto pel *F. antiquus* monstr. *contrarius,* ch'è il tipo dei generi *Neptunea* Bolten e *Chrysodomus* Swainson.". Jeffreys' sinistral morph of *F. antiquus* (L.), is confused by Monterosato's (1872, 33) subsequent equation of "*Fusus antiquus,* (*Murex*) L. Monstr. *contrarius* =*M. contrarius* L.". This identification and the dedication of the work to

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[2] Approved as nomenclatorially available by ICZN Opinion 96, dated 8 October 1926; Röding designated author in Direction 48, dated 21 November 1956.

[3] I am indebted to Druid Wilson of the Branch of Paleontology and Stratigraphy, U. S. Geological Survey, Washington, D.C. for this reference.

Jeffreys likely reflects the profound influence of Monterosato's correspondence with Jeffreys and his visit to England in 1871, where Monterosato would have observed the sinistral specimen of *N.* (*Neptunea*) *antiqua* (L.), now U. S. National Museum of Natural History (USNM) 192193, and the two *N.* (*Sulcosipho*) *contraria contraria* (L.), now USNM 192195, then in Jeffreys' personal collection. Jeffreys clearly distinguished *F. antiquus* "Monstr. *l. contrarium.* Spire reversed. [and] (*Murex contrarius,* Linn. = *F. sinistrorsus,* Desh.)". The latter species-group taxon is a junior subjective synonym of the nominate subspecies of *N.* (*Sulcosipho*) *contraria* (L.). Thus Monterosato's equation of sinistral *N.* (*Neptunea*) *antiqua* (L.) with *N.* (*S.*) *contraria contraria* (L.) is invalid, as is Habe and Sato's (1972, 2) "*Neptunea antiqua* (Linné) = *Neptunea contraria* Roeding" [non L.].

Kobelt's (1876, 63) "... Die Neptuneen der borealen und arctischen Regionen umfassen zwei ziemlich scharf geschiedene Gruppen, deren Typen einerseits Neptunea antiqua, andererseits islandica Chemnitz sind. Man hat aus ihnen zwei Gattungen, *Neptunea* und *Sipho,* ..." is not rigidly construed as required by the provisions of ICZN Article 67(c).

Dall (1902, 520-521) and in subsequent publications (1906, 291-292; 1918, 213-215; 1919, 336; and 1922, 36) believed *Neptunea* had priority for and should be restricted to muricids principally assigned to *Boreotrophon* Fischer, 1884 and then typified by *Trophon clathratus* L. This concept, although used by Oldroyd (1925, 13), was never widely adopted and was subject to a lengthy literature debate in articles by Dall, Iredale (1921, 1922) and Winckworth (1934). Rehder and Bartsch (1941), Rehder (1942, 1945), Winckworth (1945) and Dodge (1957) subsequently discussed prior designations of the type-species of *Neptunea.*

Cossmann (1901, 98) designated *Fusus despectus* (L.) as the type-species of *Chrysodomus* [sensu stricto]. His, Monterosato's, and Kobelt's selections are those most often quoted in the twentieth-century literature treating the type-species of *Neptunea.* Of subsequent designations noted in papers from that of Dall (1902) to Nelson (1974), including Golikov (1963), Strauch (1972) and Habe and Sato (1972), nine authors cite *N. antiqua* (L.), two use *N. despecta* (L.) and four employ *N. contraria* (L.). All of the last cite Monterosato as the subsequent designator. None refer to Sandberger's selection, the only unequivocal subsequent designation of a type-species of *Neptunea* Röding in the nineteenth-century literature.

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NEW FRESH-WATER MUSSEL HOST RECORDS FOR THE LEECH *PLACOBDELLA MONTIFERA*, WITH DISTRIBUTIONAL NOTES

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ABSTRACT

The leech Placobdella montifera *Moore (Annelida: Hirudinea: Glossiphoniidae) is reported for the first time from the mantle cavities of eight species of freshwater mussels (Bivalvia: Unionidae):* Anodonta grandis *Say,* Fusconaia undata *(Barnes),* Glebula rotundata *Lamarck,* Lampsilis teres *(Rafinesque),* L. ovata *(Say),* Obliquaria reflexa *Rafinesque,* Proptera purpurata *(Lamarck) and* Quadrula pustulosa *(Lea). Other specified molluscan hosts are unknown for* P. montifera. *Mussels and leeches were collected from twelve localities in eight parishes in the western half of Louisiana.*

INTRODUCTION

Placobdella montifera Moore is an uncommon species of leech about which very little is known (Sawyer, 1972). Published distributional records of *P. montifera* in the United States include Georgia (Patrick *et al.*, 1966), Illinois (Moore, 1901 and 1906; Paloumpis and Starrett, 1960), Indiana (Moore, 1920), Iowa (Mathers, 1948; Carlson, 1968), Kansas (Harms, 1959 and 1960), Michigan (Verrill, 1874; Miller, 1937), Minnesota (Moore, 1912), Missouri (Meyer, 1937), Ohio (Miller, 1929; Bangham, 1933) and Wisconsin (Pearse, 1924; Bere, 1931; Sapkarev, 1968). In Louisiana, the species was only recently reported, from fresh-water habitats west of the Atchafalaya River, where it was commonly encountered in leaf litter and on the undersurfaces of cans, bottles, sticks, boards, and other moderately smooth substrates (Curry, 1975).

Knowledge of relationships between fresh-water leeches and fresh-water mussels is so meager that any additional information giving specific identifications and/or ecological and distributional notes is of considerable importance. Relationships involving *Placobdella montifera* and various, unspecified mollusks were first observed by Kelly (1902), who considered the relationship unimportant. Clark and Wilson (1912) and Coker *et al.* (1921) commonly encountered leeches in mussels and suggested that the leeches were eating the mucus secreted by the clams. Moore (1912) observed that *P. montifera* habitually entered the shells of mussels (unspecified), but reported no feeding activities. Waffle (1963) suggested that invertebrates are probably not the usual food of *P. montifera.* Fuller (1974) regularly encountered *P. montifera* in the mantle cavities of living mussels and suggested that there is no host specificity and that there are no clear advantages secured by the leech other than "clandestine shelter."

According to Moore (1912), Miller (1929), Sawyer (1972), and Fuller (1974), *Placobdella montifera* is known to attack aquatic worms, snails, insect larvae, frogs, toads, turtles, fishes, and mammals, in addition to mussels. Klemm (1972) erroneously reported that Harms (1959 and 1960) took *P. montifera* from frogs, mussels, and snails, however, Harms (1959 and 1960) reported the leech only from a single species of fish. The only specified hosts recorded for *Placobdella montifera* are the fishes *Lepisosteus osseus* (Linnaeus) (Ryerson, 1915; Hoffman, 1967), *Acipenser brevirostrum* Lesueur (Hoffman, 1967; Pearse, 1924), *Perca flavescens* (Mitchell) (Bere, 1931), *Lepomis gibbosus* (Linnaeus) (Ryerson, 1915; Hoffman, 1967), *Micropterus salmoides* (Lacepede) (Bangham, 1933; Bangham and Hunter, 1939; Hoffman, 1967), *M. dolomieui* Lacepede (Pearse, 1924; Bangham, 1933; Bere, 1931; Hoffman, 1967), *Ictalurus melas* (Rafinesque) (Hoffman, 1967; Harms, 1959 and 1960), *Scaphirhynchus platorynchus* (Rafinesque) (Pearse, 1924), *Moxostoma anisurum* (Rafinesque) (Hoffman, 1967), and *Cyprinus carpio* Linnaeus (Hoffman, 1967; Pearse, 1924) and the turtle *Sternotherus odoratus* (Latreille) (Curry and Kennedy, 1975).

RESULTS AND DISCUSSION

Between May, 1973, and November, 1974, 28 adult and several young specimens of *Placobdella montifera* were recovered from the mantle cavities of eight species of fresh-water clams representing three subfamilies of unionids (taxonomy according to Ortmann 1910, 1911 and 1912): Anodontinae, *Anodonta grandis* Say; Unioninae, *Fusconaia undata* (Barnes) and *Quadrula pustulosa* (Lea); and Lampsilinae, *Glebula rotundata* Lamarck, *Lampsilis teres* (Rafinesque), *L. ovata* (Say), *Obliquaria reflexa* Rafinesque and *Proptera purpurata* (Lamarck). The host clams were collected from a lake in southwestern Louisiana and/or from one or more of 11 sluggish streams (bayous) from north central to southwestern Louisiana. Approximately 2,300 clams were examined during this study.

The morphology of the leeches is identical to that of free-living *Placobdella montifera* collected from other southern Louisiana bayous. The morphology is, also, consistent with that described by Sawyer (1972) for the species. Relaxed leeches ranged in length from 1.0 mm to 20.0 mm and from less than 1.0 mm to 6.0 mm in width.

No leeches were observed feeding, and there appeared to be no morphological specialization for feeding. However, there may be a physiological specialization which would indicate a trophic rather than the presently suggested protective relationship. As in the cases of other symbiotic associations not fully understood, final explanations must be preceded by careful feeding observations and/or detailed digestive tract analyses.

No more than five adult leeches were found within the mantle cavity of a single clam *(Lampsilis teres)*, although as many as 11 juveniles (1.0-2.0 mm long) and one adult (9.0 mm long) were encountered in a single clam *(Glebula rotundata)*. Fuller (1974) indicated that "although leech populations can reach epidemic proportions, these animals seem to pose no threat to mussels."

One specimen of *Placobdella montifera* occurred with 12 water mites (*Unionicola* spp., Acarina: Trombidiformes: Unionicolidae) in *Anodonta grandis*. *P. montifera* occurred with two species of *Unionicola*, and the aspidogastrid trematodes (Platyhelminthes: Trematoda: Aspidogastridae), *Aspidogaster conchicola* Baer and *Cotylaspis insignis* Leidy, also, in two specimens of *Lampsilis teres*. In one specimen of *Proptera purpurata*, 229 specimens of *A. conchicola* and 57 unionicolids (*Unionicola* spp.) occurred with *P. montifera*. Unionicolids and aspidogastrid trematodes are frequently encountered parasitizing freshwater clams in central and southwestern Louisiana (Vidrine, 1973 and 1974).

Host records and collection data are as follow:

Lampsilis teres—Evangeline Parish: Bayou Marron at Louisiana Highway 95, 2 miles northwest of Chataignier, southeast of Mamou (18 May 1973); Bayou des Cannes at La. Hwy. 10 (19 May 1973). Acadia Parish: Mamou Irrigation Canal at La. Hwys. 97 and 368 junction (1 September 1973).

Lampsilis ovata—Allen Parish: Calcasieu River, 10 mi. north of Oberlin (4 June 1973).

Glebula rotundata—St. Landry Parish: Bayou Wauksha at La. Hwy. 10 (17 November 1973). St. Martin Parish: Lake Palourde near Grassy Lake (25 August 1973).

Anodonta grandis—Avoyelles and Rapides Parishes: parish line, Big Creek at La. Hwy. 115 (7 October 1973). Iberville Parish: Bayou Maringouin, 2 mi. south of Ramah (23 November 1974). Evangeline Parish: Bayou Grand Louis, La. Hwys. 13 and 104 junction at Mamou (19 May 1973). Natchitoches Parish: Cane River at La. Hwy. 1 near Derry (22 August 1974).

Quadrula pustulosa—Evangeline and St. Landry Parishes: parish line, Bayou Grand Louis at U. S. Hwy. 167 (4 July 1973).

Fusconaia undata—St. Landry Parish: Bayou Carron at La. Hwy. 182 (17 November 1973).

Proptera purpurata—Evangeline Parish: Bayou Marron at La. Hwy. 95 (18 May 1973).

Obliquaria reflexa—Natchitoches and Red River Parishes: parish line, Bayou Pierre at La. Hwy. 174 (22 August 1974).

This study confirms the claim of Fuller (1974) that there is no host specificity exhibited by *Placobdella montifera* for clams. Although Fuller (1974) indicated that the leech-clam relationship is "more common in lentic situations", this investigation indicates that the leech (*P. montifera*)-clam relationship in Louisiana is more frequently encountered in bayous (than in lakes), which often maintain a steady, but slow, current which increases significantly following periods of intense rainfall, which are common in southern Louisiana.

We suggest that, because leeches seek relatively smooth substrates, such as the exterior of a clam shell, they are likely to haphazardly move inside the shell while it is agape. This suggestion seems to be supported by the infrequency (21 of some 2,300 clams contained leeches) of the leech (*Placobdella montifera*)-clam relationship in Louisiana.

Voucher specimens of each species of clam mentioned in this manuscript are on deposit in the Delaware Museum of Natural History, Greenville, Delaware. The leeches are in the private collection of the senior author in Metairie, Louisiana. The junior author collected and identified the clams.

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EUBRANCHUS TRICOLOR FORBES IN THE WESTERN ATLANTIC

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ABSTRACT

The aeolid nudibranch Eubranchus tricolor *Forbes, 1838, is reported for the first time in the western Atlantic. Specimens have been collected from the northern Gulf of Maine. The morphology and ecology of* E. tricolor *are discussed and related to information available on several other* Eubranchus *species.*

INTRODUCTION

Eubranchus tricolor was originally described by Forbes (1838) from a specimen dredged from 20 fathoms off Ballough, England, and has been reported a number of times from around Great Britain (Adler and Hancock, 1945; Jeffries, 1869; Garstang, 1890; Colgan, 1914; Miller, 1961; Edmunds and Kress, 1969). It has also been collected from the North Sea (Walton, 1908), the western coast of Norway (Friele and Hansen, 1876; Sars, 1878), the White Sea (Roginskaya, 1962) and the northern coast of France (Vayssière, 1913). Edmunds and Kress (1969) listed the reported occurrences of *Eubranchus tricolor* and its synonyms in their paper on the European species of *Eubranchus.* They discussed the problems earlier workers had in clarifying the taxonomic status of closely related species. Their careful description of *E. tricolor* clearly distinguishes it from two similar species, *E. pallidus* (Alder and Hancock, 1842) and *E. farrani* (Alder and Hancock, 1844).

The ecology of *Eubranchus tricolor* is poorly known. In European waters *E. tricolor* has been collected in the shallow subtidal (Garstang, 1890) and to a depth of 50 to 100 fathoms (Walton, 1908). In summarizing depth distribution records, Edmunds and Kress (1969) stated that *E. tricolor* is most commonly found offshore from depths of 16 to 60 m on shell gravel and stony deposits. Garstang (1890) reported finding *E. tricolor* on the hydroid *Obelia geniculata* (Linnaeus, 1758), although as Edmunds and Kress (1969) pointed out, Garstang did not distinguish *E. farrani* from *E. tricolor.* Miller (1961) concluded that *E. tricolor* feeds on hydroids because it was found in dredge hauls along with *Tubularia indivisa* Linnaeus, 1767, *Abietinaria abietina* (Linnaeus, 1758), *Hydrallmania falcata* (Linnaeus, 1758), and *Nemertesia antennina* (Linnaeus, 1767).

Gosner (1971) listed *Eubranchus tricolor* as occurring along the eastern coast of the United States. He was actually referring to the *E. pallidus* reported in New England waters by Gould and Binney (1870), Johnson (1915, 1934) and Moore (1964), but based his classification of *E. tricolor* on the systematic scheme used by Pruvot-Fol (1954) who listed *E. pallidus* as being a variety of *E. tricolor* (Gosner, 1974, personal communication). Edmunds and Kress (1969), however, considered *E. pallidus* to be a separate species. Four specimens of *E. tricolor* recently have been collected intertidally and subtidally in the vicinity of Eastport, Maine, and the purpose of this note is to report information obtained from these specimens.

MORPHOLOGICAL OBSERVATIONS

The morphology of the four specimens collected was consistent with that described for *Eubranchus tricolor* by Edmunds and Kress (1969). The body was translucent white to greyish white in color. The relatively numerous cerata were arranged in indistinct clusters, and were of the same color as the body. There were 52 cerata in a 6 mm specimen and 86 cerata in a 19 mm specimen. The larger cerata were inflated and anterior-posteriorly compressed. A band of white pigmentation surrounded the region of the cnidosacs. The liver diverticula were smooth and cylindrical

FIG. 1. *Camera lucida drawings of a jaw and its masticatory margin of* Eubranchus tricolor. *Scale equals 0.1 mm.*

and appeared reddish-brown in color. The acleioproctic anus was in the interhepatic space to the right and just posterior to the heart.

The large jaws possessed a single row of distinct denticles on the projecting masticatory border (Figure 1). The triseriate radulae contained 49 rows in a 7 mm specimen and 64 rows in a 17 mm animal. The rachidian tooth had a prominent central cusp and 3 to 4 denticles along each side (Figure 2). The broad lateral teeth had a sharply pointed cusp, and a width to height ratio of almost 2.5:1.

The gonopore was found on the right side ventral to the middle of the first cluster of cerata. The reproductive systems of two specimens were dissected, and neither contained a penial stylet. *Eubranchus farrani* and *E. pallidus* possess a penial stylet whereas the penis of *E. tricolor* is unarmed (Edmunds and Kress, 1969). A single egg ribbon was deposited in the laboratory in a counterclockwise coil. It was a tall collar very similar to that pictured for *E. farrani* by Alder and Hancock (1845).

ECOLOGICAL OBSERVATIONS

On May 5, 1973 a specimen of *Eubranchus tricolor* 19 mm in length was collected using SCUBA at 15 m about 200 m south of the breakwater in Eastport, Maine (44° 54′ N 66° 59′ W). The bottom in this area consisted of small rock and cobble with occasional protruding rock ledges. The area was heavily grazed by the sea urchin *Strongylocentrotus droebachiensis* (Müller, 1776) and was relatively devoid of algae except for conspicuous clumps of red algae on the larger rocks and ledges. These clumps contained several hydroid species, the most obvious being *Tubularia spectabilis* (Agassiz, 1862). This specimen of *E. tricolor* was collected near the base of one of these clumps. The nudibranch was maintained in a recirculating sea water system at the University of New Hampshire where it was observed feeding on *T. spectabilis*. No other hydroids were offered to the nudibranch.

Two other specimens of *E. tricolor* have subsequently been collected from the same area in Eastport. A nudibranch 17 mm long was collected on June 2, 1973 at a depth of 12 m. This individual was crawling over the cobble bottom apart from any large clumps of hydroids. On November 1, 1974 a third individual 7 mm long was found at about 15 m near a clump of *Abietinaria* sp.

A single individual 6 mm in length was collected at Wilbur's Neck in Dennys Bay, Maine (44° 53′ N 67° 9′ W) from a large deep tidepool near the low tide mark on a blade of the brown alga *Laminaria saccharina* (Linnaeus) Lamouroux. The dominant hydroid in this tide pool was *Dynamena (Sertularia) pumila* (Linnaeus, 1758) growing on *Ascophyllum nodosum* (Linnaeus) LeJolis.

The two smaller individuals were collected in the fall and the others in the spring and early summer, suggesting that *Eubranchus tricolor* may have an annual life cycle. Miller (1962), however, felt that *E. tricolor* had two or more generations per year but with a life span of 8-12 months.

Eubranchus tricolor has not been observed along the New Hampshire-southern Maine coastline despite extensive observations in these areas. Two other species of *Eubranchus* are found in New England waters, *E. pallidus* and *E. exiguus* (Alder and Hancock, 1848) (Moore, 1964; and personal observations). Meyer (1971) reported finding *Eubranchus olivaceus* (O'Donoghue, 1922)

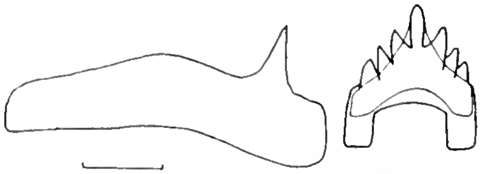

FIG. 2. *Camera lucida drawings of a rachidian and lateral tooth of* Eubranchus tricolor. *Scale equals 0.05 mm.*

in Maine waters, a nudibranch previously reported only from the West Coast of North America. Her description of *E. olivaceus* fits that of *E. exiguus* given by Edmunds and Kress (1969). It is likely that she had found *E. exiguus* and not *E. olivaceus*.

A specimen of *E. tricolor* has been deposited at the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.

ACKNOWLEDGEMENTS

We would like to express our appreciation to Terrence M. Gosliner, Frank Perron and Alan M. Kuzirian for their assistance in searching for *Eubranchus tricolor*, and to Mary-Jane Rivest and Claudia Foret for their assistance in the preparation of the manuscript.

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WILLIAM SEWARD TEATOR (1860-1930)

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It was through our Red Hook Bicentennial Committee that I heard of William S. Teator. Many of the land and freshwater snails that he collected locally had been stored in one of the Red Hook schools. They were turned over to the Committee as being of possible interest because he was a native. Since there was no one with any interest in shells but myself, I have had the exciting privilege of examining them, reading his fascinating collecting notes made during 1890, perusing letters he received and speaking with folks who knew him.

William Seward Teator was born in Upper Red Hook, New York on April 28, 1860. He was named for William H. Seward because of his family's strong Republican leanings. He grew up on a farm and must have, at an early age, become aware of all the various manifestations of life about him. He knew the names of the trees, wild flowers, birds, the kinds of soil and rocks with which he came in contact. He was full of wonder with the ways of nature. In his notes of June 5, 1890, he says, "In *Almont Woods* myriads of snails in all stages of development—two or three very sultry and rainy days have sent them all out doors--and on each log are 15 to 50 perfect specimens—wonderful where they all come from!" On June 20, 1890 he writes, "I planted 28 specimens of *Helix clausa [Mesodon clausus (Say)]* in *Almont Woods* sent me from Connersville, Indiana by Thos. F. Curry—they were young, vigorous snails. I placed them alongside of some old rails of a decaying fence—some old logs near by and a thick growth of weeds—Solomon's seal, sassafras and blood root and sweet cicely." On July 26, 1890 he visited a region north of Elizaville on the Roeliff Jansen Kill. He puts in his notes, "... discovered a colony of *Helix fuliginosus [Mesomphix cupreus* Rafinesque*]* the most flourishing I have ever met with—obtained 40 perfect and very pretty examples alive—did not take immature shells. The locality is a steep wooded hillside with gravel, debris of the glacial era, well covered with small stones and years accumulations of litter from trees, oak, elm, ash, hemlock etc. The place where the snails are most abundant is a small section of a terraced slope that a little further along forms the bank of the river, also found some *palliata [Triodopsis notata* Deshayes*]* and *concava [Haplotrema concavum* Say*]* and *alternata [Anguispira alternata* Say*]* and *tridentata [Triodopsis tridentata* Say*]*."

In his early manhood he became private to General J. Watts de Peyster of Tivoli, New York. General de Peyster (1821-1884) was an Honorary Fellow of the Society of Science, Letters and Arts of London, 1893, and a well-known author on Swedish-American history. He was awarded their Gold Medal of 1894 "for Scientific and Literary Attainments." The general took a keen interest in Teator. In 1889 he wrote to Major

FIG. 1. *William Seward Teator* (1860-1930), a formal portrait taken about 1890.

View of the Catskill Mountains from the Heights East of Upper Red Hook, Drawn by William S. Teator.

EXECUTED BY N. Y. ENGRAVING CO. FOR GENERAL J. WATTS DE PEYSTER

General John H. Ketcham and in 1890 to M. Saunders, United States Senator from Montana, to ask their help and influence in obtaining a position for Teator "in the Government employ to do work in connection with explorations which requires drawing and Commitment to paper. He is a fine looking fellow, healthy, strong, active, enured to toil. He would repay the Government by service far beyond any meager salary that the Government pays its servants..." I have found no evidence that these efforts ever succeeded.

We do know that Mr. Teator's own efforts did succeed. When he took over the old homestead he, through painstaking cultivation, became a very respected farmer. He shared his knowledge with others by describing his methods. He became an apple orchardist who won many blue ribbons here and abroad. The *Rural New Yorker* of October 18, 1930, says in part, "To him the tree was more than a stock of wood with branches and leaves—a means to an end. It was a living, breathing, sensitive thing that could appreciate a kindness and feel a hurt." This statement of Burton Coon's can be expanded to encompass all the living things with which Teator came in contact. Like the true naturalist he was, he respected all life and admired and was aware of even the most minute of the biota.

Teator published three articles on land and freshwater shells of New York in *The Nautilus* (all in volume 3, 1889-1890). He was an accomplished artist and the accompanying sketch by him shows the areas where he collected (about 1890.) His main collection of mollusks will be housed in the Delaware Museum of Natural History.

He passed away on August 17, 1930. In the 70 years of a life of active and time-consuming farming, he found time to stop, look and listen. He left us a legacy consisting of a very carefully labeled collection of all the land and freshwater mollusks to be found in his collecting vicinity.

ABNORMAL SHELLS OF *GYRAULUS PARVUS* (PLANORBIDAE)

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ABSTRACT

Two similar, malformed shells of Gyraulus parvus *(Say) are reported from the Connecticut River system in Massachusetts. Each has a prolonged body whorl that is extended obliquely downward, terminating beneath itself. A species described by F. C. Baker (1932) approaches the above but a paratype examined by Clarke (1973) was determined to be a repaired specimen. Present specimens do not show repair, suggesting mutational or pathogenetic growth.*

Shell abnormality in gastropods is a rarely observed phenomenon as indicated by the scarcity of literature citations. Instances mentioned usually involve regeneration or the occurrence of oppositely coiled specimens.

Recent intensive surveying of the aquatic mollusks in the central Connecticut River watershed has yielded two malformed but similar specimens of *Gyraulus parvus*. Both were collected in Massachusetts, the first on 18 June 1973 in the Mill River, Hampshire Co., Williamsburg (Fig. 1a), and the second on 19 May 1975 in the Connecticut River Oxbow, Hampshire Co., Northampton (Fig. 1b). Each specimen is characterized by a continuation of the body whorl downward and beneath itself. The subsequent prolongation of the body whorl presents a stacked appearance when viewed frontally (Fig. 1).

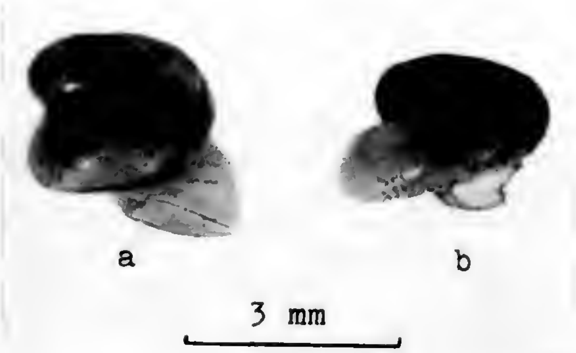

FIG. 1. *Two deformed* Gyraulus parvus *(Say) from Hampshire County, Massachusetts.*

F. C. Baker (1932:9) based his description of *G. latistomus* on the abrupt downward deflection of the apertural region, suggestive of the condition occurring in present specimens. However Clarke (1973:403), after examining a paratype of Baker's species, considered the deflected aperture to be the result of repaired damage. The Connecticut River shells show no evidence of repair indicating a pathogenetic or mutational growth. The specimens are deposited in the Museum of Zoology, University of Massachusetts at Amherst.

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SINISTRAL SPECIMENS OF *OLIVELLA*, *PRUNUM*, AND *GRANULINA* FROM THE PLIOCENE OF VIRGINIA AND NORTH CAROLINA

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In the course of the 1974 summer field season we discovered sinistral specimens of *Olivella mutica* (Say, 1822), *Prunum bellum* (Conrad, 1868), (one specimen each), and *Granulina amiantula* (Dall, 1890) (two specimens), from Pliocene deposits in North Carolina and Virginia. We believe this is the first such record for each species and the first report of sinistral abnormalities in the American Tertiary.

Our specimen of *Olivella mutica* measures 7.0 mm in height, 3.2 mm in width, and has an aperture height of 4.2 mm. The specimen is unbroken, retains a high gloss, and has a faint spiral color band on the body whorl. The specimen was discovered on spoil piles from the marina under construction by Carolina Shores, Incorporated, near Calabash, North Carolina. Age of the specimen is upper Pliocene (Waccamaw Formation).

Our specimen of *Prunum bellum* measures 6.1 mm in height, 2.9 mm in width, and has an aperture height of 4.8 mm. It is juvenile and the lip is somewhat chipped, but otherwise preservation is quite good. The specimen was discovered in place in the lowest bed exposed at Carolina Shores, Incorporated (see above).

FIG. 1. Olivella mutica *from Calabash, North Carolina. Left. Dextral specimen, 6.5 mm in height. Right. Sinistral specimen, 7.0 mm in height.*

Our figured specimen of *Granulina amiantula* measures 2.8 mm in height, 1.8 mm in width, and has an aperture height of 2.5 mm. The second specimen measures slightly larger. Both were found in place in the Lone Star Cement Company pits north of Chuckatuck, Virginia, (uppermost bed, west wall). Age of the specimens is Middle Pliocene (upper Yorktown Formation).

Dautzenberg (1914: 58) reported one recent and two fossil *Olivella* species, all European, for which sinistral specimens had been discovered. However, we have been able to discover no subsequent sinistral records for the genus.

FIG. 2. Granulina amiantula *from Chuckatuck, Virginia. Left. Sinistral specimen, 2.8 mm in height. Right. Dextral specimen, 3.1 mm in height.*

Dautzenberg (1914: 58) cited fourteen recent and three fossil species of *Marginella* for which sinistral individuals had been discovered. Many of these species have subsequently been assigned to other genera within the *Marginellidae.* The specimens described here thus become the second species of *Prunum* and *Granulina* to be reported sinistral, the first being *P. apicina* (Menke, 1828) from the recent of North Carolina to the Caribbean, and *G. clandestina* (Brocchi, 1814) from the

FIG. 3. Prunum bellum *from Calabash, North Carolina. Left Dextral adult, 8.2 mm in height. Middle. Sinistral juvenile, 6.1 mm in height. Right. Dextral juvenile, 6.5 mm in height.*

Mediterranean (Dautzenberg, *op. cit.*). Considering the propensity of marginellids to generate sinistral individuals, our new records are not surprising. Sinistral specimens of *P. apicina* are not uncommon, and sinistral *Granulina*, though exceedingly rare, are undoubtedly overlooked due to their small size. The figured specimens are in the author's collection.

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LAND SNAILS FROM MONITO ISLAND, WEST INDIES

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Monito Island is a small limestone island approximately a half square kilometer in area and adjacent to Mona Island in the Mona Passage between Hispaniola and Puerto Rico. Monito lies about 5 km northwest of Mona and the two islands are separated by a depth of only about 240 m. Monito is bordered on all sides by precipitous cliffs which rise 35 m or more above the surrounding sea and is virtually accessible only by helicopter. The ground surface is rugged and pitted and is covered with xeric scrub vegetation that seldom exceeds 2 m in height. Because of the proximity of Monito to Mona I anticipated prior to my visit that the land snail fauna of the two islands would be similar (for a report on the land snails of Mona Island see W. J. Clench, 1951, Journal de Conchyliologie, **90:** 269-276).

On May 20, 1974, through the courtesy of the United States Coast Guard, I had the opportunity to visit Monito for 24 hours, during which time I devoted nearly all of my attention to collecting mollusks, reptiles and amphibians. The following land snails were collected, and are deposited in the Florida State Museum.

Lucidella umbonata (Shuttleworth)
Gastrocopta pellucida (Pfeiffer)
Hojeda inaguensis (Shuttleworth)

It is particularly noteworthy that larger species of land snails were not found. Six other genera, *Cerion*, *Drymaeus*, *Brachypodella*, *Hemitrochus*, *Plagioptycha* and *Chonodropoma*, were anticipated but there was no evidence of these on the island, not even dead shells or fragments. The six genera not encountered are entities that would be expected on the island for biogeographic reasons. They occur on other small islands in the area. The island is ecologically suitable for them. The island is close to other islands which could serve as founder sources, and the island is in the center of a hurricane tract, which almost guarantees adventitious dispersal of some land snails.

Members of these six genera are non-secretive. They are active on exposed surfaces and they aestivate on exposed plants and rocks. I postulate that their absence is due to predation by introduced rats. The island is infested with *Rattus rattus*, which readily devours land snails in other places where this rodent occurs. (Most of the specimens of *L. umbonata* found were gnawed shells.) I suspect that the absence of the larger land snails on Monito Island is a consequence of rat predation and is not a reflection of an originally prehuman depauperate fauna.

NOTICES

1977 Amsterdam Meeting

The Sixth European Malacological Congress of the UNITAS MALACOLOGICA EUROPAEA will be held in the week 15-20 August, 1977, in the Free University, Amsterdam. Under the auspices of Dr. Vera Fretter (U.K.), Dr. A. Riedel (Poland), Dr. K. M. Wilbur (U.S.A.), Dr. J. Lever and Dr. C. P. Raven (both from the Netherlands). All malacologists, whether in a professional capacity or not, are invited to attend the Amsterdam congress. For further information write to Sixth European Malacological Congress, c/o Congresbureau van de Vrije Universiteit, De Boelelaan 1105, Amsterdam, Holland.

W.S.M. 1977 Meeting

The tenth annual meeting of the Western Society of Malacologists will be held June 15 to June 18, 1977, at Kellogg West, Center For Continuing Education, California State Polytechnic University, Pomona, California. Inquiries about the meeting should be directed to Mrs. Jo Ramsaran, Secretary, 807 North Road, San Bernardino, Ca. 92404.

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Hastings, Louise B. 1976. Index to the Taxonomic Names in Edwin A. Joyce, Jr., 1972. A partial Bibliography of Oysters, with Annotations. Florida Dept. Natural Resources, St. Petersburg. Pamphlet, 40 pp. Available from Delaware Museum of Natural History, Box 3937, Greenville, De. 19807, by sending 3 13-cent postage stamps.

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We regret to announce the death of Allyn G. Smith, August 18, 1976, at the age of 83, in California. An obituary will appear in a later issue. He is survived by his wife, Isabel, 722 Santa Barbara Rd., Berkeley, Ca. 94707, to whom sympathies are extended.

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