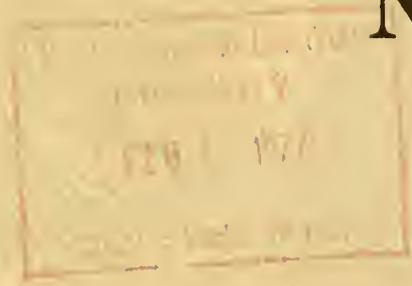


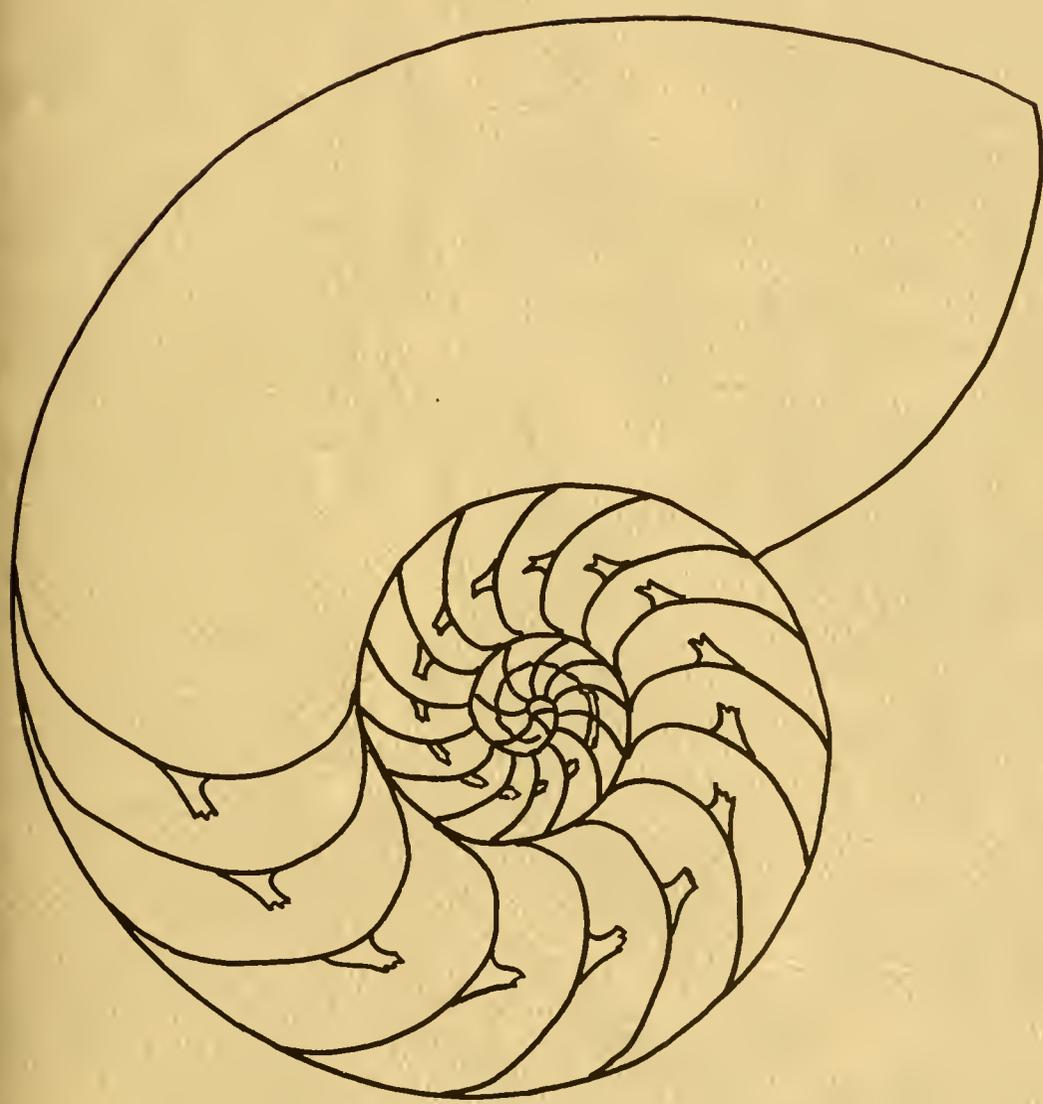
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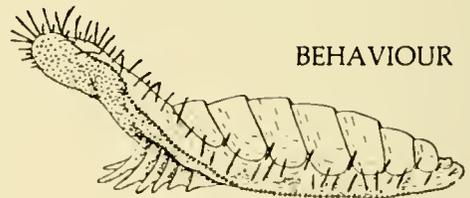
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GEOGRAPHICAL RANGE OF *PRATICOLELLA GRISEOLA* (POLYGYRIDAE)
CORRECTION AND ANALYSIS

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ABSTRACT

The geographical range of Praticolella griseola (Pfeiffer) in Texas and Mexico is discussed; erroneous but published collecting sites are discussed. The climatic causes of the discontinuity of geographic range of the species are discussed.

Three species of *Praticolella* von Martens (Polygyridae) occur in Texas: *pachyloma* (Menke), *berlandieriana* (Moricand) and *griseola* (Pfeiffer). Early records placed *griseola* over much of southern and central Texas; these records were later corrected only to be subsequently republished. In light of the reoccurrence of this misinformation, all literature records are reconsidered and the geographical range of *griseola* is re-evaluated. Mexican and Central American records of this species are also discussed.

Confusion of the range of *griseola* is no doubt due to a lack of definite phenotypic breaking points between *griseola* and *berlandieriana* even though the classic types are quite different. Some workers have felt that these two species definitely blend together (von Martens 1892; Singley 1893) while others such as Pilsbry (1940:695) felt that there were "no common links" between them. Genitalia of *berlandieriana* and *griseola* are similar but distinguishable (Webb 1967). A definitive solution to the taxonomic problem will be difficult to obtain and may be impossible due to contemporary habitat destruction. Adding to the complexity is the possibility of hybridization involving all three species in southern Texas (Hubricht 1961; in Cheatum and Fullington 1971).

The first published records of *P. griseola* that I have found are those of Binney (1885:394) for Calhoun (at Indianola) and Bosque Counties. Townsend (1897) reported it on the "lower Rio Grande." Pilsbry (1940:690-692) completely discounted the Bosque County record and doubted the Indianola record. *P. griseola* is native in

neither county. Pilsbry gave the range of *griseola* as "environs of Brownsville" which is in Cameron County.

In the first synthesis of Texas molluscan records, J. A. Singley (1893) reported *griseola* from the following counties: Caldwell, Cameron, Duval, Gillespie, Goliad, Gonzales, Kendall, Milam (from Askew); Lampasas (from Mrs. Sinks); Williamson (from Walker); Bexar, Comal, Hays, Travis (Strecker's personal records).

In the next compilation of Texas snail records, J. K. Strecker (1935) reported specimens in his collection from Cameron and Hidalgo Counties. He stated that "all other counties Singley mentions for *P. griseola* are no doubt based on *P. berlandieriana*" except Duval County. No reason was given for acceptance of the Duval County record.

The latest compilation of Texas polygyrid snail records (Cheatum & Fullington 1971) re-publishes the suspect records of Singley with no mention of the intervening correction by Strecker. No mention is made, however, of the records of Binney. Significantly, all post-Singley records listed by Cheatum and Fullington come from Cameron and Hidalgo Counties in south Texas along the Rio Grande River.

Thus, we are left with positive records for only two counties for *griseola* in Texas. Personal collecting in most of the central Texas counties has revealed no populations of *griseola*. I have personal records from Brownsville (southern Cameron County) and Laguna Atascosa Wildlife Refuge (northeastern Cameron County). Webb

(1967) worked with *griseola* collected at Harlingen (central Cameron County) by J. Campbell. Such a restricted Texas range for land snails is not unique, as *Euglandina texasiana* (Pfeiffer) and *Thysanophora plagiopycha* (Shuttleworth) exhibit similar distributions. These snails in Texas are restricted to soils of the modern delta of the Rio Grande River which includes southern and eastern Hidalgo County, all of Cameron County and most of Willacy County. Shells of *griseola* have not yet been reported from Willacy County although the Laguna Atascosa locality is no more than thirteen kilometers from the Cameron-Willacy county line. Shells collected by Ideker in Willacy County in 1974 included no definite *griseola* shells although some *berlandieriana* shells from this area may indicate introgression with *griseola*. Populations of *griseola* are to be expected in southern Willacy County.

The south Texas populations of *griseola* are isolated from Mexican populations (except for those in the southern Rio Grande delta) which occur no further north than the Tampico area at the border between Vera Cruz and Tamaulipas. Other populations occur at scattered localities in northern Yucatan, Guatemala and Nicaragua (Rehder 1966).

Other populations have resulted from introductions. McLellan (1950) reported *griseola* (could it have been *berlandieriana*?) to be abundant in his yard and adjacent lots in Bellaire, Harris County, Texas. Other adventive populations include Cuba (probably from Vera Cruz) and Key West, possibly from Cuba (Pilsbry 1940:642).

The disjunction of populations of *griseola* is similar to the dry lowland tropical Gulf Arc distribution as exhibited by several species of reptiles and amphibians (Martin 1958:92-94). Herptile migration between these areas may have occurred via a dry corridor through presently wet tropical woodland areas at some time in the Pleistocene. The occurrence of the Texas populations of *griseola* indicates a northward extension of its normal range. At some time in the recent past *griseola* apparently existed over large areas of coastal Central America, Mexico and (at least southern) Texas.

Environmental change may have resulted in widespread extinction of *griseola*, with survival

occurring only in a few scattered refugia. The restriction of *griseola* in Texas to the relatively mesic deltaic soils of the Rio Grande River indicates that increased aridity was the environmental factor involved. The area between the Rio Grande delta and the Panuco River floodplain (Tampico area) contains only one significant drainage system. The floodplain of the Rio Soto La Marina in Tamaulipas should be examined for populations of *griseola*. Although the entire area is arid, these rivers provide suitable moisture as a result of periodic flooding. The decline of *griseola* may have been accompanied by an expansion of *berlandieriana*, as the latter species occurs (possibly sparingly) in the area between the Rio Grande River and Rio Soto La Marina (Rehder 1966). A similar range disjunction in northeastern Mexico is exhibited by the Texas pocket gopher (Selander et al. 1962).

The second break is apparently not due to aridity. On the contrary, the break below Vera Cruz may result from excess moisture in the humid forest of the Campeche Lowlands. This area exhibits higher temperature, rainfall and humidity levels than either bordering area which contains *griseola* (Vivo E. 1964). Competition from tropical snail species specifically adapted to warm, moist habitats may exclude *griseola*.

Much additional field work on geographic and habitat distribution of *griseola* is needed before a definitive answer to the reasons for range fragmentation and existence of particular refugia. It is difficult at best to correlate the distributions of organisms with compilations of environmental data from the literature. The refugia of *griseola* apparently represent areas of varied vegetation, geological and climatic regimes (Leopold 1950; Wagner 1964; West 1964; Vivo E. 1964). Alternate wet-dry cycles could be important because Webb (1967) indicated such conditions were necessary for the culture of both *griseola* and *berlandieriana*.

Fragmentation of the species range of *griseola* would be favorable for genetic differentiation between refugia. This has, apparently, occurred as Rehder (1966) reported "*P. griseola* consists of a number of more or less well-characterized races" which he based on shell characters.

One additional factor may be involved in the spotty distribution of *griseola*. A number of workers have suggested that *griseola* is not native to Yucatan and Guatemala (Bequaert & Clench 1936; Harry 1950). All Guatemalan material (see Goodrich & van der Schalie 1957) was probably collected within a 20 km radius of each other according to Harry (1950); furthermore all Yucatan material collected by Harry (1950) definitely was from such a small area. These two centers of distribution are about 500 km apart. In these areas *griseola* is found exclusively in sites with orchards, railroad embankments, urban areas and savannahs managed for cattle grazing (see Bequaert & Clench 1933; Goodrich & van der Schalie 1937). Basch (1959) did not find *griseola* in Tikal National Park, Guatemala. Other workers failed to find *griseola* when collecting in various parts of Guatemala and the Yucatan (Hinkley 1920; Pilsbry 1891; van der Schalie 1940). Stating that *griseola* is a species of open, rather than forested areas, Branson & McCoy (1963) felt that "man may augment the distribution of this form by his clearing activities, rather than actually transporting it to new localities."

Time and source of these putative introductions into these southern areas are unknown. The existence of noticeable phenotypic types or "races" in the various areas of occurrence indicates the possibility of early introduction (pre-Conquest). Mayan and pre-Mayan settlements have existed in this area for centuries. Introduction of a limited stock (founder effect) and/or natural selection for individuals better adapted to local conditions would result in such genetic differentiation. The most likely source would be the Tampico-Vera Cruz populations, simply because of its close proximity. Branson & McCoy (1965) reported that specimens from Campeche were intermediate between Yucatan and Guatemalan material but closer to the Guatemalan specimens.

The possibility of these populations being introduced to southern Texas is a strong possibility. Although almost all areas of the southern tip of Texas have been cleared or overgrazed at some time in the past century, *griseola* does not appear to be particularly associated with human impact

areas. One would not expect a snail from tropical Mexico to flourish in natural habitats of subtropical Texas. Frosts occur in most years and hard freezes are not unknown. Additionally, long periods of dryness accompanied by high temperatures are common in this area. A number of foreign snails have become established in this area (Neck, R. W. 1976). These snails, however, are generally restricted to human-associated sites.

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GEOGRAPHIC RELATIONSHIP OF BENTHIC MARINE MOLLUSCS OF FLORIDA

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ABSTRACT

The geographic distributions of 1,137 species of benthic marine molluscs of Florida were analyzed. The number of Floridian endemics is 110, and those species not ranging north of Cape Hatteras is 159. The number of boreal or arctic species that range southward to Florida is only 42. Some species have migrated eastward to Florida along the Gulf Coast, and these number 158. The majority of Florida's benthic molluscs appear to have originated in the Caribbean region, and these species number 779 or 68.4 per cent of all the species analyzed.

The gastropods have a higher percentage of species endemic to Florida (12.7 per cent) as compared to only 3.6 per cent of all the species of pelecypods, and the pelecypods commonly have a higher percentage of geographically wide-ranging species than the gastropods.

Florida probably has the most diverse marine shallow-water molluscan fauna in the continental United States. Because of this, it has long been a favorite site for shell collectors, and the molluscs have been thoroughly described by malacologists. Certainly one of the reasons for the richness of this molluscan fauna is the fact that Florida is surrounded by warm shallow water, and the Florida Keys are less than two degrees north of the Tropic of Cancer. The powerful Florida Current sweeps between Cuba and the Florida Keys and can easily carry

planktonic larvae of Caribbean species northward from Florida to Cape Hatteras, North Carolina.

In order to show the close relationship of the Caribbean and Floridian molluscan faunas, the geographic distributions given in two molluscan faunal monographs were analyzed: Abbott's *American seashells* (second edition, 1974) and Warmke and Abbott's *Caribbean seashells* (1961). Only the distributions of the benthic gastropods (mainly prosobranchs), the pelecypods, the scaphopods, and the

polyplacophorans were studied. Species living at depths of 200 meters or more were largely eliminated because they commonly were known from only one or two dredging stations. The sample of molluscs analyzed included 750 species of gastropods, 335 species of pelecypods, 30 species of scaphopods, and 22 species of polyplacophorans. The total number of species analyzed was 1,137.

The derivation of Florida's benthic marine molluscan species can be summarized by grouping them into four categories of distribution: (1) species probably originating in Florida and Floridian endemics; (2) species expanding their range southward to Florida along the Atlantic Coast or those mainly of boreal or arctic origin; (3) species expanding their range eastward in the Gulf of Mexico to Florida; (4) species expanding their range northward to Florida from the Caribbean region. These are the categories shown in Table 1.

TABLE 1. *Derivation of the benthic molluscs of Florida.*

Region	No. of species	Per cent
Species originating in Florida or Floridian endemics.	159	14.0
Species migrating southward along the Atlantic Coast	42	3.7
Species migrating eastward along the Gulf of Mexico	158	13.9
Species migrating northward from the Caribbean region	778	68.4
Total	1,137	100.0

The number of endemic species, those confined to Florida, is 110. This comprises a surprising 9.7 per cent of all of the molluscs whose distributions were studied. Besides the species that are Floridian endemics, there are a few that are limited to the region extending from Florida to Cape Hatteras. Most of these probably originated in Florida and have expanded their range northward. The number of species that have this limited geographic distribution is 49, or only 4.3 per cent of all of the molluscan species studied. If one combines the number of Floridian endemic species with those that have a limited range from Florida to

no farther north than Cape Hatteras, the percentage of the total fauna in these two classes is 14 per cent.

The number of boreal or arctic species that also live in Florida, commonly in moderately deep water, is only 42, or 3.7 per cent of the total benthic fauna. Most of these species range as far north as New England and eastern Canada and some even have a circum-boreal and arctic distribution. Some of these boreal and arctic species that reach Florida are *Solemya velum* Say, *Nucula proxima* Say, *Nuculana acuta* (Conrad), *Limopsis cristata* Jeffreys, *Limopsis minuta* Philippi, *Argopecten irradians* (Lamarck), *Limatula subauriculata* (Montagu), *Astarte crenata subequilatera* Sowerby, *Thyasira trisinuata* Orbigny, *Hiatella arctica* (Linné), *Calliostoma bairdii* Verrill and Smith, *Crepidula fornicata* (Linne), *Urosalpinx cinerea* (Say), *Anachis lafresnayi* (Fischer and Bernardi), and *Ilyanassa obsoleta* (Say).

Some of Florida's molluscs are probably immigrants from the Gulf Coast that migrated eastward into Floridian waters. The number of these species is 158 or 13.9 per cent of the total fauna analyzed.

The majority of the molluscs of Florida appear to have had a Caribbean or West Indian origin. These species number 779 or 68.4 per cent of all of the species studied. Many of these species range as far north as Cape Hatteras, but some are found only in the Florida Keys. Some of these Caribbean species range as far north as Cape Canaveral on the east coast of Florida, and a few live as far north on the west coast of Florida as Tampa Bay. The molluscan fauna of Florida has been enriched by many tropical genera from the West Indies such as: *Astraea*, *Nerita* (four species each), *Strombus* (five of six species), *Trivia* (seven species), *Cypraea* (five species), *Cassis* (three species), *Cymatium* (eleven species), *Tonna* (two species), *Bursa* (six species), *Mitra* (five species), *Arca* (two species), *Barbatia* (four species), *Isognomon* (three species), *Pinctada* (one species), *Spondylus* (two species), *Lima* (three species), *Chama* (six species), *Pseudochama* (one of two species), and *Asaphis* (one species). There are a few notable exceptions to the rule that

most genera and species originated in the West Indian area. One of these is the genus *Busycon*, with five species living in Florida, and none found in the Caribbean region proper. Other exceptions are *Dinocardium robustum* (Lightfoot) and *Scaphella junonia* (Lamarck).

Waller (1973, p. 32) states that the West Indian character of the molluscan fauna of Bermuda has long been known. Many species of molluscs of Caribbean origin are found in Florida and also Bermuda. It appears that almost all of the non-endemic molluscan species of Bermuda were derived from the Caribbean region. The distribution maps presented by Warmke and Abbott (1961) are most helpful in obtaining some idea of the distribution of the molluscs of Florida. These distribution maps clearly show that many of the benthic marine molluscan species came to Florida from the Caribbean region. For the Florida Keys and much of peninsular Florida, more than two thirds of the molluscan species came from the Caribbean area.

There are some striking differences in geographic distribution when one compares the ranges of the gastropods, pelecypods, scaphopods, and polyplacophorans with one another. There are at least two main factors that influence the differences among these four classes of molluscs. One is the type of substrate; whether the bottom consists of soft sediments, which is ideal for burrowing or infaunal animals, or whether the substrate is rocky, which is ideal for epifaunal animals. The other factor is the mode of reproduction. Are eggs and sperm simply released into the water and the eggs fertilized and followed by a long free-swimming larval stage as, for example, most pelecypods? Or is fertilization commonly internal and with a short free-swimming larval stage or none at all as, for example, in many gastropods?

The comparison of the scaphopod and polyplacophoran distributions is an example of

two groups that occupy different types of substrates. The polyplacophorans are found on a rock or hard shelly substrates or are epifaunal, whereas the scaphopods live partially buried in soft sediments, or are basically infaunal. In Table 4 one sees that five, or 16.7 per cent, of all scaphopod species appear to have migrated eastward into Florida along the Gulf Coast, but none of the polyplacophoran species has this distribution. Perhaps the lack of a rocky shoreline along much of the Gulf Coast has prevented species of polyplacophorans from moving eastward into Florida. As shown in Table 3, only one scaphopod species and no polyplacophorans appear to have a boreal or arctic origin. Table 2 shows that Floridian endemics are higher among the polyplacophorans. (two species or 9.1 per cent as compared to the scaphopods with one species or 3.3 per cent of thier total species. This higher rate of endemism among the polyplacophorans may be caused by the lack of a rocky shoreline in areas adjacent to Florida. The polyplacophorans have a higher percentage of species originating in Caribbean waters as compared to the scaphopods as shown in Table 5. However, these differences between the scaphopod and polyplacophoran distributions in the latter three instances may not be significant because of the small sample sizes in these two classes of molluscs.

TABLE 3. *Species migrating southward along the Atlantic Coast to Florida.*

Class	Size of sample	No. of species	Per cent
Gastropoda	750	20	2.7
Pelecypoda	335	21	6.3
Scaphopoda	30	1	3.3
Polyplacophora	22	0	0

TABLE 4. *Species migrating eastward along the Gulf of Mexico to Florida.*

Class	Size of sample	No. of species	Per cent
Gastropoda	750	95	12.7
Pelecypoda	335	58	17.3
Scaphopoda	30	5	16.7
Polyplacophora	22	0	0

TABLE 2. *Species endemic to Florida.*

Class	Size of sample	No. of species	Per cent
Gastropoda	750	95	12.7
Pelecypoda	335	12	3.6
Scaphopoda	30	1	3.3
Polyplacophora	22	2	9.1

The pelecypods have a higher percentage of infaunal species and also a higher percentage of species that have a free-swimming larval stage

TABLE 5. *Species migrating northward from the Caribbean region to Florida.*

Class	Size of Sample	No. of species	Per cent
Gastropoda	750	504	67.2
Pelecypoda	335	233	69.6
Scaphopoda	30	22	73.3
Polyplacophora	22	19	86.4

than the benthic gastropods. The latter factor is probably the main one as to why the gastropods have a much higher percentage than the pelecypods (12.7 per cent as compared to 3.6 per cent) of endemic species. This marked difference in endemic species is seen in Table 2. However, some of the apparent greater amount of endemism among the gastropods may be because there are many smaller-sized species of gastropods than pelecypods and because of this, their geographic distributions are less completely known. Some of the gastropod species that Abbott (1974) states are endemic to Florida are species of small size, 10.0 mm or less. This does not explain all of the difference in amount of endemism between the gastropods and the pelecypods, and it is generally true that the pelecypods in the Floridian fauna have a higher percentage of wide-ranging species than the gastropods. This comparison between the geographic distributions of benthic pelecypods and gastropods should be made in other regions to see if it holds true everywhere because of its significance to biostratigraphy.

The type of substrate is probably the main factor that causes pelecypods to have 17.3 per cent of their species migrating eastward along the Gulf Coast into Florida as compared to only 12.7 per cent of all of the species of gastropods. This difference is seen in Table 4. As seen in Table 3, the pelecypods also have a higher percentage of species of boreal or arctic origin, 6.3 as compared to 2.7 per cent among all gastropod species. The fact that a higher percentage of the pelecypods are infaunal as compared to the gastropods is probably the main factor because as Thorson (1957) has pointed out, the diversity of infaunal species increases little from the polar regions to the tropics, but the diversity of the epifaunal species increases greatly from the polar regions to the tropics. The percentage of pelecypod species and gastropod species migrating from the Caribbean region to Florida is nearly identical. This is shown in Table 5.

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GROWTH OF THE FINGERNAIL CLAM, *SPHAERIUM TRANSVERSUM* (SAY)
IN FIELD AND LABORATORY EXPERIMENTS¹William F. Gale^{2,3}Department of Zoology and Entomology
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ABSTRACT

Field and laboratory experiments on Pool 19 of the Mississippi River in summer and fall of 1967 revealed that S. transversum can complete its life cycle in about a month or less. In laboratory experiments, many newborn clams entered a resting state and did not grow for 33 days after they were born; later, some grew large. Medium-sized clams grew slowly but gave birth to young that often grew faster and larger than their parents. In field experiments, clams that were moved from an open-river site (where the clam population was high) to a retainer in a cove (where the population was low) grew faster and became larger than those remaining at the collection site; they also grew larger than clams in laboratory experiments.

Fingernail clams were abundant in Pool 19 of the Mississippi River during a 1966-68 survey of the benthos. Densities of *Sphaerium transversum* reached over 100,000/m² in some areas (Gale, 1969) in spite of heavy predation by leeches, fish, and waterfowl. In autumn of 1967, diving ducks harvested about 24% (2,085,125 kg) of September's standing crop of fingernail clams (Gale, 1973; Thompson, 1973). Life history data were collected in an effort to determine the cause of the clam's success. The objective in this study was to determine how fast *S. transversum* grows.

PROCEDURES

Growth experiments were conducted during the summer and fall of 1967. Laboratory experiments

were conducted in a field laboratory above Ft. Madison, Iowa (about 200 m upstream from the Ft. Madison/Niota bridge). Water pumped from near the river channel into the laboratory kept temperatures and chemical conditions similar to those in the river and provided clams with food.

Clams were housed in individual plexiglass rearing chambers, 3.8 cm square and 5.0 cm deep inside (Fig. 1, A); the upper 3.3 cm of the chambers were covered on two sides with plastic screen (mesh with 12 openings/cm) for water passage. A set of nine rearing chambers was placed in each of nine painted plywood compartments (Fig. 1, B). A 5-cm baffle kept water levels about 6 mm below the top of the rearing chambers. Clams could not escape or move between chambers without crawling out of the water.

Each rearing chamber contained about 10 cc of strained clayey silt from the river bottom where experimental clams were collected. Water in the chambers was initially 3.5 cm deep but decreased to about 2.5 cm as chambers silted in. Compartments holding the chambers had a maximum flush rate of 6 minutes; fluctuating pump discharge and partial clogging of distribution tubing reduced flushing rate.

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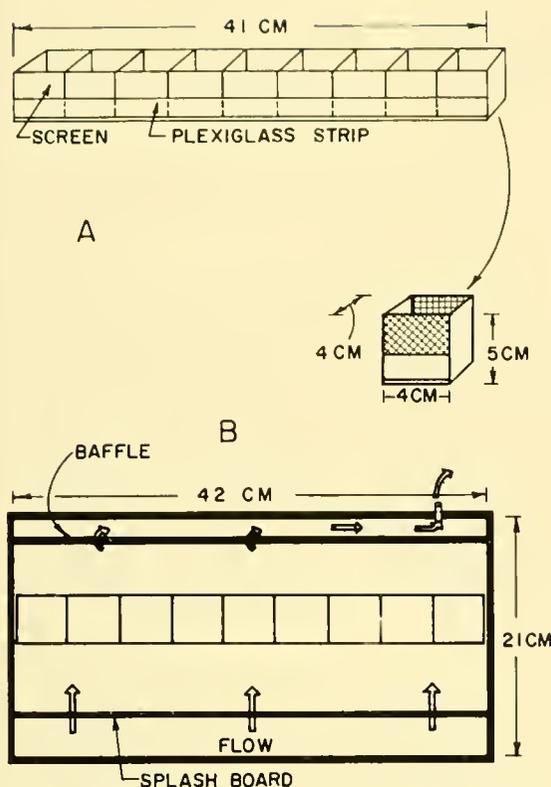


FIG. 1. Rearing apparatus. A, set of nine rearing chambers (side view). B, compartment with rearing chambers in place (top view).

TABLE 1. Reproduction and growth of *S. transversum* in chambers in the laboratory between 21 July and 23 August, 1967, and numbers present on November 15.

Chamber	July 21		August 23						November 15			
	No. per chamber	Length mm	No. Dead	No. broken in handling	No. with no growth	Lengths of those which grew (mm)			No. Young Length (mm)	Numbers Living	Dead	
1-6,9	4	1.7-2.2	3	3	19	2.7	2.8	3.0	0	—	100	22
						3.4	4.3	5.3				
						5.7						
7	4	2.0-2.3	0	1	0	5.1	6.0	8.1	2	1.4	13	9
8	4	2.0-2.3	0	0	0	3.0	3.4	4.9	1	1.8	22	7
						6.5						
10-18	2	4.9-5.7	6	0	0	6.0	6.2	6.2	76	1.6-6.0	170	65
						6.5	6.6	6.8				
						6.9	7.0	7.2				
						7.5	8.1	9.0				
19-27	1	10.2-12.1	9	—	—	—	—	—	53	1.6-9.0	237	32

Chambers 7 and 8 were treated the same as 1-6 and 9, but are listed separately since the clams showed reproduction and more growth. The clams with shells broken in handling on August 23 had not grown, nor had the dead clams in 1-6 or 19-27, but five in 10-18 had grown 0.1 to 2.6 mm and one showed no growth.

One large (over 10.0 mm long), two medium (4.0-6.0 mm long) or four small (newborn) clams were randomly assigned to each chamber; each compartment had three chambers of clams of each size group (chamber identification numbers were adjusted for presentation in Table 1). Large and medium-sized clams were collected in the river, but small clams were born in the laboratory. Small clams were removed with camel-hair brushes (Thomas, 1959) within an hour after their birth in pans of river water and measured with an ocular micrometer. Larger clams were measured with a vernier caliper; damaged clams were discarded. Similar sized clams were used as chambermates so that marking was unnecessary and handling was minimized.

The laboratory growth experiment began July 21, 1967; after 33 days, 3 units were removed, the 27 chambers cleaned, and the contents screened. Clams were measured as before and living ones returned to their respective chambers (Table 1) with fresh substrates.

To measure clam growth in the field, two retainers with 80 clams each were submerged in the river on July 6. One retainer was put in a sheltered cove adjacent to emergent and

submergent vegetation (transect 5 station 2 of Gale, 1969, p. 11) where there were less than 1,000 clams/m²; the other was placed in open water (transect 4 station 14 of Gale, 1969, p. 11) where there were about 42,000 clams/m².

Each retainer (Fig. 2, A) held 40 rearing tubes (Fig. 2, B) suspended through holes in a plexiglass plate by aluminum rods. Rearing tubes were 7 to 8 cm lengths of polyvinylchloride pipe (I.D. 2.5 cm) with plastic screen attached near the bottom; a painted wooden disk closed the lower end of the screen. A tube like that in Figure 2, C could be constructed and cleaned more easily.

Two randomly selected clams 5-7 mm long and 10 cc of strained clayey silt from station 14 were placed into each tube. The retainer was then forced into the river bottom until the two plexiglass flanges on the sides halted penetration with the rearing tubes just above the substrate.

The retainer at station 2 was removed on September 6. It had been turned over and many tubes nearly filled with mud. Tube contents were screened and the clams counted and preserved in

10% buffered formalin. Buoys marking the retainer at station 14 disappeared by September, and the retainer was lost.

RESULTS

Clam Growth in the Laboratory

Although the nine large clams stocked in chambers 19-27 died shortly after the experiment started, 53 young, 1.6-9.0 mm long (Table 1), were produced (some may have been second generation offspring). In only 33 days, or less, one of the offspring had grown approximately 7.0 mm in length (newborn clams in Pool 19 average 2.2 mm long) (Gale, 1969) to near maximum size. (*S. transversum* usually do not exceed 12.0 mm in Pool 19, but clams up to 15.9 mm long and 8.1 mm thick were found.) Reproduction in chambers 7 and 8, where newborn clams had been stocked, demonstrated that *S. transversum* not only could grow large in a month but could complete its life cycle as well.

Many newborn clams, stocked in chambers 1-9, had not grown by August 23 (Table 1) and some of them did not move for several minutes after removal from their chambers; some seemed dormant (in a resting state). The periostraca of the nongrowing clams were discolored and chalky.

Most of the 12 medium-sized clams that survived in chambers 10-18 grew slowly with a mean length increase of 1.3 mm. Clam growth in chamber 12 was not determined because five clams exceeded the initial size of parental stock and offspring and parents could not be distinguished. In most instances, offspring of the medium-sized clams grew rapidly and one was 9.0 mm long.

By November 15, when the chambers were reexamined, reproduction had occurred in all but two of the 27 chambers. Reproduction was maximum in chambers where one large clam had originally been stocked (19-27) and one clam left 79 descendants. Many of the clams that seemed dormant in August (chambers 1-9) had grown to 9.0 mm or longer (Fig. 3). Most of the clams stocked in chambers 10-18 had died without reaching 9.0 mm, and many were smaller than their offspring. Because observations of growth in chambers 28-81 did little more than confirm

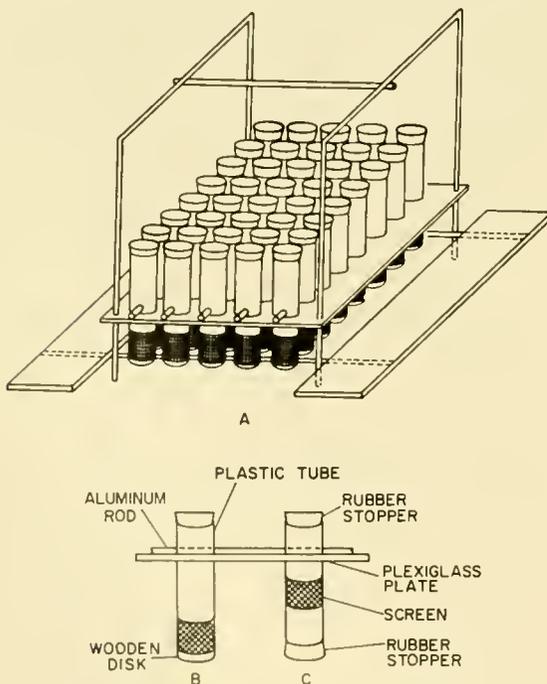


FIG. 2. Rearing apparatus used in maintaining *S. transversum* in the field. A, clam retaining apparatus; B, enlarged side view of a rearing tube used in 1967; C, rearing tube with alterations.

observations in chambers 1-27, precise data were not collected.

In November the periostraca of nearly all clams longer than 2.5 mm were speckled with dark deposits and some were nearly black. *S. transversum* usually seems very clean, and it is not known why deposits had accumulated on the clams.

Clam Growth in Field Experiments

Clams grew well in the rearing tubes at station 2, and after 62 days, 45 were 4.0 mm or more thick; the largest was 13.8 mm long and 6.6 mm thick. Clams in the tubes were larger than those living at station 14, the collection site (over 5,000 clams were examined there in mid-September but none was 4.0 mm thick). That four clams in each of 2 tubes were over 5.0 mm thick means that within 62 days, one or both stocked clams grew to maturity and discharged young that also had grown large.

Clams in the tubes contained many embryos and one large individual that seemed to have given birth to 35 young (its chambermate had died before reaching reproductive size) contained 86 embryos. A few of the 35 young may have been second generation offspring.

A specimen of *Sphaerium striatinum*, placed into a tube by mistake, had grown to a thickness of over 4.0 mm but had not given birth.

Clams in 21 tubes were dead, perhaps from senility, leech predation, or other causes (Gale, 1973). One live clam had a fungal growth nearly covering outer portions of the inner gill; embryos in the gill seemed unaffected.

DISCUSSION

In laboratory and field experiments, *S. transversum* grew extremely fast and completed its life cycle in about a month or less. Rapid growth has been noted for some other species of *Sphaerium*. *Sphaerium partumeium* grew large in 7 to 10 weeks in laboratory experiments (Thomas, 1965) and gave birth when less than 14 weeks old; clams grew even faster in the field. *S. partumeium* (as *M. partumeium*) reared by Krull (1936) grew to 4.5 to 5.0 mm long in about two months and gave birth. *Sphaerium corneum*, *Sphaerium rivicola*, and *Sphaerium solidum*

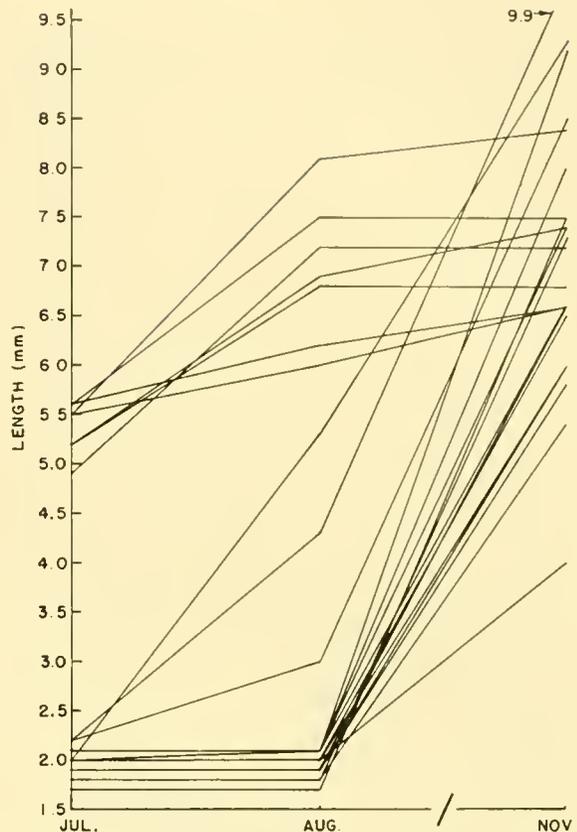


FIG. 3. Length changes in small and medium-sized *S. transversum* in the laboratory, 1967.

suspended in baskets in the Elbe River grew rapidly (Thiel, 1928, 1930), and some *S. corneum*, born in early summer, matured, gave birth, and died that autumn.

If *S. transversum* in the natural environment grew as rapidly as those in laboratory and field experiments, several generations could be produced annually. At station 14, however, medium-sized clams seemed to have grown only 2 mm longer in July and 3 mm in August (Gale, 1972), considerably less than those in growth experiments. Clam growth may have been hindered at station 14 by high clam density. Also, the clams were probably debilitated by high infestations of larval trematodes (Gale, 1973).

Although clam growth rates in the laboratory and at station 2 were similar, clams grew much larger at station 2. Because parental stock of both groups came from the same site and presumably from the same genetic stock, some factor or fac-

tors in the laboratory seem to have stunted the clams. Clams at some sites in the river did not reach maximum size either. Thiel (1928) observed that *S. corneum* in the Elbe River did not grow to maximum size in "overpopulated" areas. The fact that some medium-sized *S. transversum*, which did not grow much during the first 33 days of the laboratory experiment, remained smaller than their offspring in November (Fig. 3), suggests that, once growth is arrested or retarded, it is not completely compensated for later, when growth conditions become favorable.

Why some clams had initial growth lags and their chambermates did not is not clear, but delayed growth does not seem to have been genetically controlled (Gale, 1972). Delayed growth may involve metabolic slowdown that enables clams to bury themselves deep in the substrate to escape predation, parasitism, or unfavorable water conditions (Gale, 1973). In temporary ponds in Michigan, Kenk (1949) found that only fairly young *Sphaerium occidentale* and *S. partumeium* (as *S. truncatum*) survived the dry period.

It is sometimes pointed out that fast growth is of great advantage to inhabitants (such as some fingernail clams) of temporary ponds, because they can take advantage of a short growing period. One might conclude that, through evolution and natural selection, the advantage of being able to survive short growing periods has produced clams with tremendous growth rates. But, the fact that *S. transversum* grows rapidly but does not often inhabit temporary ponds, suggests that other factors produced rapid growth. This rapid growth may be a form of preadaptation. That *S. transversum* may have originated in tem-

porary ponds and then moved to other habitats merits consideration.

But, regardless of why *S. transversum* grows rapidly, the fact that it can complete its life cycle in about a month may be a major factor in its success in Pool 19, where predation pressures are great. If a population is to sustain itself under heavy predation, quick growth and reproduction would be advantageous, if not essential, for the shorter the prereproductive period, the greater the probability an organism has of reproducing before being consumed.

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THE FORMATION AND STRUCTURE
OF THE SHELL VARIX IN *STAGNICOLA ELODES* (SAY)
(GASTROPODA: LYMNAEIDAE)

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ABSTRACT

A life history study carried out in 1970-71 on a population of Stagnicola elodes in a temporary pond in lower Michigan reveals that a varix is laid down at the cessation of a period of shell growth which may or may not be followed by a period of dormancy. The adult snails of the Michigan population have 2 varices, one deposited before estivation of the juvenile snail, the other deposited after adult spring growth. It appears that the number of varices cannot be used to estimate the age of the snails unless the annual life cycle and environmental conditions are examined.

The microstructure of the varix was determined by microscopic examination of acetate pcds of shell sections made at right angles to the varix. The varix is formed from greatly elongated (5-6X normal) crystals of the prismatic layer. The probable function of the varix is to add strength to the outer lip.

INTRODUCTION

The freshwater snail *Stagnicola elodes* (Say) periodically puts down additional shell material, the varix (Baker, 1911), on the inside of the outer lip. In *S. elodes* the varix is purple-brown in color and parallels the outer lip. In Baker's opinion, varices, normally three in number in *Lymnaea palustris* (= *S. elodes*), mark periods of "hibernation" when the animal is "buried in mud" and do not represent annual growth markings. However, Baker was not positive of this interpretation.

DeWitt (1954) reports that when "growth in *Physa gyrina* is interrupted for some reason, the inner edge of the outer lip of the aperture is strengthened by a triangular thickened band . . . Conditions which arrest growth and lead to formation of these bands are obscure; production does not appear to be dependent upon environmental factors, rather they are a result of a physiological pattern developed within the species and perhaps modified to some extent by environment." DeWitt states that the bands might be accounted for in terms of periodic drying of the

habitat but felt it unlikely that such a thickening would be produced under adverse conditions of drought or estivation. Herrmann & Harman (1975) believe that varices in *Helisoma anceps* (Menke) reflect slow winter growth.

FIELD OBSERVATIONS

During 1970-71 a study was carried out on the life history of a population of *Stagnicola elodes* (Say) in a woodland pond in the Pontiac Lake Recreation Area, Oakland County, Michigan. The annual life cycle begins in May when eggs are laid. Egg laying continues through July. The newly hatched generation feeds until the snails reach 2-7 mm in length. At this point the young cease growth and actively leave the water to estivate on grasses and tree trunks above ground. The majority of the older snails follow the receding pond water to become stranded on the dry pond floor and there be preyed upon, most commonly by sciomyzid (Diptera) larvae. The young estivating snails eventually leave their above-ground locations and come to lie under the pond leaf litter to

over-winter. The immature snails (mean shell length = 8 mm) become active in the spring as soon as the ice melts. The snails grow rapidly so that by June the mean shell length is approximately 15 mm (Jokinen, in prep.).

The snails of the Michigan population of *S. elodes* were noted to deposit several varices during their life times. In 1970, varices on the outer lips were first noted on July 12 on 4 snails (shell lengths from 10.3 to 21.7 mm) out of 123 (3.3%). Egg masses were in evidence by this date. By July 26, 13 out of 121 snails (10.7%) had varices. On August 9, estivating immature snails were first observed and noted to have varices (100%). In 1971, 5 snails were collected from under the ice in February and March. The snails ranged from 3.7 mm to 11.8 mm and all 5 had varices on their outer lips. On April 20, 1971, 34 snails were collected. The winter varix was evident on all of the snails, and 32 had new, fragile, and thin shell growth beyond the varix. The mean linear increment of new growth beyond the varix was 1.5 mm (range .2-3.5 mm). Shell growth was rapid during May and egg masses appeared by the end of the month. By June 6, the entire sample population of 153 snails (except one) had deposited new varices.

MICROSCOPIC STRUCTURE OF THE VARIX

In order to determine the structure of the varix of *S. elodes*, a portion of shell was cut at right angles to the aperture, so that the section was at right angles to the length of the varix (Figure 1). Acetate peels were made from polished shell sections following the method of Boardman & Utgaard (1964).

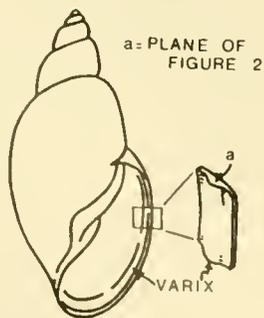


FIG. 1. Location of the varix in *Stagnicola elodes* (Sty).

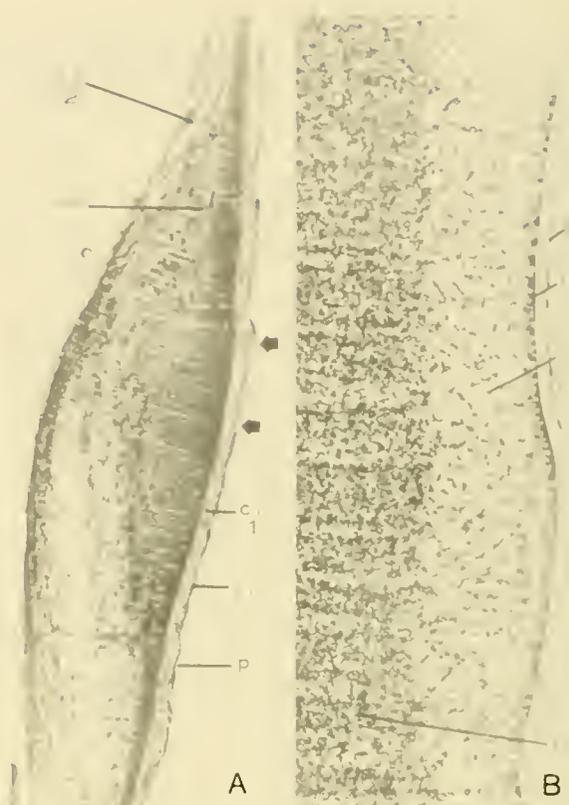


FIG. 2A. Acetate peel of a polished shell section cut at right angles to the varix. The normal shell width is demonstrated in the upper portion of the photograph. The thicker portion is the varix. p., periostracum; l.l., longitudinal lamellar layer; c.1.1, first crossed lamellar layer; c.1.2, second crossed lamellar layer; pr., prismatic layer.

FIG. 2B. 7.5x magnification of the area between the arrows of A. There are two layers of periostracum and a space beneath the periostracum. p., periostracum; l.l., longitudinal lamellar layer; c.1.1, first crossed lamellar layer; pr., prismatic layer. (750x total magnification).

According to Boggild (1950), the calcareous portion of the shell of *Stagnicola palustris* (= *S. elodes*) is composed of aragonite deposited in four distinct layers. The shells of *S. elodes* from Michigan were examined and found to also possess four calcareous layers arranged as follows: (1) a very thin outer longitudinal lamellar layer under the periostracum; (2) a crossed lamellar layer; (3) a prismatic layer; and (4) a second crossed lamellar layer (Figure 2). As illustrated, the varix is formed by an increase in the length of the crystals of the prismatic layer. The crystals are approximately 5-6 times as long

in the varix as in the normal shell. Gross examination of a ground section demonstrates that the purple-brown color of the varix is due to streaks of pigment laid down in the thickened prismatic layer. The thickened outer lip of mature *Helix [Theba] pisana* Müller is also formed by elongated prismatic crystals (Matthes, 1914).

CONCLUSIONS

Field evidence shows the pattern of varix deposition to be associated with cessation of growth. Snails without a varix were rapidly growing individuals, including the newly hatched. Snails with a terminal varix were estivating juveniles, overwintering individuals, and egg-laying adults which had completed their spring growth. The varix is laid down at the end of a period of growth and not during a period of dormancy. Therefore, the number of varices cannot be used to estimate the age of snails unless the annual life cycle and environmental conditions are examined.

The number of varices in adult snails will differ, depending upon annual activity. If a pond dries up in summer, gains water again before temperatures become too cold for gastropod activity, and then warms up again the following spring, breeding adult snails will have 3 varices; two representing periods of pre-dormancy and one the termination of growth before egg deposition. This is probably the situation observed by Baker (1911) who found 3 varices normal for *L. palustris* (= *S. elodes*), one varix on the third whorl, one on the fifth, and a third on the apertural lip of the adult.

The snails from Michigan all had a varix inside the outer lip in early spring before the ice thawed. In this case the summer-fall estivation, marked by a varix on the juveniles, had continued into the overwintering period, the pond not refilling until freezing temperatures had arrived. Therefore, the snails were not given the opportunity to renew growth in the fall. After the pond thawed and the water warmed, new shell material was rapidly laid down, the purple-brown color of the summer-fall varix marking the initiation of dormancy. By June the

snails had grown considerably in length and the new shell growth was very thin. Then linear growth slowed, the new shell material thickened and another varix was deposited. Under such conditions an adult snail will exhibit only two varices.

Microscopic examination suggests that the varix adds considerable strength to the shell lip as is the case with the shell lamellae found in *Biomphalaria* (Richards, 1964). It is doubtful that the varix would protect against desiccation since it extends into the shell aperture only a short distance. A likely function would be to strengthen the shell lip and thus protect against breakage between periods of growth, whether or not the snails are active.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Dr. David R. Cook for his advice and encouragement, Dr. Osborn B. Nye for technical instruction, and Dr. Peter H. Rich for critically reviewing the manuscript. Preparation of the manuscript was aided by the facilities of the Biological Sciences Group at the University of Connecticut.

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PREDATION BY WINTER FLOUNDER
 (*PSEUDOPLEURONECTES AMERICANUS*)
 ON THE SIPHONS OF THE CLAM, *TELLINA AGILIS*

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The bivalve *Tellina agilis* Stimpson commonly inhabits marine, shallowwater, sand-mud sediments (see Maurer, *et al.*, 1974). These small clams (max. length = 1.6 cm) burrow 1-3 cm into the sediment and deposit-feed on the sediment surface with separate, extensible, inhalent siphons (Gilbert, 1970), movements of which may attract visual predators such as the commercially important winter flounder, *Pseudopleuronectes americanus* (Walbaum). Edwards, *et al.* (1970) have shown that small flounder, *Pleuronectes platessa* (L.), in Scotland obtain a large part of their food by preying on siphons of *Tellina tenuis* da Costa, which can regenerate their siphons. The aim of our study was to seek evidence that small winter flounder prey on siphons of *T. agilis* in nature.

Eight winter flounder (lengths = 4-6 cm) were collected (27 September 1969) at the mouth of Barnstable Harbor (Cape Cod Bay), Massachusetts. The fish were captured by hand net during the flooding tide on a sand flat 0.5 m above mean low water. An abundant population of *T. agilis* (100-600/m²) occurred on the flat, but other clams with similar siphons (e.g., *Cumingia*, *Macoma*, and *Petricola*) were rare or absent (see Edwards, 1975). The fish were placed immediately in 95% ethyl alcohol to terminate digestion, and stomach contents were examined later in the laboratory.

Stomachs of four of the eight fish contained 1-3 siphon fragments (9 total). These fragments and intact siphons of *T. agilis* collected at the site had similar measurements (made at 7× power with an eye-piece micrometer) for total width, width of circular muscle bands, and width of

longitudinal bands (Fig. 1). The length of an extended siphon is 3-4 times shell-length; the fragments ranged from 0.5-2.5 mm in length and were usually identifiable as the siphon tip.

Levinton (1971; Levinton & Bambach, 1975) report that *Macoma tenta* (a subtidal clam) deposit-feeds on detritus at night when its siphons are not visible to fish predators, but that *T. agilis* deposit-feeds on benthic diatoms during the day. Many benthic diatoms concentrate during the day at the sediment surface, which turns a golden-brown hue as a result (Sanders, *et al.*, 1962). Thus the efficiency of daytime grazing by *T. agilis* may outweigh the hazard of exposing siphons to fish predators.

In the laboratory, we observed the behavior of a small winter flounder placed in a water tank with a tray of sediment containing several live *T. agilis*. On two occasions, the fish uncovered clams by lunging at the sediment surface where siphons were deposit-feeding. When each clam attempted to burrow back into the sediment, the fish took a bite out of its foot.

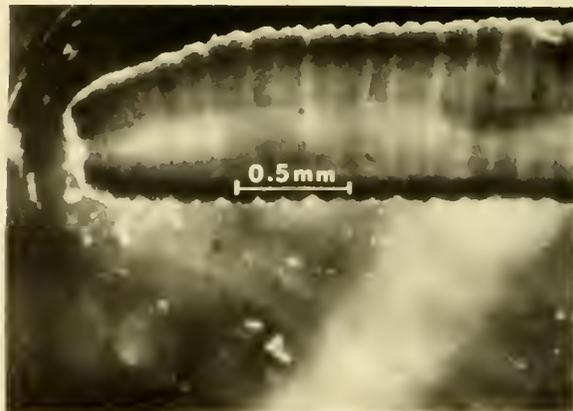


FIG. 1. Intact siphon of a *Tellina agilis* (shell-length = 1.0 cm) in 50% ethyl alcohol.

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Martin (1940) reports that *T. agilis* (as *T. tenera*) is an intermediate host for *Monorcheides cumingiae*, a parasitic trematode which encysts (as metacercariae) in siphon and foot tissues of the clam. Martin fed infected clams to eels and flounders (species unspecified) and obtained adult *Monorcheides* later from intestinal mucosa of the fish. Our observation that small winter flounder prey on *T. agilis* suggests that these fish might take in *Monorcheides*. Further studies are needed to determine (1) whether or not winter flounder is a definitive host for this parasite, and (2) the importance of *T. agilis* siphons in the diet of young winter flounder.

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ECOLOGY OF THE SNAIL, *MELANOIDES TUBERCULATA* (MÜLLER), INTERMEDIATE HOST OF THE HUMAN LIVER FLUKE (*OPISTHORCHIS SINENSIS*) IN NEW ORLEANS, LOUISIANA

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ABSTRACT

The habitat and associates of a series of populations of the prosobranch snail, Melanoides tuberculata (Thiaridae) introduced to a drainage canal in New Orleans, Louisiana, are described. These snails, and associated fish, could serve as intermediate hosts of the Chinese Liver Fluke, Opisthorchis sinensis.

In the spring of 1975, two populations of *Melanoides tuberculata* (Müller) (Thiaridae) were discovered in New Orleans, one in the People's Avenue Canal, Orleans Parish, and the other in the canal on the neutral ground of General DeGaulle Drive, Jefferson Parish. A third population has recently been reported to us in 1975 from the west Metairie canal in Jefferson Parish.

This oriental prosobranch had previously been reported from two localities in Texas (Murray, 1964; Murray and Wopschell, 1965), one in Arizona and another in Oregon (Murray, 1971). Abbott (1973) summarized its spread into Mexico at Vera Cruz and in Panama and Puerto Rico. The role of *M. tuberculata* as an intermediate host in the life cycle of the Chinese Liver Fluke,

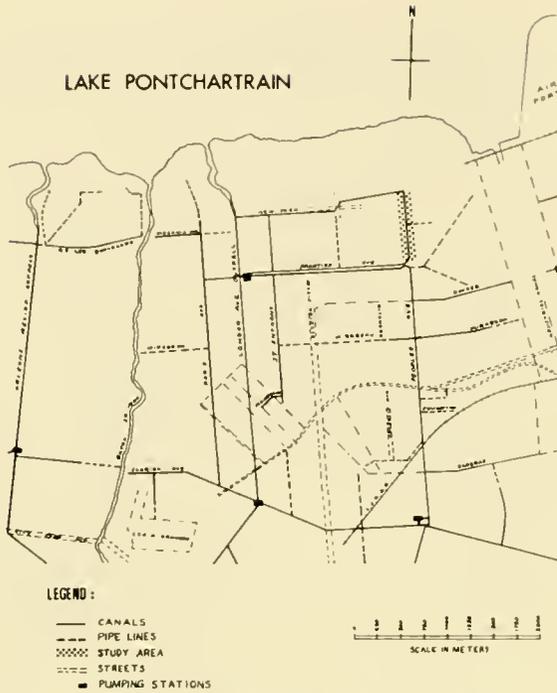


FIG. 1. A portion of the New Orleans drainage system in relation to the People's Avenue canal.

Opisthorchis sinensis, makes the occurrence of it in the U. S. of more than casual interest.

This study was done in a section of People's Avenue Canal which is part of the New Orleans storm drainage system. Since this city is largely below sea level, drainage is accomplished by pumping stations at intervals in the drainage canal network (Fig. 1). This locality (Fig. 2) is per-

manently supplied with slightly brackish water from a 600' well tapped by American Standard Co. for use as cooling water in their air conditioning system.

THE HABITAT

The reported habitat of *Melanoides tuberculata* elsewhere in the U. S. is freshwater springs with a pH of 7.0-7.5, a water temperature of 18-25° C, and soft mud or gravelly-mud bottoms (Murray, 1971). The People's Avenue habitat is similar to this. With few exceptions the stream bed is 50-70 cm wide and 10-40 cm deep. The flow during the study was 42-51 cm/sec. Once we noticed a brief threefold flow increase, from an unknown source. At this time the level in the basin at the north end rose 20 cm in a five minute period. The non-vegetated bottom is sandy with scattered pebbles and shells of *Rangia cuneata*, a brackish-water mactroid clam which is used for gravel. Few *Melanoides* are found in this type of bottom. Flow is much slower and the accumulation of silt and detritus much greater behind the overhanging stems and protruding roots of the bank vegetation. This seems to be the prime *Melanoides* microhabitat, supporting up to 251 snails/sq. ft. (2700/m²).

The canal banks are covered with vegetation. The predominant cover is a prostrate species of medium-height grass (probably *Eragrostis*) with *Typha* and *Lysimachia* constituting most of the rest of the cover. The grass and *Lysimachia* are

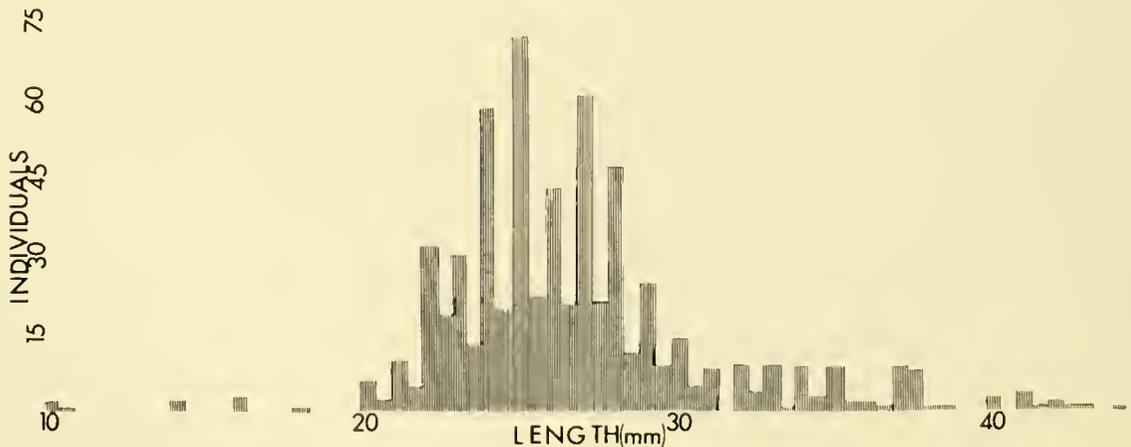


FIG. 2. Histogram showing population age groups in the spring of 1975.

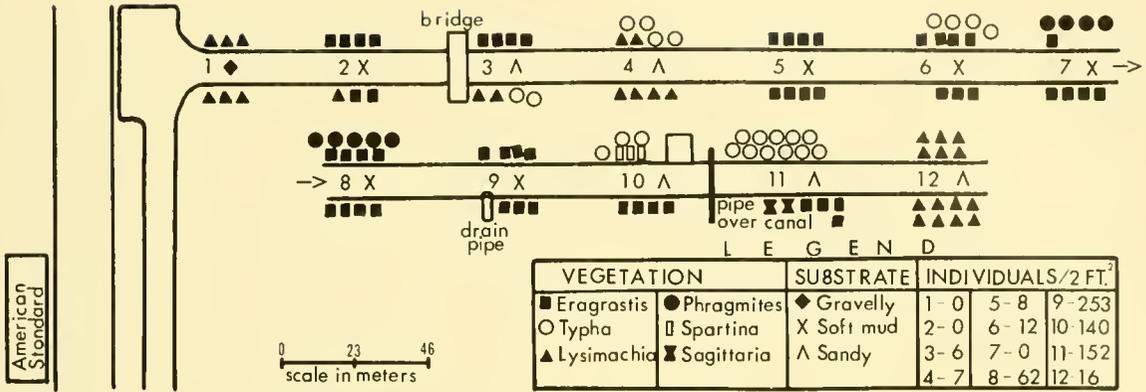


FIG. 3. Diagram of People's Avenue Canal showing distribution of snails in relation to substrate and vegetation.

the only plant species directly in contact with *Melanoïdes*. At the stream bank they create the sheltered environment that *Melanoïdes* seems to prefer. Other plants in the area are: *Polygonum* sp., *Spartina alterniflora*, *Phragmites communis*, and *Sagittaria falcata*.

Animal species associated with *Melanoïdes* at this site include insects (*Ranatra* and *Pelocoris*, both predaceous hemipterans; Chironomidae, dipterans), crayfish, oligochaetes, and fishes (*Poecilia latipina* and *Heterandria formosa*). The fishes are of particular interest since various poecilids are known to be second intermediate hosts for *Opisthorchis sinensis*, the human liver fluke which has *Melanoïdes tuberculata* as its first intermediate host.

POPULATION SAMPLINGS

Square foot (.093 m) quadrat samples were taken starting from the northernmost end of the canal (Fig. 3) at 46-meter intervals downstream (12 stations in all) to the point where the canal turns westward and goes underground. Two samples were taken at each station, at opposite banks just underwater and at the surface. Individuals were returned to the lab, counted, measured, and whorl counts made. Histograms were then plotted from these data for each station. The population for September-October 1975 follows a normal curve pattern with a few young of 10 mm and 8 whorls, a few older individuals of 44 mm and 14.5 whorls, and the bulk of the population in-between. The best-represented size class is 25 mm long with 12 whorls. Fig. 2 is a histogram of the snail total lengths—lumping all

of the stations (656 individuals) to present an overview of the population. The histogram will doubtlessly shift considerably during reproductive seasons. Only one cluster of young was found indicating that late summer is not a major reproductive season for these live-bearers here. A parthenogenetic mode of reproduction has been reported for *Melanoïdes* (Jacob, 1957).

TABLE 1. The range of physico-chemical values encountered for each parameter.

	Low	High
chlorides in ppt	1.39	1.65
salinity in ppt	2.50	3.00
dissolved oxygen in ppm	3.70	5.00
free CO ₂ in ppm	24.00	41.00
phenolphthalein alkalinity expressed as ppm CaCO ₃	0.00	0.00
total alkalinity expressed as ppm CaCO ₃	300.00	560.00
Temperature (water)	20.5°C	25.0°C
pH	7.5	7.5

The flow from the well is 4500 liter/min. This water has some interesting properties related to its origin. The usual alkalinity values encountered for Lake Pontchartrain are in the 30-50 ppm range; free CO₂ is generally less than 5 ppm. At the pH values we recorded, carbonate ion is absent; the high CO₂ and alkalinity values are what might be expected for a subterranean water source that is far from being in equilibrium with the atmosphere. The low dissolved oxygen content (saturation at 25° C is 8.1 ppm) also suggests this water is recovering from subsurface conditions. All these water quality parameters may have been affected by passage

through the American Standard Company air conditioning system. The slight brackishness of this water is usual for southeastern Louisiana waters and does not seem to inhibit *Melanooides*.

SIGNIFICANCE

The introduction of *Melanooides tuberculata* into an area where poeciliid fishes occur plus the fact that Vietnamese people are being settled nearby could be highly significant, particularly if some of these people are infected with trematodes and if they are still including raw fish in their diet. It is not known at the time of this writing whether the incoming Vietnamese were screened for liver flukes. Since all of the ingredients for the *Opisthorchis* life cycle might now be present, it is important that we learn more about the snail and continuously monitor the spread of it.

ACKNOWLEDGEMENTS

We wish to thank Dr. Harold Murray of Trinity University for verifying our determination of

the snails. Voucher specimens have been deposited in the Delaware Museum of Natural History, No. 113847. Also the following University of New Orleans graduate students were equally responsible for the results of this study: Bill Copeland, Tom Chin, Ben Garrett, Cheryl Noble, Mike Rayle and Mary St. Martin.

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NEW RECORDS AND ECOLOGICAL NOTES FOR *CORBICULA MANILENSIS* IN TEXAS

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ABSTRACT

Corbicula manilensis is distributed through seven major drainage systems in Texas. Potential mechanisms of dispersal are discussed. The species seem to prefer sandy substrates in Texas reservoirs but occurs in a variety of bottom types. Specimens of *Corbicula* have been removed from stomachs of three species of fish—*Lepomis microlophus*, *Minytrema melanops* and *Aplodinotus grunniens*.

The first reports of *Corbicula manilensis* in Texas were from the western portion of the state (Metcalf, 1966 and Metcalf and Smartt, 1972). Murray (1971) discusses the presence of *Corbicula* in South Texas and notes its eastward progression from the Rio Grande drainage to Lake Corpus Christi, 25 miles north of Corpus Christi. He

also reports large populations of the Asiatic clam from Lake LBJ in the Colorado River drainage of Central Texas (Murray, 1972).

Corbicula was reported in Louisiana waters as early as 1961 (Dundee and Harman, 1963). Considering its rapid range expansion in other parts of the United States, it is interesting that no

reports of *Corbicula* in eastern Texas have yet appeared in the literature. It seems inevitable, however, that the eastern and western populations of *Corbicula* will finally converge in this state.

We have compiled a list of new distributional records of *Corbicula* in central, northeastern and eastern Texas. The first record of the species in northeastern Texas was from Lake Grapevine (Tarrant County), a reservoir of the upper Trinity River drainage. Mr. Donnie Roberts provided the senior author with several specimens collected from Lake Grapevine in November, 1972. Subsequently, several reservoirs in Tarrant County were found to harbor *Corbicula* populations. The authors recovered specimens from Lake Arlington on January 21, 1974; from Lake Benbrook on February 3, 1974; and from Eagle Mountain Lake in September, 1974. In August, 1973, the senior author collected a specimen from the Colorado River at Marble Falls in central Texas.

During October and November, 1974, and March and April, 1975, the Texas Christian University Research Foundation provided financial support which enabled us to briefly survey a number of Texas reservoirs east of the Colorado River system. We visited Possum Kingdom Reservoir (Brazos River drainage), Lake Ray Hubbard, Navarro Mills Reservoir, Cedar Creek Reservoir, and Lake Livingston (Trinity River drainage), Lake Conroe (San Jacinto River drainage), Lake Tawakoni (upper Sabine River drainage), Diversion Lake, Lake Wichita, and Lake O' the Pines (Red River drainage), and Lake Sam Rayburn and Steinhagen Reservoir (Neches River drainage). Most of the surveys were not exhaustive (exceptions were those at Possum Kingdom, Diversion Lake and Lake Wichita) so the failure to detect *Corbicula* at a locality does not necessarily indicate the absence of the species in an area. In fact, only Lake Sam Rayburn and Lake Texoma yielded specimens. The Rayburn specimens were collected from a sandy substrate on the northwestern shore of the lake on October 18, 1974, whereas specimens from Lake Texoma were taken from sand along the northern shore of the lake near the University of Oklahoma Biological Station on April 24, 1975.

Harold Murray has provided additional distribution data from central Texas. He has received specimens collected by Emily Mims from Lake Buchanan on June 30, 1973. On September 21, 1973, the ecology class of Trinity University recovered *Corbicula* from Canyon Lake, Guadalupe River. Scott Horn provided Murray with specimens collected on September 8, 1974, from the Guadalupe River below the dam at Highway 90 and 90A near Seguin, Texas.

Ray Dinges of the Texas Water Quality Board has provided us additional records. He has collected Asiatic clams from Lake Austin on the Colorado River, along the Colorado River between Austin and Bastrop, and in the Nueces River along Texas Farm Road 1025, north of Crystal City.

The known distribution of *Corbicula* in Texas now includes seven major drainages: the Rio Grande, Nueces, Guadalupe, and Colorado Rivers, with dispersal apparently occurring within these systems generally from west to east, the upper Trinity River drainage and the Red River drainage with populations recruited from an uncertain source, and the Neches River drainage with this population possibly recruited from Louisiana (see Figure 1). Considering the apparent lack of *Corbicula* populations immediately adjacent to the upper Trinity River assemblage, it seem possible that the species gained access to

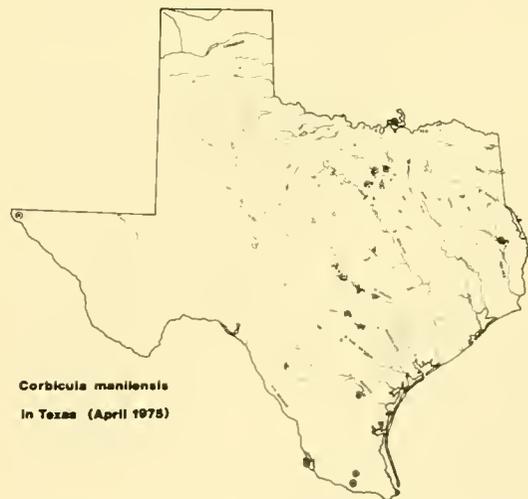


FIG. 1. The known distribution of *Corbicula manilensis* in Texas through April, 1975.

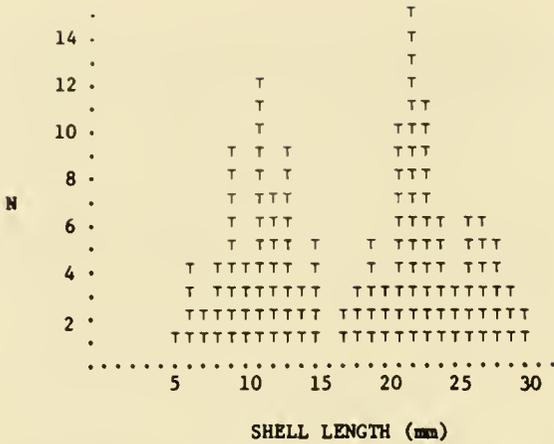


FIG. 2. Size frequency distribution of a random sample of paired valves of *Corbicula manilensis* collected from Lake Benbrook, Texas, November, 1974.

North Texas waters as a result of introduction from a remote source. Many live-bait establishments obtain minnows from Arkansas or Louisiana, transporting several hundred gallons of water with each shipment of minnows. Perhaps *Corbicula* larvae may have been transported with this water. Fisherman could just as likely bring an establishing population into the area in a live-bait hold of a boat. The pattern of distribution of *Corbicula* in Texas is decidedly trending along a roughly north to south axis. This fact may be due only to coincidence, but since it parallels closely a migratory bird flyway, it may suggest an alternative dispersal mechanism.

From whatever source that *Corbicula* became established in Tarrant County reservoirs, it is certain the Asiatic clam is firmly entrenched there. In 1973, Britton, Murphy, Keith and Mauldin completed a study of the bivalve fauna of Tarrant County Reservoirs. From June 1971 to August 1972, extensive bivalve collections were made in Benbrook and Eagle Mountain reservoirs. At that time there was no evidence of *Corbicula* in either lake. By November 1974, shell debris accumulations of *Corbicula* along portions of the western shore of Benbrook Lake yielded densities in excess of 800 valves per foot. A random sample of 140 paired valves was taken from this shell debris material. Measurements were made of each individual in the sample. The

length of the largest was 30.4 mm. A frequency distribution of length or height measurements obtains a distinctly bimodal curve, suggesting two major age classes among the Benbrook *Corbicula* population (Figure 2). This correlates well with the time available for the species to have become established.

Considering the rapid spread of *Corbicula* in southwestern Texas and among the Tarrant County reservoirs, it is interesting that the species apparently has not yet entered the Brazos River system (or, at least the upper Brazos from Possum Kingdom Reservoir to Waco, Texas). In the summer and fall of 1974, we made extensive collections of bivalves from Possum Kingdom Reservoir during a period when the lake was significantly below normal. *Corbicula* was never observed. In addition, Mr. Chuck Fontainer has been intensively studying unionid populations in the Brazos River near Waco. He has employed numerous collecting techniques including SCUBA diving to recover clams. To date he has not encountered *Corbicula* in the Waco area. The Brazos drainage should be monitored closely during the next few years, as it is the only major river system between western and eastern *Corbicula* populations which still lacks the species.

The substrate preferences of *Corbicula* in Texas are variable. We have taken the species from sandy gravel, sandy mud and muddy sand, and from deeper water muds. The most abundant populations seem to be on or in sandy or muddy sand substrates. Clams can be found on the surface of the substrate or buried as much as two centimeters below the surface. At Sam Rayburn Reservoir we found a population of *Corbicula* in a muddy sand substrate. The clams were approximately 2 cm below the surface, but produced a hole which emerged at the sandy water-substrate interface for water currents to enter the mantle cavity. The origin of this tube is curious, as the siphons of *Corbicula* are too short to be extended 2 cm to the surface to produce it. Although we have tried to reproduce the situation with laboratory specimens, we have not been successful.

The largest concentrations of *Corbicula* have been collected from shore to depths of about 8

feet. Living specimens have been recovered by dredging in silty substrates in Lake Benbrook at a depth of approximately 20 feet.

Our students have removed *Corbicula* from stomachs of three fish species from North Texas waters. A red ear sunfish, *Lepomis microlophus*, from Lake Benbrook was found to contain *Corbicula* shells up to 5 mm in length. A spotted sucker, *Minytrema melanops*, from the same lake had ingested shells up to 3 mm in length. From Eagle Mountain Lake a freshwater drum, *Aplodinotus grunniens*, had five specimens of *Corbicula* in the gut ranging from 3 to 5 mm in length.

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OPISTHOBRANCHS FOUND OFF LITTLE EGG INLET, NEW JERSEY, WITH NOTES ON THREE SPECIES NEW TO THE STATE

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ABSTRACT

An intensive ecological survey in the vicinity of Little Egg Inlet, New Jersey found three species of opisthobranchs which are new to New Jersey (Pleurobranchaea tarda, Onchidoris bilamellata, and Facelina bostoniensis) and southern range extensions for Dendronotus frondosus and Tergipes tergipes. The occurrence of cold water opisthobranchs in New Jersey is explained in part by ocean water temperatures which rarely exceed 25°C, by the numerous submerged artificial structures, and by the predominant southwest flow of coastal water which may transport eggs and young from breeding populations located to the north.

INTRODUCTION

In October, 1971, Ichthyological Associates, Inc. began an ecological survey of the New Jersey coast from Long Beach Island to Brigantine Island. Since March, 1972, invertebrates were systematically collected by a variety of methods including substrate panels, clam dredge, ponar grab, lobster pots, trawl, and SCUBA gear as reported by Garlo, Hondo, and Miller (1975) and

McCullough (1975).

Recent reports by Franz (1968a, 1970) and Loveland, Hendler, and Newkirk (1969) recorded nudibranchs from Shark River, Delaware Bay, Manasquan River, and Barnegat Bay. Loveland et al. (1969) provided a checklist which summarized distributional records of nudibranchs from New Jersey. Franz (1968b), Marcus (1958), Miner (1950) and Pruvot-Fol (1954) discussed their taxonomy and distribution.

SPECIES	NO. SPECIMENS	LOCATION	DEPTH(m)	TEMP. (C)	SALINITY (ppt)	MONTHS-COLL.	HABITAT
<u>Pleurobranchaea</u> <u>arda</u>	13	Approx. 15 km SE of Little Egg Inlet	18.0-20.0	14.2-17.0	32.0	August, October, November	Coarse sand bottom
<u>Acanthodoris</u> <u>pilosa</u>	45 + eggs	Little Sheepshead Creek, Little Egg Inlet to approx. 4.7 km SE of Little Egg Inlet	2.1-10.9	6.5-25.0	29.5-30.5	April-September	Dead clam shells encrusted with <u>Alcyonidium</u> sp.; <u>Cliona</u> sp.
<u>Onchidoris</u> <u>bilamellata</u>	8	Approx. 6.4 km SE of Little Egg Inlet	13.7-15.5	13.5	29.5-30.5	August	Lobster pot
<u>Dendronotus</u> <u>frondosus</u>	1	Approx. 3.7 km SSE of Little Egg Inlet	10.6	20.0	29.5	July	Approx. 15 ft below MLW on weather tower
<u>Doto</u> <u>coronata</u>	29 + eggs	Little Egg Inlet to approx. 3.7 km SSE of Little Egg Inlet	0.9-10.6	6.0-20.0	26.0-30.5	May-July and December	Drifting Serulariidae; substrate panels
<u>Terripes</u> <u>terripes</u>	815	Approx. 3.7-4.0 km SE of Little Egg Inlet	10.6	6.0-20.0	29.0-31.0	May-August and December	12 ft below MLW on weather tower; substrate panels
<u>Facelina</u> <u>bostoniensis</u>	3	Approx. 4.0 km SE of Little Egg Inlet	9.1-12.1	19.0	29.5	August, October	Bouy line; lobster pot
<u>Gratena</u> <u>pilata</u>	164	Approx. 3.2-6.4 km SE of Little Egg Inlet	7.6-12.1	13.0-21.5	30.0	August, October	Lobster pot; substrate panels; weather tower
<u>Aeolidia</u> <u>papillosa</u>	4 + eggs	Approx. 8.8 km SE of Little Egg Inlet	15.2	10.0	30.5	June	Shipwreck colonized by <u>Meridium senile</u>

TABLE 1. *Opisthobranchs* collected in the vicinity of Little Egg Inlet, New Jersey between March 1972 and September 1975.

RESULTS

More than 325 macroinvertebrate taxa were collected from the study area during the period between 1971 and 1975. Opisthobranchs were taken between Little Sheepshead Creek and 15 kilometers southeast of Little Egg Inlet (Fig. 1). Nine species of opisthobranchs (represented by 1,082 specimens) are discussed below (Table 1). Specimens are deposited in the collections of Absecon Laboratory of Ichthyological Associates, Inc.

Some 95% of the specimens collected were taken from artificial structures which included lobster pots, substrate panels, buoy lines, ship wrecks, and a weather tower. The rest were collected from natural substrates such as shell rubble encrusted with bryozoans and drifting hydroids.

Pleurobranchaea tarda (Verrill 1880)

Thirteen specimens were collected by trawl during August, October, and November, 1975, approximately 15 kilometers southeast of Little Egg Inlet. Specimens were taken at depths of 18 to 20 m. Bottom water temperature at the time of collection ranged from 14.2° to 17.0° C and salinity was 32.0 ppt.

Abbott (1974) reported specimens off Massachusetts and Delaware at depths from 51 to 567 m. Moore (1964) noted specimens from floating *Sargassum* in Vineyard Sound, Mass. and in dredge samples taken at depths from 60 to 400 m. Our specimens are the first reported occurrence for New Jersey.

Acanthodoris pilosa (Müller 1776)

Forty-four specimens were collected from 27 April 1972 through 3 September 1974. They were taken in Little Sheepshead Creek, and from Little Egg Inlet to a point 4.8 kilometers southeast of Little Egg Inlet at depths of 2 to 11 m. Bottom temperatures were 6.5° to 25.0° C and salinities were 29.0 to 30.5 ppt. Egg masses were collected in June when bottom temperature was 16.0° C and salinity was 29.0 ppt.

Acanthodoris pilosa was found on shell rubble which was covered with encrusting bryozoans (particularly *Alecyonidium* sp.) and on cement and masonite substrate panels colonized by *Al-*

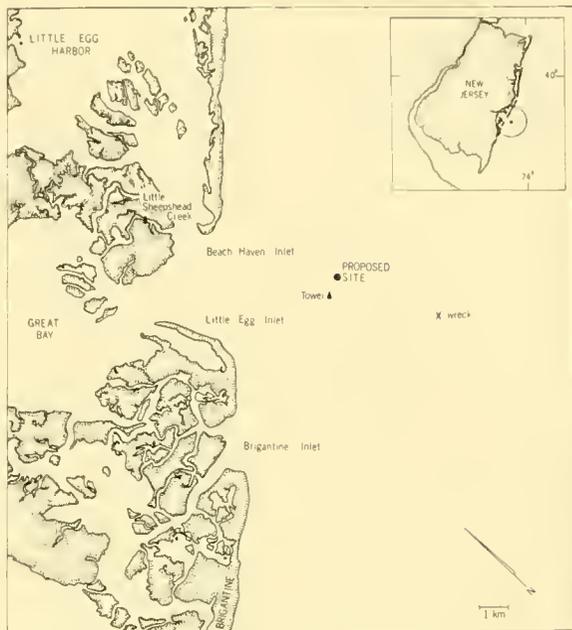


FIG. 1. Area sampled in the vicinity of Little Egg Inlet, New Jersey.

cyonidium, *Obelia flabellata*, and *Tubularia crocea*; 7 were found on the gamma stage of *Cliona* sp. The color of *A. pilosa* varied from gray to gray-pink to yellow and blended with the habitat.

Abbott (1974) reported that it was found from the Arctic to Ocean City, Maryland and in the north Pacific, Japan, and Europe. A specimen found in Delaware Bay, New Jersey, was reported by Loveland et al. (1969). *Acanthodoris pilosa* is established in natural and man-made habitats near Little Egg Inlet but is uncommon.

Onchidoris bilamellata (Linnaeus 1767) (*Lamellidoris fusca* in Abbott 1974, *Onchidoris fusca* in Moore 1964)

Eight specimens were collected on a lobster pot set from 23 July to 14 August 1973 near a wreck located approximately 6.4 kilometers southeast of Little Egg Inlet. They were relatively small (total length ranged from 5.7 to 6.9 mm; mean 6.3 mm). The depth ranged from 14 to 16 m; the bottom temperature was 12.5° C, and salinity was 30.5 ppt.

Abbott (1974) reported its range in the Atlantic from the Arctic to Massachusetts and Europe.

These are the first specimens reported from south of Long Island, New York (Rozsa 1974).

Dendronotus frondosus (Ascanius 1774)

One specimen (1.8 mm total length) was collected on a masonite panel which was set from 23 April to 1 July 1974. The panel was placed approximately 5 m below mean low water on a weather tower located 3.7 kilometers southeast of Little Egg Inlet. The bottom temperature was 20.0° C and the salinity was 29.5 ppt. *Dendronotus* was associated with the hydroids *Obelia flabellata* and *Tubularia crocea*.

Abbott (1974) reported its range in the Atlantic is from the Arctic to New Jersey and Europe. Loveland et al. (1969) found hundreds of specimens associated with *Tubularia* on a floating wharf in Shark River, N. J.

Doto coronata (Gmelin 1791)

Twenty-nine specimens were collected from early May, 1973, to early December, 1974. Small specimens and eggs were collected on floating hydroids (Sertularidae) in May, 1973, in Little Egg Inlet. A few were found associated with *Obelia flabellata* on cement and masonite panels placed 3.7 kilometers southeast of Little Egg Inlet. Bottom temperatures were 6.0° to 20.0° C and salinities were 26.0 to 30.5 ppt.

Abbott (1974) reported it was distributed from the Bay of Fundy to New Jersey and Europe. Loveland et al. (1969) noted that it was originally described from a collection taken in Great Egg Harbor, N. J. by Verrill and Smith (1873). They rediscovered it in Shark River in 1968. Our findings indicate it is established but uncommon in the coastal waters off New Jersey.

Tergipes tergipes (Forskäl 1775), (**Tergipes despectus** in Moore 1964, and in Franz 1968a)

Some 815 specimens were collected between 29 August 1972 and 6 December 1974 from a weather tower, buoy lines, and cement and masonite substrate panels located between 3.2 and 4.8 kilometers southeast of Little Egg Inlet. Bottom temperatures were 6.0° to 20.0° C and salinities were 29.0 to 31.0 ppt. Most specimens were found where *O. flabellata* was abundant and *T. crocea* was common.

Tergipes was reported previously from the Arctic to New Jersey and Europe and Brazil (Abbott 1974). Loveland et al. (1969) stated it was rare in New Jersey; the two previous records were from the Shark River.

Facelina bostoniensis (Couthouy 1838)

Three specimens were collected between 29 August 1972 and 8 October 1973 from lobster pots and a buoy line located between 3.2 and 4.0 kilometers southeast of Little Egg Inlet in depths of 9 to 10 m. Bottom temperatures were 19.0° to 22.0° C and salinities were 29.0 to 29.5 ppt.

Abbott (1974) gave its range as Nova Scotia to Connecticut. Rozsa (1974) reported specimens from Long Island, New York. These are the first reported from New Jersey.

Cratena pilata (Gould 1870)

Some 164 specimens were collected between 29 July 1972 and 5 August 1974 on lobster pots, buoy lines, and cement panels located 3.2 and 4.8 kilometers southeast of Little Egg Inlet at depths from 8 to 15 m. Bottom temperatures were 13.0° to 21.5° C and salinities were 30.0 ppt. Most specimens were collected where *T. crocea* was abundant.

It occurs from Nova Scotia to North Carolina (Abbott 1974) and has been reported from Barnegat and Delaware bays, New Jersey by Franz (1968a). Our findings indicate it is abundant in the coastal waters off Little Egg Inlet.

Aeolidia papillosa (Linné 1761)

Four specimens and several egg masses were collected on 11 June 1973 by SCUBA divers on a wreck approximately 8.8 kilometers southeast of Little Egg Inlet at a depth of 15 m. *Metridium senile*, the prey of *A. papillosa*, was abundant on the wreck. Bottom water temperature was 10.0° C and salinity was 30.5 ppt.

Its range in the Atlantic is from the Arctic to Maryland and Europe (Abbott 1974), and it has been reported from the Shark and Manasquan rivers, N. J. by Loveland et al. (1969). Our findings indicate that breeding populations exist in some coastal waters off New Jersey.

DISCUSSION

Of the 9 opisthobranchs collected from the study area, 6 are amphi-Atlantic (occur on both sides of the Atlantic) and 3 are west-Atlantic endemic. Franz (1970) concluded that 37% of the species north of Cape Hatteras are west-Atlantic endemics and our findings agree.

Of the amphi-Atlantic species, *A. pilosa*, *D. coronata*, and *T. tergipes* are boreal and successful reproduction cannot occur above 25° C (Franz 1970). In this study egg masses of *D. coronata* and *A. pilosa* were collected at 15° C and 16° C, respectively. *O. bilamellata*, *D. frondosus*, and *A. papillosa* are boreo-subarctic species and successful reproduction cannot occur at temperatures above 15-20° C. In this study egg masses of *A. papillosa* were found at 10° C.

Three factors contribute to successful establishment of northern nudibranchs in New Jersey. Temperature regimes near shore and in Little Egg Inlet favor boreal species. Bottom temperature never exceeded 25° C between March, 1972, and December, 1974. At depths greater than 15 m bottom temperature never exceeded 21° C, however, during the summer it was between 20 and 21° C about 12% of the time. One boreo-subarctic species was found reproducing below the summer thermocline and this is a suitable area for other boreo-subarctic species to inhabit.

Loveland et al. (1969) stated that nudibranchs and their eggs may be transported southward and become rapidly established on man-made structures in New Jersey. Some 95% of those collected in this study were from submerged man-made substrates.

In summer, 1973, small specimens of *O. bilamellata* and *D. frondosa* were collected on recently deployed substrates; this suggests they were transported by water currents. Charlesworth (1968) redrew maps from Bumpus (1965) which show the general southwest drift in the Middle Atlantic Bight. E. G. & G., Environmental Consultants (1974) found that the prevailing current in the study area in summer, 1973 was southwest with an average velocity of 12.1 km/day (surface) and 4.3 km/day (bottom). *D. frondosa* could drift from existing populations

in Shark River to Little Egg Inlet in less than 2 weeks. The southwest drift may transport eggs and young from northern populations and the availability of suitable habitats and thermal regimes in the study area facilitate their survival.

ACKNOWLEDGMENTS

This work is part of an ecological study for the proposed offshore Atlantic Generating Station sponsored by Public Service Electric and Gas Company of New Jersey. Martha M. McCullough, Jeffrey J. Hondo, and Charles B. Milstein collected many of the specimens. Dr. David R. Franz, Brooklyn College, confirmed the identification of *Acanthodoris pilosa* and *Lamellidoris fusca* and Dr. Larry G. Harris, University of New Hampshire, verified the identification of *Facelina bostoniensis*.

I thank Dr. David R. Franz and Dr. Edward C. Raney for reviewing the manuscript, Felicia A. Swiecicki for the figure, and Linda N. Dill for typing.

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NOTES ON OCCURRENCE OF *EUPLEURA SULCIDENTATA* DALL (GASTROPODA: MURICIDAE)

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ABSTRACT

Eupleura sulcidentata is reported from estuarine and coastal sites in southeast Florida, Cuba, and two Bahamian Islands, demonstrating that the species is not a west Florida endemic, and confirming Dall's original record from Cuba.

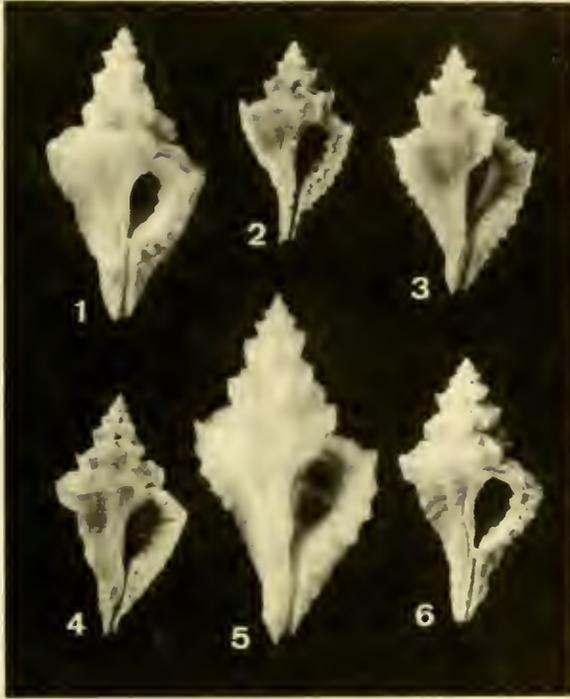
In 1972, I collected six freshly dead shells of *Eupleura* (Fig. 1) in beach drift along a sand spit at White Sound on the lagoonal side of Elbow Cay, Great Abaco, Bahamas. A literature search (part of an ongoing treatment of the shallow water Bahamian molluscan fauna) failed to reveal any Bahamian records of *Eupleura*, so specimens were sent to Dr. Emily Vokes, Tulane University, who identified them as *E. sulcidentata* Dall, 1890. The specimens are deposited in the Marine Research Laboratory invertebrate reference collection (FSBC I) at St. Petersburg.

In his original description, Dall defined the range of *E. sulcidentata* as "Gulf coast of Florida, shores of Cuba." Smith (1937) also listed Cuba within the range of the species, but Dall's Cuban citation was evidently considered erroneous by Johnson (1934), who listed only the Gulf coast of Florida and Florida Keys, and by Abbott (1954, 1968), who further restricted it to west Florida. Lyons et al. (1971) followed the latter in considering the species a west Florida endemic. Abbott (1974) listed *E. sulcidentata* at Bimini, Bahamas, revising its range to include both the west coast of Florida and Bimini. A report of *E. sulciden-*

tata from Caibarién, on the north central Cuban coast (Jaume and Sarasua, 1943) has evidently been overlooked by subsequent authors. Dr. Abbott suggested I contact Mr. J. C. Finlay, who allowed me to examine nine Cuban specimens (Figs. 2, 3) collected by him during 1957-1958 in depths of 3-4 m on the Varadero side of the Bay of Cardenas, about 200 km northwest of Caibarién. Mr. Dan Steger provided an additional specimen from Varadero. Mr. Finlay also provided three specimens (Fig. 4) collected off Rickenbacker Causeway, Biscayne Bay, Miami, Florida, during 1949-50. Most recently, I have examined 12 specimens (Fig. 5) collected by Mr. Gene Everson while night diving in depths of 5-6 m immediately off Lake Worth Inlet, north of West Palm Beach, Florida.

Eupleura sulcidentata occurs in estuaries along the entire Florida west coast. Tabb and Manning (1961) report specimens from Cape Sable and northern Florida Bay, Cooley (manuscript) has found the species at Pensacola Bay, and others have been reported at many points intermediate to these localities. The snails are common in Tampa Bay (Fig. 6), where they usually live on rocks over sand, on oyster reefs, or in grassbeds in higher salinity portions of the Bay; they also

¹ Contribution No. 290.



FIGS. 1-6. *Eupleura sulcidentata* Doll: Fig. 1 — Elbow Cay, Gt. Abaco (FSBC I 10131). Figs. 2, 3 — Cardenas Bay, Cuba (Finlay Coll.). Fig. 4 Biscayne Bay (Finlay Coll.). Fig. 5 — Lake Worth Inlet (Everson Coll.). Fig. 6 — Tampa Bay, Florida (FSBC I 2672). All figures $\times 2$.

occur near beaches where conditions remain essentially estuarine. Habitat near the beach at Elbow Cay included sand and turtle grass, (*Thalassia testudinum* König) with occasional rocks scattered throughout the area. Mr. Finlay states that he commonly dredged *E. sulcidentata* in 2-3 m on muddy sand in the Bay of Cardenas. At Biscayne Bay, specimens were "not infrequently found clinging to the outside of smooth objects such as bottles, cans, etc." Lake Worth Inlet specimens were found in shell rubble on sand, apparently similar to areas where the species occurs in nearshore waters of west Florida. The Bahamian, Cuban, and Biscayne Bay sites are relatively estuarine compared to other tropical habitats, but faunal assemblages differ considerably from those where *E. sulcidentata* occurs along west Florida.

Lake Worth Inlet may approach the northern range limit of *E. sulcidentata* on the Florida east coast. Extensive collecting by me at St. Lucie In-

let, 45 km to the north, has not produced this species, although its northern congener, *E. caudata* (Say, 1822) has been found there.

Mr. Finlay's specimens, as well as the report by Jaume and Sarasua, confirm Dall's original contention that *E. sulcidentata* is a component of the Cuban fauna. Specimens from Lake Worth, Biscayne Bay, and two Bahamian localities demonstrate that the range of the species is considerably greater than has been recently recognized.

ACKNOWLEDGMENTS

I thank Messrs. John C. Finlay, Newark, Delaware, the late Dan Steger, Tampa, Florida, and Gene Everson, Ft. Lauderdale, Florida, for graciously loaning specimens, and Mrs. Sally D. Kaicher, St. Petersburg, for preparing the figures. Dr. R. Tucker Abbott, Greenville, Delaware, provided additional information and comment. David K. Camp and Mark J. Poff kindly read the manuscript.

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NORTH AMERICAN LAND SNAILS IN ISRAEL

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ABSTRACT

Three North American land snails: Gastrocopta procera (Gould), Hawaiia minuscula (Binney) and Zonitoides arboreus (Say) are reported from Israel.

Recent investigations have revealed the presence of several North American land snails in Israel. Preliminary information is given in this report in the hope that more attention will be paid to other cases of introduced land mollusks in the Middle East.

The material on which this work is based was collected during field work carried out by the author in support of the land snail project of the "Fauna Palaestina Committee".

The following North American land mollusks were collected in Israel:

Gastrocopta (Gastrocopta) procera (Gould, 1840)

In December 1972 a few empty shells of this species were collected by Mr. S. Davis during a field trip of students of the Hebrew University of Jerusalem to the oasis of 'En Gedi, on the western shore of the Dead Sea. About one week later, very large numbers of this minute species were found in litter under palm trees in the irrigated palm gardens bordering the fields of kibbutz 'En Gedi by Prof. G. Haas, Mr. S. Davis, Miss T. Felsenburg and the author. More than ten thousand specimens were extracted from less than four kilograms of litter.

It was first identified as *Gastrocopta procera meclungi* (Hanna & Johnston, 1913) by Dr. L. Forcart, but according to Mr. L. R. Hubricht (per. comm.) all the specimens belong to the nominate species *Gastrocopta procera* (Gould). According to the latter, it is almost impossible to discriminate properly any subspecies within the species *G. procera* because of the many intermediate forms.

Hawaiia minuscula (Binney, 1840)

Like *Gastrocopta procera* this species was

found in large numbers in a litter sample taken in the irrigated palm gardens of kibbutz 'En Gedi. The identification of this species based on shell characters was confirmed by Dr. L. Forcart. Dr. A. Riedel later found the anatomy of a living specimen to agree in every detail with that of typical *H. minuscula*.

Zonitoides (Zonitellus) arboreus (Say, 1816)

Very large colonies of this species are present in the open tree nursery of kibbutz Netzer Sereni. Snails were first observed by the author in January 1970, but this species must have already been well established as thousands of living snails were present. The snails are living on and underneath containers (mainly tin cans) in which saplings of sub-tropical fruit trees are cultivated, in densities reaching 25 per container. Eggs and juveniles are found during the entire year, but are most numerous in the spring (March-May). With the sale of young trees, snails are transported to orchards and other nurseries.

The identification of *Z. arboreus* from kibbutz Netzer Sereni has been confirmed by Dr. L. Forcart and Dr. C. O. van Regteren Altena.

Recently additional specimens of *Z. arboreus* were collected by the author in an open greenhouse of the Old Botanical Garden of the Tel Aviv University near Abu Kabir, Tel Aviv (8 January 1975). A single specimen was found in a hothouse of the Botanical Garden at the Givat Ram campus of the Hebrew University of Jerusalem (5 June 1975).

DISCUSSION

Zonitoides arboreus is a well known greenhouse species which is widely distributed

over the whole world. (Pilsbry, 1946). It may have been introduced with plants imported from North America or from hothouses in Europe.

In the cases of *Gastrocopta procera* and *Hawaiiia minuscula*, there is a clear indication that they were imported directly from Southern California. Both species were found in litter under palm trees which were directly imported from a nursery in the Coachello Valley in the Salton Lake area. According to Pilsbry (1948) this species was not known to live outside America.

From the large numbers in which these three species have been collected, it is clear that all have adapted very well under the artificial conditions in Israel. Further passive dispersal of *Zonitoides arboreus* is currently going on. However, there is no positive data available regarding the presence of this species in other

nurseries or orchards in Israel. Further dispersal of *Gastrocopta procera* or *Hawaiiia minuscula* seems very unlikely, as both are living in the isolated oasis of 'En Gedi in the Judean Desert, and there only in irrigated palm gardens.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Dr. L. Forcart (Basel), Dr. C. C. van Regteren Altena (Leiden), Dr. A. Riedel (Warszawa) and Mr. L. R. Hubricht (Meridian) for their help in the identification of the discussed material.

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EFFECT OF UPWARDLY-DIRECTED SHELL APERTURE ON THE AESTIVATING LAND SNAIL *ACHATINA FULICA*

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Water conservation is a serious problem in land snails. Aestivation is the normal mechanism to tide over the adverse conditions during dry seasons in temperate and tropical countries.

Studies on the orientation of the shell aperture in hibernating snails are very few. An upwardly directed aperture during hibernation is common in many land snails (Binney, 1851), in *Mesodon thyroideus* and *Allogona profunda* (Blinn, 1963), and commonly upward in *A. ptychophora* (Carney, 1967). A pronounced effect is expected in specimens with long periods of aestivation, which is supported from the studies on *Achatina fulica*.

METHODS AND MATERIALS

Three cages measuring 600 x 450 cm and 240 cm high were erected in a shady place in the

campus of Calcutta University at Ballygunge. Sized wood, 7.5 x 5 cm thick, and of appropriate length were used. The posts were fixed in the soil with concrete bases. The sides and the ceiling were covered with 1-cm expanded metal net. The soil of the floor of the cages was loosened with forks.

A limited amount of water was sprayed on the soil on October 13 and 14, 1974. Then 200 healthy, active, juvenile and adult *Achatina* collected from their natural habitat were released in each of the cages No. 1 and 2. The snails were acclimatized for 18 days and water was regularly sprayed during the period to keep the soil sufficiently moist and maintain a high percentage of humidity in the cages. Favourite food was supplied in excess and strict hygienic conditions were maintained. The

snails were vigorously active in the period of acclimatization.

To simulate the natural habitat of *Achatina*, water-spraying was stopped on 2nd November, but the food supply was continued.

OBSERVATIONS

Nov. 7, 1974: Most of the snails in both the cages were partially buried in the soil or moving to a corner indicating preparation for aestivation. Some of the snails started moving up the frame of the cage but they were brought down and released on the soil.

Nov. 11, 1974: The rest of the snails became inactive.

Nov. 13, 1974: Epiphragm was formed in all specimens. In all cases the shell aperture was directed downward.

Nov. 17, 1974: The aestivating snails in cage No. 1 were turned upside down, i.e., the aperture was directed upwards. The snails of the cage No. 2 were left undisturbed.

There was no rainfall until February, 1975, when there occurred a total rainfall of 10.2 mm in 5 days at certain intervals. Feb. 11, 1975: rainfall 3.9 mm. Feb. 12, 1975: rainfall 3.2 mm.

The humidity in February was maximum 95%, minimum 35%. Temperature mean maximum 27°, mean minimum 15.5°.

Feb. 12, 1975: 173 snails became active in cage No. 1. The remaining were already dead. Four specimens pushed out the epiphragm but soon died. 114 snails became active in cage No. 2. Ten snails were found dead under the epiphragm.

In a few days the snails in both the cages underwent aestivation, all with the aperture downward. The snails of cage No. 1 were again turned upside down, so that the aperture faced upward.

The month of March was dry. In the following month the total rainfall was 5.1 mm in 4 days. Apr. 25, 1975: Rainfall 3.2 mm; Apr. 26, 1975: Rainfall 1.6 mm. The humidity in April was maximum 91% and minimum 19%. Temperature mean maximum 35.4°, mean minimum 24.8°.

Apr. 26, 1975: 107 snails became active in cage No. 1. They were immediately transferred to cage No. 3. 76 snails were active in cage No. 2. Apr. 27, 1975: 55 snails were dead under the

epiphragm, the foot and head of 11 snails were pushed out of the shell and died in that state in cage No. 1, and dead snails counted were 26 in cage No. 2.

The snails in cages 3 and 2 aestivated within a few days with the aperture downward. The snails of cage No. 3 were again turned upside down.

A weak monsoon appeared in the first week of June and with heavy showers in the middle of the month all live snails in the cages became active. The number dead was 44 in cage No. 3 and 56 in cage No. 2.

DISCUSSION

The aestivation period in Stylommatophora differs with species and the country where they live. For *Achatina*, the period is long between the rains in Mauritius and Ceylon (Green, 1910; Hutson, 1920); during the dry spell in Singapore (South, 1926); November to March in Hong Kong (Herklots, 1948); November to June in India (Ghose, 1959) and February to March in Hawaii (Kondo, 1964). *Helicella virgata* aestivate for about 5 months in Australia (Pomeroy, 1968), while the period is only 2 months during summer for *Macrochlamys glauca* in India (Hora, 1928). *Ariophanta* is reported to aestivate in summer in India (Hora and Rao, 1928) but the duration is not on record.

Observations on the orientation of shell aperture during hibernation in cold countries are on record (Binney, 1851; Blinn, 1963; Carney, 1967). The sole information on the influence of orientation of shell aperture during aestivation in *Allogona ptychophora* is that of Carney (1966) in Montana, U.S.A., where the snails are covered with snow for sometime.

The main function of epiphragm appears to be conservation of water. Both permeable and non-permeable epiphragms have been reported in different Stylommatophora. The epiphragm is perforated in *Helix aspersa* (Allman, 1894-95), but Smith (1899) recorded no perforation in the epiphragm of *H. aspersa* and *H. pomatia*. Rees (1964) considers the epiphragm of *H. pomatia* as slightly permeable. Perforations on the epiphragm have been reported from *Thaumastus sangoae* (Smith, 1904), *Gessula hastula* and *Zootecus insularis* (Hora, 1928) but these are

lacking in *M. glauca* (Hora 1928). The epiphragm of *Achatina* is not permeable and a narrow slit-like opening in the epiphragm against the pneumostome maintains communication between the lung and the atmosphere. Smith (1899), however, states that the slitlike structure in *A. immaculata* is closed.

Loss of water, though in small amounts, is associated with a reduced rate of respiration during aestivation. It appears that to minimize the loss further the shell aperture in *A. fulica* is placed against the substratum, be it soil or some other substance. The air locked in between the epiphragm and the soil is considerably cooler than the surrounding air. After two months of aestivation and a week after a shower, considerable amount of moisture in the expired air condenses into small drops of water on the epiphragm. In specimens with upturned apertures such phenomenon was totally absent.

In *Allogona ptychophora* the mortality rate is normally 15.8%, but in specimens turned upside down it is 36% (Carney, 1966). In *Achatina*, the normal mortality percentage was 46 but increased to 68.5 in the upside down group.

It appears that the method of aestivation with the aperture of *Achatina* placed against the soil is an adaptation towards conservation of water to the highest possible degree.

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AMERICAN MALACOLOGICAL UNION



1977 ANNUAL AMU MEETING—The Naples Shell Club will host the A.M.U. during its 42nd Annual Meeting July 11-15, 1977. There will be a symposium on the Evolution of Mollusca, as well as regular papers. Contact President George M. Davis, Academy of Natural Sciences of Philadelphia, 19th and the Parkway, Philadelphia, Pa. 19103. Accommodations will be in the spacious Naples Beach Club Hotel (\$19 single; \$22 double). Contact Jerome M. Bijur, 135 Seventh Avenue North, Naples, Fl. 33940. Detail notices are being mailed to A.M.U. members.

THE ASIATIC CLAM, *CORBICULA MANILENSIS*,
AS A FOOD OF THE NORTHERN RACCOON, *PROCYON LOTOR*

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In the growing mass of literature concerning the Asiatic clam, *Corbicula manilensis* (Philippi), few references have been made to their use as a food item by other organisms. Lowery (1974) noted in his mammal survey of Louisiana that the northern raccoon, *Procyon lotor* (L.) utilizes many molluscs in its diet. Many small streams in West Virginia attest to this habit as sand bars in these streams are often littered with many broken, empty shells of bivalves surrounded by footprints and scats of *P. lotor*. The present note reports the use of *C. manilensis* as a component in the diet of *P. lotor* in West Virginia.

Shells of *C. manilensis* were found in great numbers along the southern bank of the Ohio River, adjacent to a marsh, 2 miles north of

Lesage, Cabell County, West Virginia, in September 1976. Many of the shells were broken and found in scattered heaps. Surrounding the shells were the footprints and scats of *P. lotor*. Analysis of the scats revealed the presence of shell fragments and one intact valve of a young *C. manilensis*, as well as assorted varieties of seeds.

Voucher specimens have been placed at the Delaware Museum of Natural History (DMNH 111490).

LITERATURE CITED

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THE ASIATIC CLAM, *CORBICULA MANILENSIS*
IN THE ILLINOIS RIVER

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ABSTRACT

In 1974-75, specimens of the Asiatic Clam, Corbicula manilensis, were collected at six locations on the Illinois River. Age determinations of clams collected suggest that Corbicula first appeared in the Illinois River in 1970-71.

Recent collections of the introduced Asiatic clam, *Corbicula manilensis*, at six locations on the Illinois River indicate a rapid range extension into this river system. On 23 August 1974, we found 3 non-living shells of *Corbicula* on the gravel shore of the Illinois River just downstream

from the ferry landing at Kampsville, Calhoun County, Illinois (Illinois River mile 32.0).¹ The second find was made on 18 September 1974 at

¹ River miles above the confluence with the Mississippi River as recorded in Charts of the Illinois Waterway, 1970, U. S. Army Corps of Engineers.

Turkey Island Chute, Illinois River above Kingston Mines, Fulton County, Illinois (River mile 148.3). As before, the specimens were collected on shore—this time in a concentration of dead and weathered mollusk shells. In all, 12 individuals were collected at Turkey Island, 6 of which contained tissue. Three specimens were tightly closed and were found at water's edge, suggesting recent desiccation. On 28 October 1974, a third collection of 6 dead shells was made at the lower end of Bath Chute, Illinois River below Bath, Mason County, Illinois (River mile 106.7). Once again, all specimens were found on shore in a deposit of dead mussel shells. Clam collections were made after a rapid July-August drop in pool water levels of 18 feet at Bath and Kingston Mines and 8 feet at Kampsville. Prior to this, the nearest previous locality record was for the Mississippi River at Granite City, Madison County, Illinois—first appearing there in 1965 (Thomerson and Myer, 1970). Three new records were made in 1975: four specimens were found on-shore at Upper Bath Chute (Illinois River mile 113.5) on 20 August, 1975. They ranged in shell length from 10 to 14 mm, indicating they were two-year-old clams. One live individual was collected with an Eckman dredge from Sugar Creek Island Chute (Illinois River mile 95.0) on 3 September, 1975. Shell length was 8 mm, also a clam of the second-year-class. One other live specimen was collected by Eckman dredging at Sugar Island Chute (Illinois River mile 260.5) on 25 September, 1975. It was 12 mm long, a two-year-old individual.

Other known Illinois records include the entire length of the Ohio River bordering Illinois; at two localities on the Wabash River—below New Haven, Gallatin County and below Rising Sun, White County (Parmalee, 1965); Granite City, Madison County (Thomerson and Myer, 1970); the Kaskaskia River near Baldwin, Randolph County, 25 miles above the confluence with the Mississippi²; Crab Orchard Lake, Williamson County³; and at Lake Sangchris, a 2700-acre Com-

monwealth Edison power company impoundment near Springfield, Sangamon County³. At this latter site, *Corbicula* has impeded water flow in the plant cooling system.

National distribution records have been compiled by Sinclair (1971). A recent discovery near Lansing, Iowa (Eckblad, 1975) establishes the northernmost extent of *Corbicula* in the Mississippi River System and the Midwest. It is noteworthy that *Corbicula* at Lansing occurs in heated effluent from a power plant. Also, the Illinois River in the vicinity of our collection sites is warmer than the Mississippi at approximately the same latitude. In 1973 during the period 1 November to 28 February, there were 103 days when the water temperatures were measured on the same days on both the Mississippi River at Alton, Illinois and 75 miles north on the Illinois River at LaGrange (River mile 80.2) (USGS, 1973). Even though the Illinois River location was farther north than the Mississippi River station, there were only 19 days when the minimum daily temperature was at the freezing point on the Illinois and 36 days at the freezing point on the Mississippi. The yearly mean temperature on the Illinois at Havana (River mile 119.6) was 55° F. while the Mississippi at Keokuk, Iowa, at approximately the same latitude was 49° F. (Illinois EPA, 1972). The thermal tolerance and preference of *Corbicula* need to be determined before any definitive statements can be made about the probable northern limits of its range extension.

Identification of *Corbicula manilensis* was made by descriptive characters given by Sinclair and Isom (1963) and Burch (1972). Shell length measurements were made on all specimens and compared with published growth values (Sinclair and Isom, 1961) for approximate age determination. All three valves found at the Kampsville location were 12 mm in length indicating they were clams of the second "year-class". Of the specimens taken at Turkey Island seven ranged from 12-18 mm and five ranged from 20-26 mm, two- and three-year-old clams. Valve lengths for the Bath Chute collection ranged from 17-29 mm, also two- and three-year-old specimens, with the largest individual, 29 mm, possibly representing the fourth year-class. If the clams collected in the

² Personal communication, Mr. Donald W. Dufford, Aquatic Biologist, Illinois Natural History Survey.

³ Personal communication, Dr. R. Weldon Larimore, Aquatic Biologist, Illinois Natural History Survey.

Illinois River are considered to be representative. *Corbicula* first occurred in the river in 1970-1971.

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BOOK REVIEW

Pseudothecosomata, Gymnosomata and Heteropoda (Gastropoda). By S. van der Spoel. 1976. 484 pp., 246 figs. Bohn, Scheltema and Holkema, Utrecht. Hardback, \$60.00 U.S.

This book serves to bring together most of the current information on the pelagic pteropods and heteropods. A large mass of data, identification keys and drawings, and distributional maps will assist oceanographers working on plankton. The bibliography is extensive. The book, however, is difficult to use.

The several indices are tucked away in various places in the text, and upon finding a reference the reader is led, not to a page number, but to a species number located on pages 16-22. Finally at this point the figures, maps and page numbers are revealed. The main treatment of a species does not give any geographical information, nor a reference to the proper maps at the end of the book. One must search first among the systematic table of contents to find a reference to the maps.

The nomenclatorial treatment of the heteropods is very unsatisfactory, with a few names being entirely ignored, such as *Atlanta inflata* Orbigny, 1836. The *Atlanta* names legitimately proposed by Orbigny in 1836, Mandralisca in 1840 and J. E. Gray in 1850 are erroneously considered to be *nomina nuda* (*tesselata* [sic] Gould, 1852 and *pulchella* Verrill, 1884), presumably in an attempt to conserve certain better-known names. However, Gray's 1850 *Cavolinia* names are accepted. The genus *Microdonta* Bonnevie, used by van der Spoel, is three times a homonym, and should be replaced by *Prionoglossa* Tesch, 1950.

Some additional illustrations of recently described, shelled pteropods and newly recognized forma are included with convenient keys. The new subfamily Glebinae is proposed in the Cymbuliidae.

R. Tucker Abbott
Delaware Museum of Nation History



*Portrait of Allyn G. Smith taken in 1955
by Moulin Studios of San Francisco.*

OBITUARY

ALLYN GOODWIN SMITH, 1893-1976

With the passing of Allyn G. Smith on August 18th, 1976, malacology lost one of its most admired and knowledgeable students of West American mollusks. Born June 4, 1893, in Hartford, Connecticut, Allyn went to California in 1908, and later attended the University of California at Berkeley, receiving a B. S. in Electrical Engineering in 1916. After serving in the U. S. Army in World War I, he returned to his

Alma Mater, to chair the Technical Department in the Extension Division (1920-1924). In 1925, he joined the Pacific Telephone and Telegraph Co., where he held the title of Supervisor of Personnel at the time of his retirement in 1955.

His special interests in pulmonate gastropods and the chitons was initially generated by his close friend, S. Stillman Berry, who fondly refers to him as "one of my boys". He also knew the Californian malacologist, Josiah Keep. During his business career Allyn devoted much of his spare time to field work, and he contributed numerous malacological articles to journals. A major contribution was a survey of "The Marine Mollusks and Brachiopods of Monterey Bay, California and Vicinity" (with Mackenzie Gordon, Jr.) published in 1948.

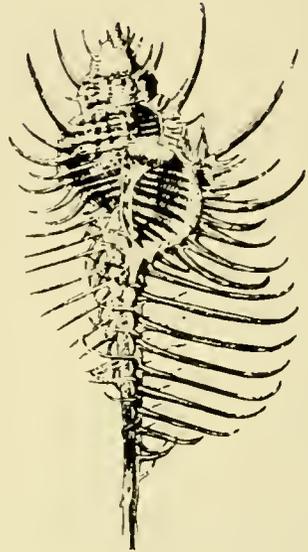
Upon his retirement, he had hoped to devote full time to research, but his administrative talents were drafted by the California Academy of Sciences, where he had served as a Research Associate in Malacology since 1939. There he started a new career in the capacity of Executive Assistant to the director, 1955-1960, and as Chairman and Associate Curator, he later revitalized the Department of Invertebrate Zoology, 1960-72. Despite these duties, he prepared the section on "Amphineura" for the *Treatise on Invertebrate Paleontology*, 1960, and he continued publishing and field work, including participation in the Galapagos International Science Project in 1964. Author of 104 papers, two of which appeared in 1976, he was active until shortly before his death.

An energetic and compassionate man of many interests and achievements, Allyn will be sorely missed by his many friends and colleagues. He leaves his wife, Katharine, and three children.

*William K. Emerson, Curator of Mollusks
The American Museum of Natural History
New York, New York*

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AN ILLUSTRATED GUIDE TO THE MURICIDAE.
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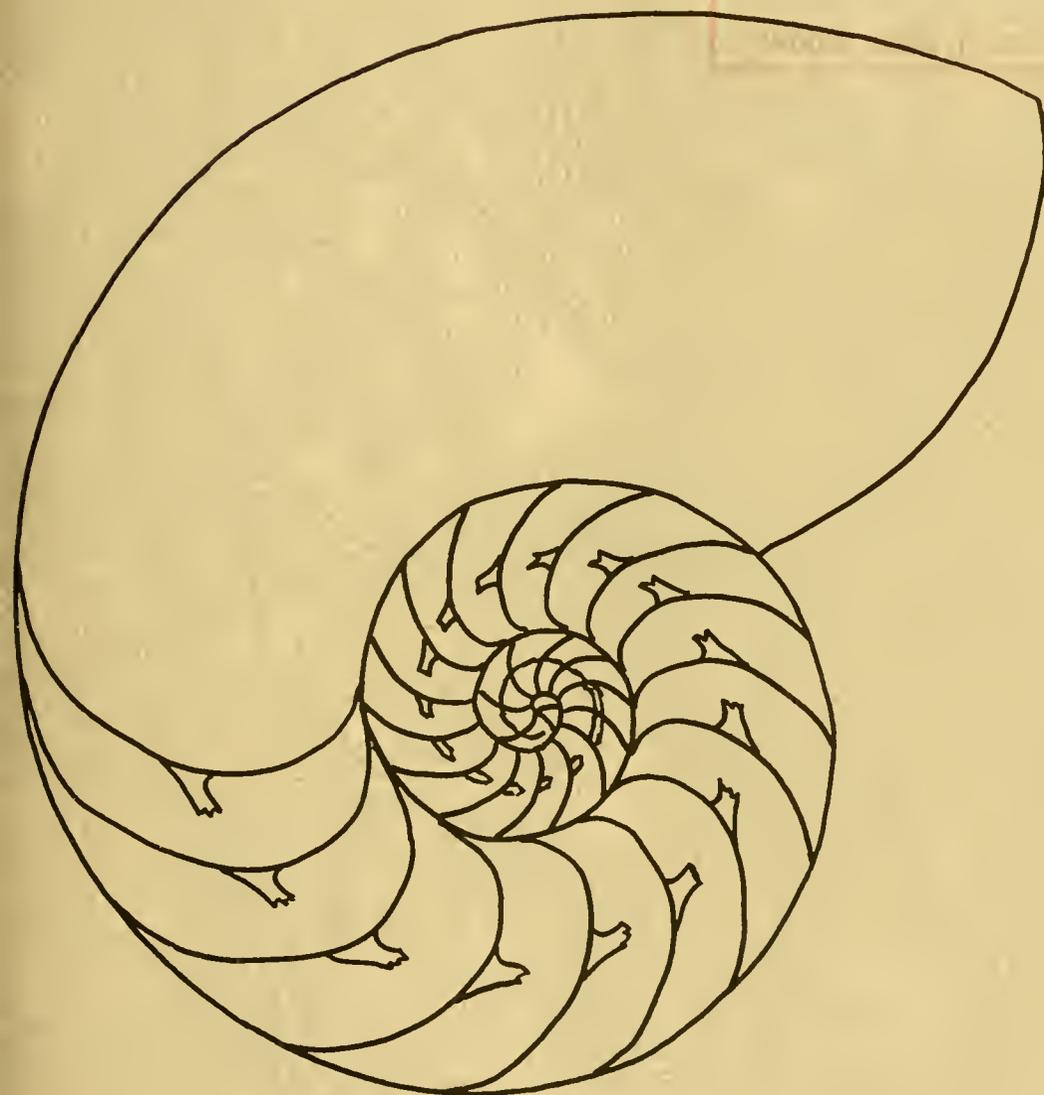
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DESHAYES' TEREBRID TYPES IN ÉCOLE DES MINES, PARIS

Twila Bratcher

8121 Mulholland Terrace
Hollywood, Ca. 90046

It has been well over a hundred years since Gérard Paul Deshayes published his descriptions of 95 new terebrid taxa. The 33 species published in 1857 in the *Journal of Conchyliologie* were written with surprising detail for that period. Those written by most of his contemporaries were sketchy descriptions in Latin and could fit any number of species. Deshayes followed his Latin descriptions with excellent word pictures in French of the species he was describing. Deshayes must have loved each species he described. He discussed them with such phrases as "beautiful and precious," "this very beautiful and remarkable species," "charming species." In one description he said, "All the shell is smooth, polished, shining as though it were made of porcelain." The figures in his 1857 monograph are exceptionally good in quality and detail.

The 62 taxa Deshayes described in the Proceedings of the Zoological Society of London, 1859, are less easy to evaluate. Although the Latin descriptions are somewhat more detailed than most of that period, they were not followed by his fine French descriptions. They were published without figures. Some of the taxa were subsequently figured by Reeve. Some have never been figured. In all his descriptions Deshayes stated whether the material was from the Cuming collection, now in the British Museum (Natural History), or from his own collection, now in the École des Mines, Paris. In 1944 in his "Deshayes' Review of *Terebra* in the *Journal of Conchology*," Tomlin stated, "Probably there is more synonymy to be worked out with regard to Deshayes' new species. It would be a great advantage to get the types at the École des Mines overhauled."

When I visited the École des Mines in the spring of 1975, I located nine of the holotypes and one probable holotype in the Deshayes collection. Deshayes' detailed French descriptions, in addition to his original measurements, made this task

easier than it might have been. Because of his careful attention to detail, specimens differing substantially in measurement from those published by Deshayes could not be accepted as holotypes. An exception was *Terebra eximia* Deshayes, 1859. Deshayes' measurements were 92 x 8 mm, which is evidently a misprint. The specimen which appears to be the holotype measures 46 x 8 mm. It is obvious that if a specimen of this species should reach a length should reach a length of 92 mm, the diameter would be greater than 8 mm.

Some of the Deshayes taxa represented as being from his own collection could not be found at all. The measurements of some differed substantially from the original Deshayes measurements, and are here considered paratypes.

TEREBRIDS FROM DESHAYES' COLLECTION

Terebra archimedis Deshayes, 1859, holotype, fig. 1 & 1A. Not previously figured. Dimensions 31 x 5.8 mm. Original measurements 31 x 6 mm. In his description Deshayes stated that this species was represented in his collection only. Therefore I believe the specimen in the École des Mines is the holotype rather than the specimen in the British Museum (Natural History) cited as the type by Cernohorsky (1969) which measures 32.7 mm in length. Type locality unknown. This is conspecific with the Indo-Pacific species, *T. funiculata* Hinds, 1844, and *T. langfordi* Pilsbry, 1921, as there are integrades between the forms. Schepman illustrated *T. archimedis* in his Siboga Expedition report, but the figure was of the *funiculata* form rather than the *archimedis* form.

Terebra approximata Deshayes, 1859. No figure was published. Type locality unknown. Reeve considered this taxa to be a junior synonym of *T. undulata* Gray, 1834, a fairly common Indo-Pacific species. No specimens of this taxa were found in the Deshayes collection.

Terebra argenvillii Deshayes, 1859. No figure was published. Type locality unknown. Reeve places this taxa in synonymy with *T. strigilata* Linnaeus, 1758. No specimens of this taxa were found.

Terebra chilensis Deshayes, 1859, holotype, fig. 2. No figure previously published. Dimensions 40.2 x 7.9 mm. Original measurements 42 x 8 mm. Type locality Chile. This is a synonym of *T. gemmulata* Kiener, 1839, a rare species reported from Chile, Patagonia, and Brazil.

Terebra chinensis Deshayes, 1859. No figure was published. Type locality is China Seas. Reeve considered this conspecific with *T. cingulifera* Lamarck, 1822, a common Indo-Pacific species. No specimens of this taxa were found.

Terebra columnaris Deshayes, 1859. No figure was published. Type locality unknown. Reeve con-

sidered this conspecific with *T. cingulifera* Lamarck, 1822, as did Tryon. No specimens of this taxa were found.

Terebra crassula Deshayes, 1859, paratype, fig. 3. No figure was previously published. Dimensions 23.6 x 5.2 mm. Original measurements 27 x 7 mm. Differences of measurements are sufficient that this must be considered a paratype. Type locality unknown. This is a synonym of *Hastula hastata* (Gmelin, 1891), a common western Atlantic species.

Terebra crossei Deshayes, 1859, holotype, fig. 4. No figure was published previously. Dimensions 24 x 5 mm. Original measurements 23 x 5 mm. Type locality Indian Ocean. This is a synonym of *Hastula penicillata* (Hinds, 1844) a common Indo-Pacific species.

Terebra difficilis Deshayes 1859. Figured by Reeve, *Conch. Icon.* vol. 12, pl. 18, fig. 86. Type locality unknown. Reeve said of this species, "a shell of solid growth, partaking somewhat of the character of *T. larvaeformis*, in which the fine ribs are so crowded as almost to lap one on the other. It comes even nearer to *T. souleyti*." Tryon said it is conspecific with *T. cancellata* Quoy & Gaimard, 1832. No specimens were found in the Deshayes collection.

Terebra dispar Deshayes, 1859. Figured by Reeve, pl. 25, fig. 137. Type locality unknown. Reeve said, "shining-white, semi-transparent. Very closely resembles *T. micans*." Tryon said it equals both *cinerea* (Born, 1778) and *aciculina* (Lamarck), two species which are quite distinct from one another. No specimens found in the Deshayes collection.

Terebra eximia Deshayes, 1859, probable holotype, fig. 5. Figured by Reeve, pl. 21, fig. 106. Dimensions 46.2 x 8 mm. Original measurements 92 x 8 mm, evidently a typographical error. Type locality unknown. This is conspecific with *T. corrugata* Lamarck, 1822.

Terebra fimbriata Deshayes, 1857, holotype, fig. 10. Figured by Deshayes, pl. 5, fig. 1. Length 88.6 mm. Original measurements 88 x 19 mm. Type locality unknown. There is a paratype in the British Museum (Natural History). This taxa is a

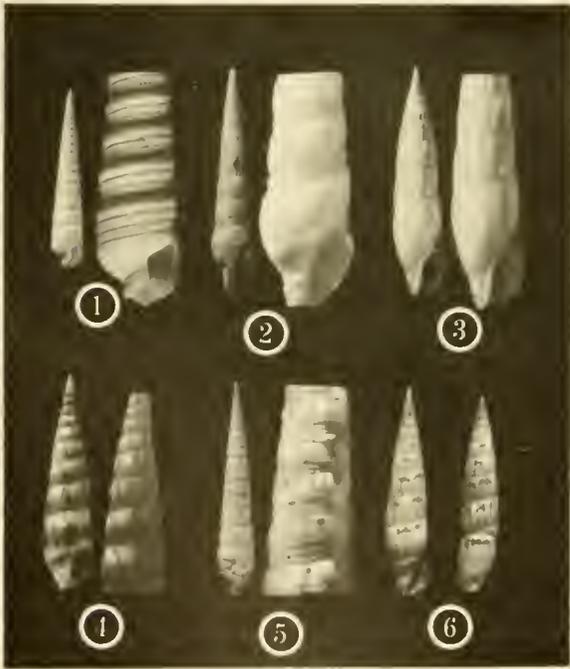


FIG. 1. *Terebra archimedis* Deshayes, 1859, holotype.
 FIG. 2. *Terebra chilensis* Deshayes, 1859, holotype.
 FIG. 3. *Terebra crassula* Deshayes, 1859, paratype.
 FIG. 4. *Terebra crossei* Deshayes, 1859, holotype.
 FIG. 5. *Terebra eximia* Deshayes, 1859, holotype.
 FIG. 6. *Terebra matheroniana* Deshayes, 1859, holotype on left, paratype on right.

junior synonym of *T. crenulata* Linnaeus, 1758.

Terebra glabra Deshayes, 1857. Figured by Deshayes. Type of locality is China Seas. No specimen was found in the Deshayes collection in the Ecole des Mines. There is a specimen in the British Museum (Natural History) marked Type, *T. glabra*, which is obviously erroneous. Cernohorsky (1969) pointed out that "The specimen present in the Cuming collection and measuring 43.3 mm in length (original measurement 70 mm) is not the type; the holotype is probably in the École des Mines in Paris". The specimen in the British Museum is a worn specimen of *T. consors* Hinds, 1844, and Tomlin said it equals *T. consors*. Deshayes said in shape, size, and coloration it more nearly resembles *T. cingulifera* Lamarck, 1822. He also stated that the shell is all white or of a white washed with pale beige. He made no mention of the yellow blotches typical of *T. consors*. Tomlin made his evaluation from the specimen in the British Museum, and whether that specimen is the same species as Deshayes' *T. glabra* probably will not be known unless the Deshayes holotype is found.

Terebra histrio Deshayes, 1857. Figured by Deshayes. Type locality unknown. Reeve and Tomlin both mention that the type is cited from the Deshayes collection but that there was one in the Cuming collection which is merely a form of *T. corrugata* Lamarck, 1822. Neither Deshayes' description nor his figure is that of *T. corrugata*. No specimen found in the Deshayes collection.

Terebra matheroniana Deshayes, 1859, holotype, fig. 6 paratype, fig. 6 (right). Not previously figured. Dimensions 17.4 x 3.3 mm. Original measurements 18 x 3 mm. Type locality Tahiti. This is a species about which there has been much confusion. E. A. Smith considered it a good species and Tomlin agreed, citing *Terebra lauta* Pease, 1869 as a synonym. I agree with that. Reeve considered *T. matheroniana* a synonym of *T. aciculina* Lamarck, 1822, to which it bears no resemblance.

Terebra obsoleta Deshayes, 1859, holotype, fig. 7. Figured by Reeve, pl. 21, fig. 107. Dimensions 38.9 x 7 mm. Original measurements 40 x 7 mm. Type locality unknown. Reeve mentioned that this shell had indications of a brown band at the base

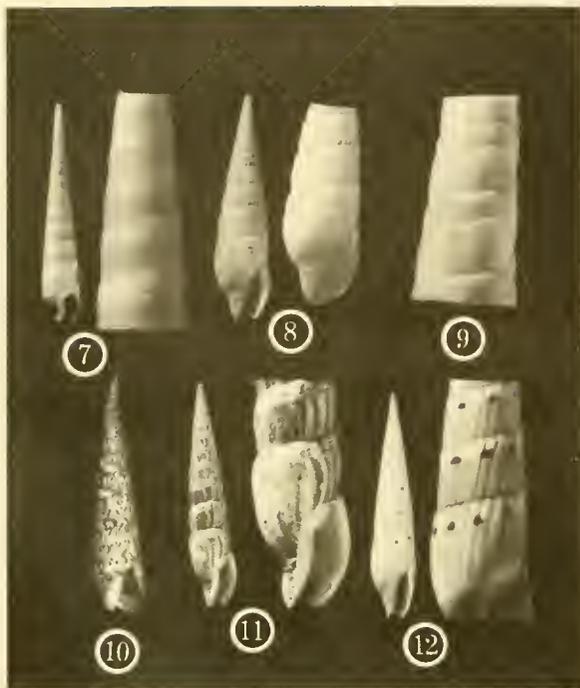


FIG. 7. *Terebra obsoleta* Deshayes, 1859, holotype.
 FIG. 8. *Terebra puncticulata* Deshayes, 1859, holotype.
 FIG. 9. *Terebra splendens* Deshayes, 1859, holotype.
 FIG. 10. *Terebra fimbriata* Deshayes, 1857, holotype.
 FIG. 11. *Terebra subangulata* Deshayes, 1859, holotype.
 FIG. 12. *Terebra verreauxi* Deshayes, 1857, holotype.

which may have faded during the last hundred years.

Terebra puncticulata Deshayes, 1859, holotype, fig. 8. Previously figured by Reeve, pl. 20, fig. 99. Dimensions 24.6 x 6.2 mm. Original measurements 25 x 6 mm. Type locality unknown. Synonyms: *T. flava* Hinds, 1844 (non Gray, 1834); *T. lutescens* E. A. Smith, 1873.

Terebra souleyeti Deshayes, 1859. Figured by Reeve, pl. 17, fig. 78. Type locality Gulf of Mexico. No specimens found.

Terebra splendens Deshayes, 1857, holotype, fig. 9. Figured by Deshayes, pl. 5, fig. 11. Dimensions 73.8 x 12.6 mm. Original measurements 75 x 12 mm. Type locality is China seas. This is *T. dimidiata* Linnaeus, 1758.

Terebra semidecussata "Deshayes". This is evidently a manuscript name. It equals *T. dislocata* (Say, 1822).

Terebra subangulata Deshayes, 1859, holotype, figs. 11. Previously figured by Reeve, pl. 18, fig. 87. Dimensions 33.6 x 6.8 mm. Original measurements 34 x 7 mm. Type locality unknown.

Terebra verreauxi Deshayes, 1857, holotype, figs. 12 & 12 A. Figured by Deshayes, pl. 5, fig. 3. Dimensions 37.9 x 7.8 mm. Original measurements 38 x 9 mm. Type locality unknown. This is a synonym of *Hastula strigilata* (Linnaeus, 1758).

ACKNOWLEDGMENTS

I am indebted to the personnel of the École des Mines in Paris, particularly Mme. E. Fatton, for the privilege of working with and photographing the *Terebridae* in the Deshayes collection and for help through correspondence since my return. I also wish to thank Sally Kaicher for her advice on shell photography and for her work in making prints for publication from my negatives taken at the École des Mines; Dr. James McLean for his comments and suggestions regarding this manuscript; and Dr. R. Tucker Abbott for the use of his picture of the holotype of *Terebra fimbriata* Deshayes.

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THE INVASION OF ASIATIC CLAM, *CORBICULA MANILENSIS* IN THE NEW RIVER, VIRGINIA

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ABSTRACT

Corbicula manilensis appears to have successfully invaded the New River at Glen Lyn, Giles County, Virginia in 1975. Mean population densities of 18 *Corbicula*, m^{-2} were recovered downstream from a coal-fired generating plant while 29 individuals m^{-2} were found immediately upstream. This seems to be the present limit of *Corbicula* immigration in the New River as no specimens were taken from sampling sites farther upstream. Relationships between shell dimensions and shell weights, and viscera wet and dry weights were calculated from the one size "year class" present. Correlation coefficients ranged from 0.9683 for shell length and viscera wet weight to 0.6135 for shell dry weight and viscera dry weight.

INTRODUCTION

The present paper is the first report of *Corbicula manilensis* Philippi in the New River, Virginia, and to our knowledge, only the second report of *Corbicula* in this state (Diaz, 1974)¹. Until recently, extensive investigations of benthic macroinvertebrates of the New River (considered by many to be the second oldest river in the world) and its tributaries had not reported any specimens of this clam. The range extension of the Asiatic clam up this river is being carefully monitored, since the New River is an important source of water for various industries and municipalities. The biology of this organism and its relationships to other benthic and molluscan fauna can be studied, since pre-invasion data are available and this potential problem was revealed in its infancy.

MATERIALS AND METHODS

Forty specimens of *Corbicula manilensis* were

randomly selected from quantitative collections starting on 12 October 1976, from sites above and below a coal-fired generating plant located on the New River at Glen Lyn in Giles County, Virginia (latitude—37°22'20", longitude—30°51'45", river mile 95) (Fig. 1). The upriver station was established 45 m above the intake pump station through which water is drawn for condenser cooling in the power plant. The plant generating capacity is approximately 300 MW with a maximum of 340 MW. After passage through the plant, the heated water may be raised to a maximum of 8 C above ambient; however, during these collections there was a 3 C difference between the upriver and downriver stations (13 C and 16 C respectively). The substrate was characterized by gravel, sand and silt with sand and silt comprising minor portions (after Hynes, 1970). The downriver station was located approximately 50 m below the pipe through which the heated water is discharged. The heated effluent was usually chlorinated three times daily to control biofouling of the condenser pipes. At this station, the substrate ranged from cobbles and pebbles to very fine sand with a predominance of the former. During sampling, water depth at both

¹ The Delaware Museum of Natural History has numerous adult specimens collected in 1974 by Mrs. Betty Piech near Lanexa, Virginia, in the Chickahominy River which flows into the James River.

stations ranged from 0.5 to 0.9 m with average flows of 18-21 cm sec⁻¹. Alkalinity (as CaCO₃), pH and turbidity were 39 mg l⁻¹, 7.80 and 35.0 Jackson Turbidity Units, respectively.

Samples were taken at each station using a 0.25 m² quadrant and a net to a depth of 15 cm. Clams were picked from each sample, counted, placed in water on ice and transported to the laboratory for further analyses. Travel time was less than two hours and samples were processed immediately. Dimensions and weights were determined as described by Joy and McCoy (1975).

RESULTS AND DISCUSSION

The invasion rate of *Corbicula* in the Upper Ohio and Kanawha River Drainage basin can be estimated from available reports. Due to the distinctive morphology of the adults and larvae, the Asiatic clam is easily and likely to be distinguished from indigenous bivalves. A collection of *Corbicula* reported from Chelyan, West Virginia, (Fig. 1) indicated, by size "year classes," that a population had been established there since 1961 (Thomas and Mackenthun, 1964). A subsequent collection in Cabell County, West Virginia, was made in 1973 (Joy and McCoy, 1975). If the downriver area is the source of propagules for the population becoming established at Glen Lyn, Virginia, the clams would have traversed a distance of about 138 river miles in a period of 15 years, or an average rate of about 9 miles year⁻¹. Several physical barriers encountered along the suspected path of invasion include London Lock and Dam above Chelyan, Kanawha County, West Virginia, and Kanawha Falls and Bluestone Dam at Hinton, Summers County, West Virginia. This dam forms Bluestone Lake, a reservoir which is utilized for both flood control and hydroelectric power. The relatively rapid movement of the clam implies some augmentation of its natural dispersive mechanisms. It is highly improbable that the nonparasitic planktonic veliger larvae would be capable of moving against the current at such a rate. Since no parasitic stage is present in the life cycle, a fish host would not be involved in dissemination (Sinclair, 1964). More likely, their movement was probably aided by fishermen as fishing pressure is relatively intense in this river system. Additionally, transportation may have been provided by waterfowl since Clench (1970) stated that *Corbicula* may be able to pass through the intestinal tracts of ducks in viable condition. Live specimens are being sold and shipped to fish hobbyists around the country (Abbott, 1975). Subsequent intensive sampling of the New River upstream from Glen Lyn at Lurich, Narrows and McCoy, Virginia, did not yield any specimens (Fig. 1). These results indicated that the clam had not yet been able to invade these areas.

Based on approximations of age from shell

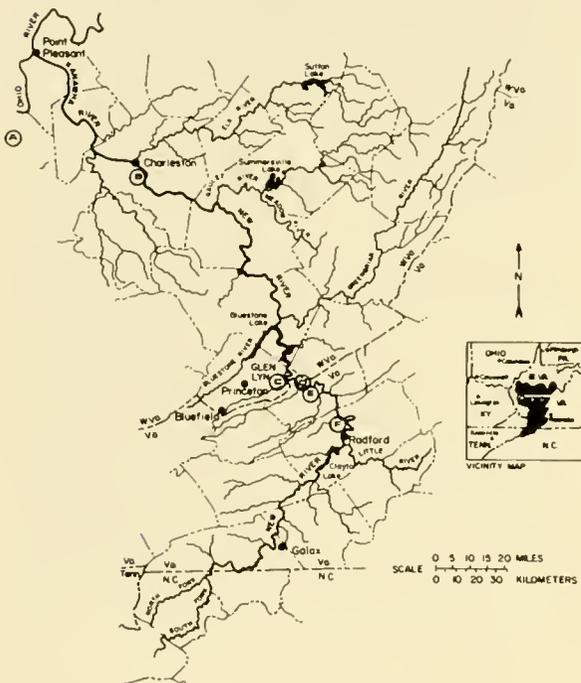


FIG. 1. Kanawha River basin and sampling sites on the New River. A—Mud River, Cabell County, West Virginia; second report of *Corbicula* from West Virginia, 10 October 1973 (Joy and McCoy, 1975); B—Chelyan, Kanawha County, West Virginia; first report of *Corbicula* from West Virginia, 17 July 1963—population had been established since 1961 by size "year class" data (Thomas and Mackenthun, 1964); C—Glen Lyn, Giles County, Virginia; *Corbicula* collected 12 October 1976—population had been established since 1975 by size "year class" data (River Mile 95); D—Lurich, Giles County, Virginia (River Mile 97); E—Narrows, Giles County, Virginia (River Mile 102); F—McCoy, Montgomery County, Virginia (River Mile 131).

TABLE 1. Means (\pm SE) and ranges of parameters measured for *Corbicula* sampled from upriver and downriver stations.

Measured Parameter	Upriver		Downriver	
	$\bar{X} \pm S.$	Range	$\bar{X} \pm S.$	Range
Shell Length (mm)	9.8 \pm 0.37	7.2 - 12.3	9.6 \pm 0.32	7.1 - 12.0
Shell Width (mm)	6.6 \pm 0.27	5.0 - 8.3	6.6 \pm 0.25	5.1 - 8.4
Viscera Wet Weight (mg)	26.8 \pm 1.31	18.7 - 35.1	25.9 \pm 1.09	19.0 - 34.1
Viscera Dry Weight (mg)	8.0 \pm 0.45	5.2 - 10.7	8.7 \pm 0.54	5.7 - 11.6
Shell Dry Weight (mg)	105.4 \pm 9.74	8.9 - 141.1	106.6 \pm 7.99	8.3 - 140.9

lengths (Joy and McCoy, 1975), it was apparent that the *Corbicula* collected at Glen Lyn were in their first year (Table 1). Most of these specimens were probably sexually mature (Gardner et al., 1976) and should have been in the area since 1975. Mean density at the downriver station of 18 clams m^{-2} was significantly less (t-test, 0.05 level) than the mean density of 29 m^{-2} at the upstream station. This difference may be attributed to the influence of the power plant discharge or a substrate-associated distribution phenomenon. This subject as well as seasonal density dynamics will be further examined in future research.

Least squares regressions (of the form $y = a + bx$) and Pearson product-moment correlation coefficients (r) were calculated for ten relationships between shell dimensions and weights, and viscera mass weights (Table 2). All correlations

TABLE 2. Regression analysis equations ($y = a + bx$) and correlation coefficients for various relationships between shell dimensions and weights, and wet and dry viscera weights of *Corbicula*.¹

Equations	r - Value ²
W = - 0.1643 + 0.7072 L	0.9259
S = - 92.5123 + 20.5729 L	0.8017
VWW = - 6.5322 + 3.4099 L	0.9683
VDW = - 2.2559 + 1.0988 L	0.7616
S = - 55.0134 + 1.0988 L	0.7197
VWW = - 1.4196 + 4.2002 W	0.9052
VDW = - 2.5536 + 1.6476 W	0.8666
VWW = 15.7612 + 0.1000 S	0.7292
VDW = 4.6899 + 0.0345 S	0.6135
VDW = 0.0892 + 0.1334 VWW	0.7648

¹W = width of shell (mm)

L = length of shell (mm)

VWW = wet weight of visceral mass (mg)

VDW = dry weight of visceral mass (mg)

S = dry weight of shell (mg).

² Significance level, $P = 0.0001$.

were highly significant ($P < 0.01$) although the correlation coefficients were slightly less than those of Joy and McCoy (1975). This can be explained by the variability associated within the one size class in this study compared with a range of size classes (from about one to more than four years) collected by Joy and McCoy (1975). It is interesting to note that the width of their specimens averaged about 66% of the clams' lengths which agreed closely with the average of 70% in this study. Sinclair and Ingram (1961) reported somewhat different morphology in specimens from the Tennessee River (shell width about 89% of length based on their published photographs). Only the correlation between shell length and viscera wet weight was greater in this study ($r = 0.9683$) than in the investigation of Joy and McCoy (1975) ($r = 0.9407$). Results of this study agreed with the observation of Joy and McCoy (1975) that viscera wet, rather than dry, weight correlation coefficients are greater and indicate that noncombustible mineral uptake varied more per individual than water content.

It is anticipated that the impact of *Corbicula* on this river system will be exhibited primarily in two different areas: 1) decline in populations of other bivalves as seen during the invasion of the Altamaha River in Georgia (Gardner et al., 1976); and 2) increase in problems associated with industrial and municipal water use (Sinclair, 1964, 1971). The survival of indigenous species of *Margaritifera*, *Tristigonia*, *Elliptio*, *Sphaerium* and *Pisidium* in the New River appears to be seriously threatened.

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SEASONAL MOVEMENTS OF THE POND SNAIL, *LYMNAEA CATASCOPIUM* IN A NORTHERN LAKE

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ABSTRACT

*These data from a 3-year study in Lake Ann, located north of Interlochen in the northern Lower Peninsula of Michigan, indicate that the freshwater pulmonate snail *Lymnaea catascopeum* (formerly *L. emarginata*) does not migrate into deep water with the approach of winter. This behavior pattern differs from that reported by Cheatum (1934). The observations indicate that while these snails do move within the population, their movements are random in nature with no tendency to migrate into deeper off-shoal water in the fall. If anything, the data collected actually show their movements were more toward shore than away from it. The difference in migration reported could be due to differences in the periods the observations were made. The studies by Cheatum and Brackett were primarily in late summer, early fall, and late spring; this study covered all seasons in the course of 3 years, i.e., late fall, winter, and early spring as well as the periods designated by Cheatum and Brackett. It was established that while there were snail movements within the population as exhibited by *L. catascopeum* during the winter, those movements were random in nature, and not migratory.*

INTRODUCTION

Some pulmonate snails that inhabit temperate lakes are known to migrate from shallow into deeper water with the onset of cold weather in the fall; they return from deeper water onto shoals of the lakes in the spring. This pattern of migration has been assumed to be normal for most of the larger pond and lake snails and malacologists assumed it was the usual pattern. However, data obtained in a 3-year study indicates that the seasonal migration of at least one species does not follow that pattern.

Earlier work by Cheatum (1934) in Douglas Lake, Cheboygan County, Michigan indicated there was seasonal movement of several aquatic gastropod species which he interpreted as "migration." Later, Brackett (1940) concluded that snails he observed did not have an annual migratory cycle, but remained "year round in the vicinity of where they hatched." Unfortunately, neither Cheatum nor Brackett obtained winter data from Michigan's northern lakes. More recently, Clampitt (1972a,b) studied

migration patterns of pulmonate snails in Douglas Lake. The following information was obtained during a 3-year study of *Lymnaea catascopeum* Say, 1817 (of which *L. emarginata* Say, 1821, is a synonym, fide H. J. Walter, 1969). The observations were made in Lake Ann, north of Interlochen in the northern Lower Peninsula of Michigan to determine whether this snail shows any appreciable seasonal migratory movement.

Snails involved in the transmission of a skin disease in the Great Lakes region known as schistosome dermatitis or swimmers' itch, are often in colonies or "beds" covering fairly extensive areas in shallow water (less than 1.5 meters in depth). Assuming a seasonal migration takes place and the host snails migrate into deeper water in the fall to assemble in smaller and restricted profundal areas, control could then be easier, more efficient, and less costly. Under those circumstances less damage would occur to the biota in the lake than with the treatment methods currently utilized. The best method of

control would involve applying chemical treatment just after fall migration or early in spring before the snails come back into shallower water. Such considerations tend to stress the importance of resolving the controversial question as to whether host snails migrate or not in the seasonal way described.

LAKE ANN STUDY SITE

This investigation was started August 1966 and terminated in June 1969 at the beginning of the annual breeding season of *Lymnaea catascopium*. During the summer of 1966 an extensive survey was undertaken in the Lower Peninsula of Michigan to determine which lakes were reported to have outbreaks of schistosome dermatitis. Among them, Lake Ann, Benzie County, had on its northern shoal a thriving colony of *Lymnaea (Stagnicola) catascopium*, the snail reported by Cort (1950) as a principal vector of schistosome dermatitis. Although "swimmers' itch" was reported in that lake and copper sulphate treatment had been applied, several years had intervened prior to this study, so that the snail population had again become well established.

Lake Ann is 13 miles southwest of Traverse City, Michigan in Benzie County, T. 27N, R. 13W, Sections 22, 23, 26 and 27, and covers 515 acres; its maximum depth is 23 meters. The bottom of the lake, at about 12 meters in depth, is covered with a pulpy peat. In the more shallow areas marl covers the bottom; a narrow band of sandy shore occurs only along the north and east with a long stretch of beach to the west. The snails studied were on a sandy shoal along the north side of the lake where they were most abundant in the area extending from shore to 8 meters out into water up to 0.5 meters deep. Snail density near shore averaged 240 per square meter; it declined sharply with increased depth of water, so that beyond 39 meters from shore and at depths greater than 1.5 meters, snails were scarce. Using a motor boat and wire-mesh dredge, quadrat sampling was made from 1.5 meters of depth to 12 meters of depth; however, no live specimens of *L. catascopium* were recovered. The snail bed clearly was confined to that shallow shoal area.

PROCEDURE AND OBSERVATIONS

The First Year: Trips were made from Ann Arbor to the study area at Lake Ann on a schedule as follows: August 15, September 25, October 6 and 25, and November 17, 1966; January 24, March 28, April 27, June 1, July 12, and September 28, 1967—a total of 11 trips during the first year of the study. On October 25, 1966, 1280 snails were marked with red nail polish covered by lacquer. Specimens varied in size from 11 to 22 mm in length (measured from apex to base of aperture). As soon as the markings were dry, the snails were returned to the area from which they were collected and scattered randomly over the snail bed.

During the periodic visits to that site in the fall, winter and spring of 1966 to 1967, it was clearly evident that, contrary to information obtained from Cheatum's earlier studies, these snails did not exhibit a seasonal migration. While they tended to "group" in two's or three's, there was no mass movement of that population into deeper water as compared to their position on the shoal area then inhabited during August. Observations made of their position on the shoals and under the ice during January and March 1967 also indicated that they remained in the same area inhabited during that fall and winter. In January and March a thick ice cover was found on the lake except for a strip about 3 meters wide along the shore. Snails were seen from the water's edge outward. Since the opaqueness of the ice made observations through it impossible, a hole was chopped and live snails were seen on the substrate. Many of the marked snails were observed among others in the open water near shore; however, none of the marked individuals were seen through the hole in the ice. Although the red nail-polish on the marked snails had faded badly, it still was visible. In April, soon after the ice had melted, a quadrat sampling was made using a wire dredge. Samples were taken at approximately 25 meter intervals from near shore (in a southwesterly direction) out into water 12 meters deep. The total distance of the quadrat was about 350 meters. No snails other than a few small *Campeloma*

decisum were recovered in water deeper than 2 meters.

The number of marked individuals seen during the June visit was estimated to be about 10 per cent of the sample marked. By this time the nail polish had almost completely faded making it extremely difficult to distinguish marked from unmarked individuals. Even with the aid of a glassbottom bucket, wave action made observation difficult in shallow water.

Very few (about 5 per cent) of the marked, dead (shells) were recovered during the April and June visits. Possible explanations for the small percentage of "sightings" of marked individuals, both living and dead, are: fading of the nail polish made them difficult to spot; many individuals were almost completely buried in the substrate; disappearance as caused by various snail "predators;" marked individuals may have been selected because of their conspicuousness; marking materials may unknowingly have been toxic to the animals; wave action which tended to be quite severe on this shoal made seeing them difficult. For whatever reason, the true significance of this study was finding marked animals only in the immediate vicinity of the shoal where they had been placed rather than where these snails were subsequently recovered. Although during the 3-year period numerous checks made in all directions from the area in which marked individuals were placed. No marked individuals, living or dead, were ever found more than 2 meters from the shoal on which snails had been placed.

The Second Year: Based on information obtained during the first year, the frequency of visits to the study area during the next 2 years was reduced from 11 to 5 trips. However, throughout the 3 years, observations were made at the study site every month of the year except December.

In October of the second year, 3 study quadrats, each covering one quarter square meter, were laid out as follows: Plot I, 14 meters from shore in water .12 meters deep; Plot II, 27 meters out in water .51 meters deep; and Plot III, 39 meters from shore in water .69 meters deep. These measurements were made from the shore

to each study plot, compass readings were made, and onshore landmarks were recorded so that several criteria were available to help relocate the study plots on subsequent visits. The purpose of these quadrats was to determine whether the snails moved around within the larger snail bed. The number of snails in each of the 3 plots was counted and a sample of 15 snails per plot was marked with red India ink and then returned to their respective plots. Because of its longer lasting quality, India ink was used instead of the nail polish to mark those shells. There were 115 snails in Plot I; 41 in Plot II; and 35 in Plot III. During subsequent visits the number of marked and unmarked snails per plot was determined. Visits to the study area were made on November 16, 1967; February 14 and May 15, 1968.

During the November visit the weather was cold (air temperature 1.5°C, water temperature 3.0°C) and windy. Many snails were tossed about by wave action, others were observed buried to various degrees of submergence in the substrate: only 2 snails (unmarked) were seen in Plot I; some may have been buried in the substrate. In order not to disturb the study plot, it seemed advisable not to dig into the substrate. Two marked snails (13.2% of the sample placed in this area) were sighted .5 meter from Plot I toward shore; 12 snails, including 2 marked individuals, were seen in Plot II. Two additional marked snails were found .3 meter inshore from Plot II. Thus, 26.4% of the marked snails placed in this area were seen. Fourteen snails were observed in Plot III, none of which had been marked. Two marked specimens were observed .3 meter inshore from this plot. The area around each study plot, out to a distance of 3 meters, was checked. No other marked snails were seen. Although more specimens were observed outside the study plots than inside, they were less numerous everywhere than in October. Many were now buried in the substance.

During the following February a heavy ice cover was on the lake ranging from 5 cm at the shoreline to 45 cm at 27 meters from shore. Although snails were seen at the shore and through a hole chopped in the ice 27 meters from shore, no marked snails were seen during this

visit. On May 15, the air temperature at Lake Ann was 25.5°C and the water temperature was 16.0°C. Only one marked snail (6.6% of the marked sample) was found in the area around Plot I; it was 3 meters west of the plot. Three marked animals (19.8% of the sample placed in Plot II) were found inshore within 5 meters of Plot II. None of the marked snails placed in Plot III was found. Since all snails had been marked with the same color of India ink, there was no way to determine the plot from which they had come. As expected in terms of the annual cycle, population density again dropped drastically from an average of 240 per square meter in October to an average of 30 per square meter in mid-May. Population densities were greatest near shore and declined rapidly toward deeper water during all of the months in which observations were made.

The results of the first year were again substantiated since these snails did not migrate into deeper water off the shoal, but remained where they had been during summer and fall. While there were movements of snails within the population, it was impossible to determine whether these movements gave evidence of a pattern or were of a random nature.

The Third Year: Based upon the studies of the first and second years, some innovations were made this third and final year of investigation. The three established quadrat plots were left intact. Three samples, each with 200 individuals, were marked but a different color of a paste India ink was used for each of the samples. Sample one was yellow; sample two, red; and sample three, blue. Specimens in sample one (yellow) were then scattered in a 20 meter radius arc in the study Plot I, some 14 meters from shore; the sample two (red) snails were scattered in a 30 meter arc in Plot II at a distance of 27 meters from shore; and the sample three (blue) snails were likewise scattered in a 40 meter arc in Plot III at 39 meters from shore. Care was taken to be sure that these samples passed through each of the 3 earlier study quadrats established during the second year of the study. This arrangement served to determine the extent to which the snails ranged within the total population area.

The 3 snail samples were marked October 25, 1968. Subsequently, 3 trips to examine the extent of movement were made to the study area on March 7, April 19 and June 16, 1969. An unforeseen accident made visits to the study area impossible during December or January as originally planned.

By March 7 the air temperature was 4.0°C and the water was 4.5°C. The lake was still covered with a thick cover of ice except for a strip about 6 meters wide along the shore. Although all 3 study plots were ice covered, 4 yellow-marked snails (2% of the total sample) and numerous unmarked animals were seen in that open water. The population density again had decreased considerably as in the previous 2 years.

On April 19 it was ascertained that the ice on that lake disappeared about April 15. The air temperature on the 19th was 15.0°C, the water was 5.0°C. Using a glass-bottom bucket and the distance guide used for setting the 3 plots, a careful survey was made in each area. Dredgings were made with sweeps on the arcs established for Plots I, II and III; additional sweeps were made at 1 meter intervals between plots. Only those snails marked with the color designated within the plot distances (Plot I, yellow; Plot II, red; Plot III, blue) were found within the plot arcs. With but one exception, all marked snails observed at other than the plot arc distance from shore were *inshore* from their respective plot arcs. The exception was 2 red-marked individuals found 3 meters out from the Plot II distance arc. A total of 77 per cent of the marked snails recovered were at plot arc distance from shore, 19 per cent were inshore from their plot arc distance, and only 4 per cent of the marked snails recovered were out beyond their plot distance arc. Of the 200 yellow marked specimens 23 or 11.5% were seen on this visit; 13 or 6.5% of the 200 red; and 17 or 8.5% of the blue were found.

During the final visit on June 16, the air temperature was 22.0°C; the water was 21.0°C. A general survey of the whole snail bed revealed that most adult snails had already died. Many shells had eggs attached to them; however, no young snails were found. As during the April 19 visit, a careful survey was made of the study

area. In sweeps made at 1 meter intervals from shore outward to 2 meters beyond the Plot III distance from shore, very few live snails were seen and but a few shells. The following marked shells and 1 live, marked snail were found: 1 yellow shell at Plot I arc distance from shore; 1 red shell 1 meter inshore from the Plot II arc distance; 1 blue shell 3 meters inshore from Plot III arc; 1 blue shell 2 meters inshore from Plot III arc distance; 1 live blue marked near Plot III; and 2 blue marked shells (one with eggs attached) 2 meters out from Plot III arc distance from shore.

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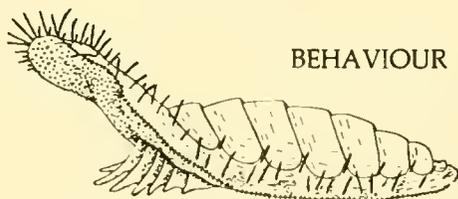
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FREQUENT SCALARIFORMY IN A POPULATION OF
THE POND SNAIL, *LYMNAEA STAGNALIS*

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ABSTRACT

Two populations of *Lymnaea stagnalis* that had been exposed to chronic low-level gamma radiation in situ were examined for the presence of shell abnormalities. One population showed no abnormalities. In the other population scalariformy was found at a frequency of 0.5%, and occurred consistently in initially non-scalar shells. Gamma radiation is apparently not a direct cause of scalariformy.

Scalariformy in natural populations of *Lymnaea stagnalis* (Linnaeus) is normally a rare and isolated occurrence, the causes of which are unknown. Studies of this phenomenon are difficult because of the very few, scattered and poorly documented specimens known to be in existence (Pip, 1975) and because the probability of recurrence in wild populations that have produced such individuals is too low to merit observation. However there is evidence that populations showing a relatively high frequency of scalariformy exist. F. C. Baker (1911) cited a population sample from Spoonbill Slough, Deuel County, South Dakota, that contained several scalariform individuals. This study documents the discovery of another such population of *L. stagnalis*. Perhaps coincidentally, this population has been exposed to chronic low-level gamma radiation.

METHODS

The study sites were located in an area, 1 km in diameter, of mixed boreal forest that had been reserved in the late 1960's for a radiation ecology study within the Whiteshell Nuclear Research Establishment's controlled area near Pinawa in eastern Manitoba. Chronic gamma radiation began in early 1973 by a 10,000 effective curie ¹³⁷Cs source located at the top of a 20 m tower placed at the center of the area (Dugle and

Thibault, 1974). Irradiation continued at an average of 19 hours per day. By the end of August, 1975, the area had received a total of 17,000 hours of irradiation. The western portion of the area contained numerous small shallow ponds that had originated as gravel excavations prior to 1965. Of these ponds, two contained populations of *Lymnaea stagnalis*, their centers located 300 m (site 1) and 480 m (site 2) from the irradiator respectively. Site 1 was densely colonized by cattails (*Typha latifolia*); small patches of open water contained the pondweeds *Potamogeton gramineus*, *P. pectinatus* and *P. natans* (nomenclature after Scoggan, 1957). The mean dose rate at site 1, estimated during the growing season by lithium fluoride dosimeters placed 1 m above the center of the pond's surface, was 12.428 mrad/h. Site 2 was much more exposed; there was no emergent vegetation except for one small stand of cattails. The sparse submerged vegetation consisted of *Potamogeton foliosus* and a species of the algal stonewort *Chara*. The mean dose rate 1 m above the center of the pond's surface was 3.082 mrad/h. Because of the pond's exposure, water temperatures during midsummer reached 30 C. Although both ponds were less than 1 m deep, temperatures at site 1 were consistently lower because a large proportion of the water surface was shaded. Surface water samples collected in July, 1975 were analyzed according to methods recommended

by the American Public Health Association (1971). The two sites showed few differences in the monitored variables: pH 7.7 - 8.7, total filtrable residue 135 mg/l, alkalinity 80 mg CaCO₃/l, sulphate 0 mg/l, chloride 0 mg/l, nitrate 1 mg/l, orthophosphate 2 mg/l (site 1) and 7 mg/l (site 2). Besides *L. stagnalis*, site 1 also contained *Stagnicola palustris* while site 2 contained *S. palustris* and *Physa gyrina*.

During the 1975 season all visible live and dead individuals of *L. stagnalis* at the two sites were scored for presence or absence of shell abnormalities. Individuals of other species were examined as well.

RESULTS AND DISCUSSION

The small populations of *L. stagnalis* and *S. palustris* at site 1 showed no evidence of morphological abnormalities. The larger population of *L. stagnalis* at site 2 showed a constant frequency of scalariformy during the 1975 season of 5 per 1000 individuals. Scalariformy occurred consistently in initially non-scalar shells (Fig. 1), a characteristic noted in previous reports (Pip and Paulishyn, 1970; Jackiewicz, 1972; Pip, 1975). Onset of scalariformy was abrupt and well-defined. In approximately 75% of the affected individuals, scalariformy commenced in the fourth and fifth whorls. In the remainder of specimens scalariformy was apparent earlier; in some individuals it occurred as early as in the second

whorl. One specimen showed onset of scalariformy in the sixth whorl; this was the only specimen where mechanical injury to the shell was apparent. Scalariformy was frequently accompanied by curvature or breakage of the shell axis. Other aberrations were not observed in *L. stagnalis*. The small populations of *S. palustris* and *P. gyrina* at site 2 were morphologically normal.

The unusually high frequency of scalariformy at site 2 is difficult to explain. Because site 1 received 4 times the mean dose rate of site 2, with no scalariformy or other abnormalities recorded, radiation appears to be an unlikely direct cause. Radiation may have contributed towards the stress already placed on the organisms by elevated temperatures. The two factors are related in that elevated temperatures increase the time breathing at the surface (McDonald, 1973). Since attenuation of radiation with increasing water depth is considerable, the snails are exposed to the maximum dose rate when they are at the surface. The additional exposure to radiation, combined with the effects of heat stress, may result in some disturbance to growth. Because scalariformy occurs, as a rule, relatively late in the development of the snail, the causative agent is not operating at the nuclear level. Verdonk (1973) has shown that in *L. Stagnalis* few gene deficiencies become active beyond the veliger stage. It is therefore likely that mechanical or physiological agents are among the responsible factors. The occurrence of *Chara* at site 2 is interesting in that Geyer (1929 in Jackiewicz, 1972) and Pip (1975) have noted the presence of this alga in habitats where scalariform snails have been collected. Further study is necessary before this phenomenon is understood.

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FIG. 1. Scalariform shells of *Lymnaea stagnalis* collected at site 2 in Manitoba, Canada, during 1975. $\times 1/2$

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SHELL SIZE—FREQUENCY DISTRIBUTIONS OF *CORBICULA MANILENSIS* PHILIPPI FROM A CLAM—FOULED STEAM CONDENSER¹

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ABSTRACT

Specimens and empty whole and half shells of the introduced Asiatic freshwater clam, Corbicula manilensis, were collected from the inlet (cold water) box, condenser tubes and outlet (warm water) box of a clam-fouled steam condenser of an electric generator utilizing raw water from Lake Arlington, Texas. Size-frequency distributions of length, height, and width of shells removed from these three sections indicated that the clams were not growing in the condenser but had been carried into it with intake currents from an external population in the intake embayment and tunnel. It appears that the condenser tubes acted as a sieve becoming fouled only with shells of an appropriate size to become lodged in the tubes while smaller specimens passed through and larger shells were retained in the inlet box. It is suggested that increasing tube inside diameter to 29.0 mm or more will allow even the largest specimens of C. manilensis to pass through condensers and thereby avoid fouling problems with this species.

The introduced Asiatic freshwater clam, *Corbicula manilensis*, was first recorded in the Columbia River, Washington, in 1938 and has since spread through a large portion of the freshwater

environments of the southern United States (Sinclair, 1971, and references within). The high reproductive capacity and fast growth of this clam has allowed it to become a major pest species in many drainage systems (Ingram, 1959; Sinclair and Isom, 1961, 1963; Sinclair, 1963, 1964, 1970; Prokopovich and Herbert, 1965; Prokopovich, 1969). Recently *C. manilensis* has been

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reported to have fouled raw watercooled steam condensers of electric generating and other industrial facilities in several regions of the United States (Ingram, 1959; Sinclair and Isom, 1961, 1963; Sinclair, 1963, 1964, 1970; Thomas and MacKenthun, 1964; Thomerson and Myer, 1970; Diaz, 1974). This report describes the distributions and means of shell size for specimens of *C. manilensis* collected from a clam-fouled steam condenser of an electrical generator and proposes a possible design solution to the problem of fouling by the shells of this species.

MATERIALS AND METHODS

On 12 January, 1976, whole specimens and whole and half shells of *Corbicula manilensis* were collected from the clam-fouled steam condenser of the Number Two electrical generator of the Handley Steam-Electric Generating Plant, maintained by the Texas Electric Service Company on Lake Arlington, Texas (USGS map quadrangle, Arlington, 32° 43' 15" N; 97° 12' 57" W). This plant utilizes raw lake water as a coolant for the steam condensers of its three generating units. The maximum flow of lake water through the condensers is 1.298×10^6 liters per minute (1.870×10^9 l/day) and the monthly average discharge rate is 1.052×10^6 l/per minute (1.514×10^9 l/day (Hall, 1972; McMahan, 1975). The clams were collected from three areas in the steam condenser: the inlet or cold water box (CWB) which receives raw lake water for cooling from the intake canal; the condenser tubes (CT) which carry water from the CWB and which are used to cool and condense the steam passed over them before it is returned to the generator's boilers; and the outlet or warm water box (WWB) which receives warmed water from the condenser tubes. Water is passed from the WWB to the discharge canal and is then returned to the lake (for a more complete description of the Handley Power Plant's operation see McMahan, 1975).

The condenser tubes of the Number Two generator have an outside diameter of 22.2 mm, an inside diameter of 19.7 mm and a tube wall thickness of 1.24 mm. The Number Two generator is a "peaking" unit which operates only during

periods of high demand. It has an output of 80 MW and a maximum flow through its condenser of 132,469 l/min. Average water velocity in the intake tube to the condenser is 2.44 m/min and velocity increases to 2.26 m/sec in the condenser tubes.

C. manilensis was first observed in Lake Arlington during the spring of 1973 (John Barnett, personal communication) and it first fouled the Number Two condenser at the Handley Power Plant in the summer of 1974. Since that time the Number Two unit has been shut down several times in order to remove *C. manilensis* shells from its condenser tubes. Such fouling has never occurred in the larger Number Three unit, a continuously running "base load" generator, with an output of 400 MW and a water flow through its condensers of 435,322 l/min. This unit's water velocities are similar to that of the Number Two unit, but the condenser tubes are larger with an outside diameter of 25.4 mm, an inside diameter of 22.9 mm and a tube wall thickness of 1.24 mm.

Living specimens and empty whole and half shells of *C. manilensis* were collected from the Number Two condenser 72 hours after the generator had been shut down on January 9, 1976. Samples were randomly removed from each of three areas (CWB, CT and WWB) and returned to the laboratory. For each individual in each sample three shell dimensions were measured to the nearest 0.05 mm using a dial micrometer. The shell dimensions recorded were: shell length (SL), the greatest dimension anterior-posterior across the shell; shell height (SH) the greatest dimension dorsal-ventral across the shell from the umbones to the ventral edge of the valves; and shell width (SW), the greatest lateral dimension between the two valves (for single valves shell width was estimated by multiplying the greatest lateral dimension by two). No significant differences occurred in the mean dimensions of whole and half shells in each sample ($P > 0.10$); therefore, the dimensions of whole shells and single valves were combined, allowing the computation of a mean SL, SH and SW with corresponding standard deviations for each of the three samples (CWB, CT, WWB). The distributions of sample shell dimensions from all three

collection sites were then compared for significance using students' t test.

RESULTS

Figures one, two and three illustrate the shell size distributions of *C. manilensis* collected from the cold water box (CWB) (Fig. 1), the condenser tubes (CT) (Fig. 2) and the warm water box (WWB) (Fig. 3) of the Number Two steam condenser. Approximately 20-30% of the shells removed from each of the three portions of the condenser contained intact soft parts. There was no evidence of byssal attachment by the clams to tube walls or any other portion of the condenser as has been previously suggested for fouling by this species (Sinclair and Isom, 1961, 1963).

The 122 shells collected from the intake or cold water box (CWB) had a mean SL of 21.1 mm (s.d. = ± 6.19 mm, range = 5.7 - 33.8 mm), a mean SH of 19.98 mm (s.d. = ± 5.29 mm, range = 4.9 - 28.1

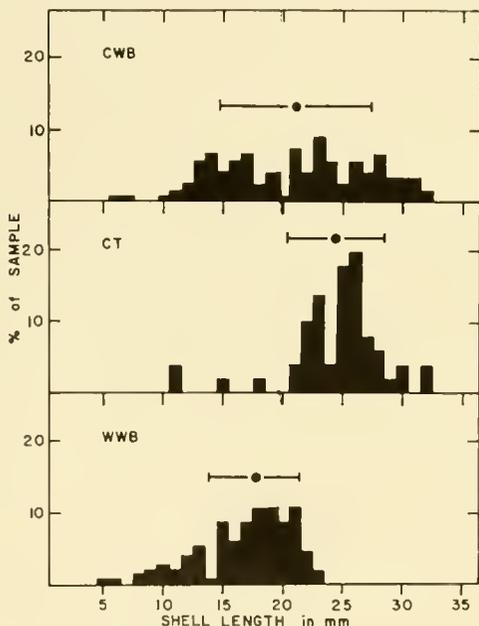


FIG. 1. Length frequency distributions of *Corbicula manilensis* shells collected from the inlet or cold water box (CWB), condenser tubes (CT) and outlet or warm water box (WWB) of a steam condenser utilizing raw lake water as a coolant. The vertical axis is per cent of total sample numbers and the horizontal axis is shell length (SL) in millimeters. The darkened circles represent mean shell lengths for each sample and bars about the means, standard deviations. The stipled vertical line represents the inside diameter (19.7 mm) of the condenser tubes.

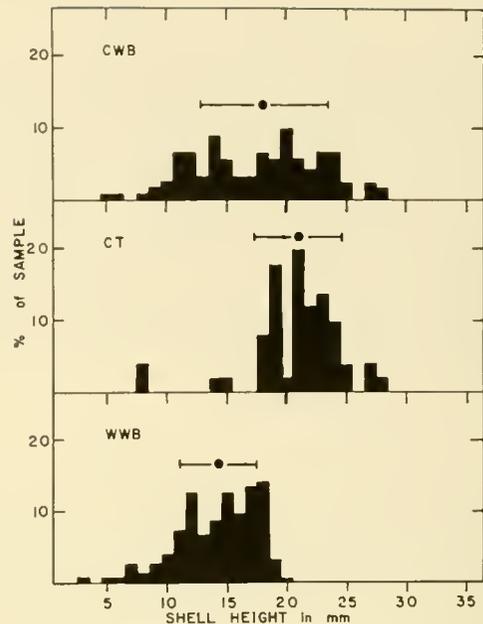


FIG. 2. Height frequency distributions of *C. manilensis* shells collected from the inlet or cold water box (CWB), condenser tubes (CT) and outlet or warm box (WWB) of a steam condenser utilizing raw lake water as a coolant. The vertical axis is per cent of total sample numbers and the horizontal axis is shell height (SH) in millimeters. The darkened circles represent mean shell heights for each sample and bars about the means, standard deviations. The stipled vertical line represents the inside diameter (19.7 mm) of the condenser tubes.

mm) and a mean SW of 12.37 mm (s.d. = ± 3.48 mm, range = 3.8 - 20.0 mm). Corresponding mean shell dimensions for the 51 shells removed directly from the condenser tubes were: mean SL = 24.4 mm (s.d. = ± 4.17 mm, range = 10.6 - 32.0 mm); mean SH = 20.95 mm (s.d. = ± 3.74 mm, range = 8.2 - 27.8 mm); and SW = 14.22 mm (s.d. = ± 2.41 mm, range = 6.1 - 18.8 mm) (Fig. 2). Mean dimensions for the sample of 150 shells drawn from the warm water box (WWB) were: mean SL = 16.72 mm (s.d. = ± 3.75 mm, range = 4.6 - 23.1 mm); mean SH = 14.28 mm (s.d. = ± 3.75 mm, range = 3.4 - 19.7 mm); and mean SW = 9.89 mm (s.d. = ± 2.17 mm, range = 2.7 - 13.6 mm) (Fig. 3). The shell samples drawn from all three regions of the condenser (CWB, CT, WWB) were significantly different from each other ($P < 0.05$) in all three dimensions measured (SL, SH, SW).

DISCUSSION

Since 1960 there have been a series of reports recording the fouling of water-cooled steam condensers by *C. manilensis* in both steam-electric power plants and other industrial facilities (Ingram, 1959; Sinclair and Isom, 1960, 1963; Sinclair, 1963, 1964, Thomas and MacKenthun, 1964; Thomerson and Myer, 1970, Diaz, 1974). Several of these reports suggest that *C. manilensis* attach as young by a byssus to the walls and insides of tubes carrying cooling water in the condensers (Sinclair, 1963, 1964; Sinclair and Isom, 1960, 1961). Unlike these previous reports no small clams (SL < 5 mm) and no evidence of byssal attachment could be observed in any part of the Handley Power Plant's Number Two condenser even though living clams with intact soft parts represented a significant proportion of all three samples.

A comparison of the size distributions of the three samples indicates that the clams fouling the condenser are not a resident population, but instead, must have been carried into it from an external population. The distribution of SL in the CWB had a mean of 21.1 mm. (s.d. = ± 6.19 mm) (Fig. 1) which was significantly different ($P < 0.05$) from the distributions of SL of both the CT and WWB. The distribution of SH in the sample of *C. manilensis* shells drawn from the condenser tubes was significantly different from both the samples taken from the CWB and WWB (Figs. 1, 2 and 3) and had a mean SH of 20.95 mm and a rather narrow distribution of shell height about the mean (s.d. = ± 3.74 mm) (Fig. 2). The inside diameter of the Number Two unit's condenser tubes at 19.7 mm is almost equal to the mean SH (20.95 mm) of the shells sampled from them. As shell height (SH) approximately represents the smallest diameter across the plane between the two valves, these data appear to indicate that *C. manilensis* shells are transported into the condenser tubes and only those of an appropriate size (i.e., an SH closely approximating the inside diameter of the tube) would become lodged in the tubes at points of slight constriction (primarily at regular bends in the condenser tubing). The few smaller shells (SH < 17 mm) found in the condenser tubes were taken from tubes already oc-

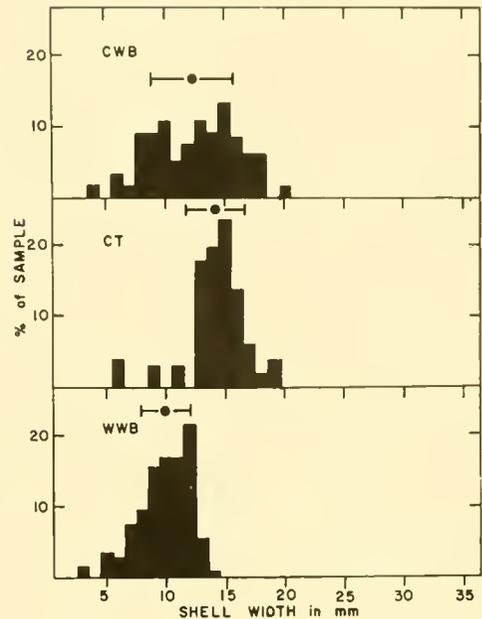


FIG. 3. Width frequency distributions of *C. manilensis* shells collected from the inlet or cold water box (CWB), condenser tubes (CT) and outlet or warm water box (WWB) of a steam condenser utilizing raw lake water as a coolant. The vertical axis is per cent of total sample numbers and the horizontal axis is shell width (SW) in millimeters. The darkened circles represent mean shell widths for each sample and the bars about the means, standard deviations. The stipled vertical line represents the inside diameter (19.7 mm) of the condenser tubes.

cluded with larger wedged shells which prevented their passage. In the outlet or warm water box (WWB) only shells with a SH less than the inside diameter of the condenser tubes (SH < 19.7 mm) were taken (Fig. 3), the sample from this area having significantly smaller shell dimensions ($P < 0.05$) than the samples from both the CWB and CT. Thus, it appears that the shells in the WWB must be carried from the CWB through the condenser tubes to the WWB and that only clams with an SH smaller than the inside diameter of the condenser tubes may pass through them. Ingram (1959) has reported a similar accumulation of *C. manilensis* shells in tubes with an inside diameter of 15.8 mm from a condenser in California.

In this sense the condenser acts as a sieve. Clams are drawn into the CWB from an external population with intake currents and therefore

shell size distributions in this area are representative of those in natural Lake Arlington populations of *C. manilensis* (Aldridge, 1976). Of those shells drawn into the CWB those with SH's of less than the inside diameter of the condenser tubes eventually pass through the condenser to the discharge canal leaving the largest shells in the CWB. The condenser tubes themselves become initially fouled only with those shells with a SH approximately their inside diameter. These shells apparently become lodged at slight constrictions in the tubes or at bends in the tubes. Water velocities in the condenser tubes at 2.26 m/sec are probably much too great to allow veliger settlement and therefore shells must be transported into this portion of the condenser.

Relatively dense populations of *C. manilensis* occur both in the intake canal of the power plant and in the shallow shore areas of Lake Arlington (Aldridge, 1976). Throughout the year living specimens of *C. manilensis* in Lake Arlington have been observed to move entirely out of the substrate and be carried over the bottom by currents and wave action. Similar observations have been made for a *C. manilensis* population on the James River, Virginia (R. J. Diaz, personal communication). *C. manilensis* may move out of the substrate when environmentally stressed and be carried by currents in the power plant's intake canal to traveling screens in front of the intake tunnels to the condensers. The traveling screens of the Handley Power Plant on Lake Arlington have a mesh size of 12.7 mm which prevents clams large enough to foul the condensers from entering the intake tunnels. However, smaller clams with an SH less than 12.7 mm, spat and veligers will pass easily over the screens. If these clams settle in the embayments behind the screens or in the intake tunnels where water currents are relatively slow (2.44 m/min) they will grow very rapidly and reach an SH large enough to allow them to lodge in condenser tubes (approximately 19 mm) in two to six months (Aldridge, 1976). Thereafter, if the quality of lake water drawn into the intake canal is lowered by natural means (i.e., high summer temperatures or low oxygen concentration) or as the result of human activity (shock chlorination and other per-

turbations) the now resident *Corbicula* populations behind the screens may move out of bottom slits to be carried by intake currents into the condensers. Such populations of adult *C. manilensis* have been observed behind the traveling screens at the Handley Power Plant on Lake Arlington (M. W. Zengerle, personal communication).

It has been reported that adult *C. manilensis* are not susceptible to shock chlorination as a method of control (Sinclair and Isom, 1960, 1961; Sinclair, 1963, 1964); instead, constant chlorination of intake waters at levels of 1.5-10 ppm (up to 50 ppm for two weeks) have been recommended as a means of preventing this species from impinging upon condensers (Sinclair and Isom, 1960, 1963; Sinclair, 1963, 1964). Present Environmental Protection Agency regulations generally prohibit constant chlorination of raw intake water used for cooling purposes and shock chlorination may actually enhance condenser fouling by stressing resident populations.

It is notable that the larger Number Three generating unit at the Handley Power Plant on Lake Arlington has never had its steam condensers fouled with *C. manilensis*. The only discernable difference in the operation of its condensers and those of the often-fouled Number Two unit is that the inside diameter of its condenser tubes is larger at 22.9 mm (see Methods). As such it would only stop clams with an SH greater than 22 mm which represents only about 1.51% (s.d. = $\pm 2.22\%$, range 0 - 8.9%, N = 28) of the normal Lake Arlington *C. manilensis* population over 1975 while the Number Two unit's condenser tubes have a smaller inside diameter (19.7 mm) and would stop about thirteen times as many clams (19.45%, s.d. = $\pm 13.41\%$, range = 3.7 - 64.4%, N = 28) (Aldridge, 1976). Since so few clams of the appropriate size for fouling impinge upon this larger unit's steam condenser (inside diameter 22.9 mm), it is hypothesized that the high water velocities in its condenser tubes abrade and break up lodged shells at a rate which prevents serious fouling. In contrast, a far greater number of appropriately sized shells impinge on the smaller tubes of the Number Two unit's condenser (inside diameter = 19.7 mm)

allowing a steady accumulation of lodged shells in the condenser tubes, eventually impairing the condenser's efficiency.

It may be possible to avoid *Corbicula* fouling in water-cooled steam condensers of future electrical generating and industrial facilities by designing steam condensers with condenser tubes of inside diameters greater than 29.0 mm, the approximate SH of a specimen of *C. manilensis* 50 mm in shell length (Aldridge, 1976). A specimen of this shell length (50 mm) was the largest ever taken in over a year of bi-weekly collections of *C. manilensis* on Lake Arlington (Aldridge, 1976) and is roughly equal to or less than the maximum shell lengths reported for other populations of this species near fouled condensers (Sinclair and Isom, 1961, 1963; Sinclair, 1963, 1964; Thomas and MacKenthun, 1964; Thomerson and Meyer, 1970; Diaz, 1974). Therefore, designing condensers which would allow passage of even relatively large specimens of *C. manilensis* (inside diameter of condenser tubes > 29.0 mm) might eliminate all possibility of *Corbicula* fouling.

ACKNOWLEDGMENTS

I wish to express my deep appreciation to Monta Zengerle, Texas Electric Service Company Biologist, who allowed me to be present when the condenser was inspected and who supplied data on the steam condenser's operation; to David W. Aldridge for his advice and discussions on the biology of *C. manilensis*; and to Nancy B. Banks, for her assistance with the preparation of the manuscript.

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ABNORMAL HYPERSTROPHY IN *LITTORINA LINEOLATA*
(GASTROPODA: LITTORINIDAE)

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ABSTRACT

A specimen of Littorina lineolata Orbigny from Oistins Bay, Barbados was found to have a normal, orthostrophic protoconch and an abnormal, hyperstrophic teleoconch, based on examination of anatomy, shell, protoconch and operculum. This is believed to be the first report of such an abnormality in gastropods.

The occurrence of anomalous shell morphologies is well documented in the Littorinidae of tropical as well as boreal waters (Rosewater, 1972). It was therefore not too surprising to discover what appeared to be a sinistral specimen of *Littorina lineolata* Orbigny, 1840 while sorting material collected in Oistins Bay, Barbados. Closer examination, however, revealed this specimen to be dextral and hyperstrophic.

It is necessary at this point to make a distinction between asymmetry of the shell and asymmetry of the soft parts. The terms dextral and sinistral, in the strict sense, refer to the orientation of organ systems in the gastropod body. The vast majority of prosobranchs are dextral and have lost the osphradium, ctenidium, hypobranchial gland and auricle on the post-torsional right side of their body. This was accompanied by a shifting of the anus to the right side of the body and modification of the right kidney into a reproductive organ. The reverse is true of sinistral gastropods, which are mirror images of their dextral counterparts. Dextrality or sinistrality is detectable as early in development as the late two cell stage (Crampton, 1894), long before even the first appearance of a shell.

The terms orthostrophy and hyperstrophy refer to the orientation of the asymmetrical shell with regard to the soft parts. The term orthostrophic is applied to gastropods in which the spire is on the same side of the body as the anus and pallial reproductive organs, while the term hyperstrophic is applied to gastropods in which the

spire is on the same side of the body as the unpaired osphradium, ctenidium, hypobranchial gland and auricle. The direction of coiling is determined in the larval stage, but, in some gastropods, is changed at the time of metamorphosis (e.g. Architectonicidae, Pyramidellidae).

Robertson and Merrill (1963) reported the abnormal occurrence of post-larval hyperstrophy in two species of *Heliacus*, in which the normal hyperstrophy of the protoconch was abnormally retained by the teleoconch. The specimen of *Littorina lineolata* discussed here, however, is believed to be the first reported occurrence of a gastropod with a normal orthostrophic protoconch and an abnormal hyperstrophic teleoconch. This specimen (figure 1), in the collection of the Academy of Natural Sciences of Philadelphia (ANSP no. 342287), was compared to normal specimens from the same locality (ANSP no. 342286) and proven to be dextral and hyperstrophic on the basis of the following evidence.

Anatomy. Tissue as far up as the rear of the mantle cavity was well preserved. The orientation of the mantle cavity organs was that of a dextral animal, the anus and capsule gland being on the right side of the body, while the osphradium, ctenidium and hypobranchial gland were on the left.

Operculum. As demonstrated by Pelsener (1893, fide Robertson and Merrill, 1963), the direction of coiling of the operculum can be used to distinguish between dextral and sinistral animals, the former producing opercula which

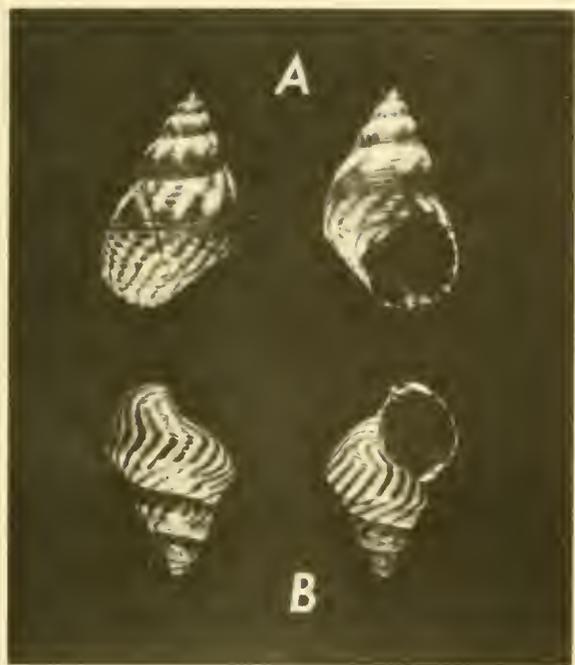


FIG. 1. A, normal specimen of *Littorina lineolata* Orbigny from Oistins Bay, Barbados. $\times 2$. B, Hyperstrophic specimen from the same locality. $\times 3$.

coil counter-clockwise when viewed externally, and latter produce opercula which coil in the clockwise direction when viewed externally. The operculum of the specimen in question (figure 2) is coiled in the counter-clockwise direction, indicating that the animal which produced it was dextral.

Protoconch. As there is considerable pitting of the early whorls, it is not possible to locate the exact boundary between protoconch and teleoconch stages, but there is clearly a change in the direction of coiling of about 140 degrees between the axis of the early whorls of the protoconch and the axis of the adult shell (figure 3), indicating that the specimen was initially dextral



FIG. 2. External view of operculum of the hyperstrophic *Littorina lineolata*. $\times 10$.

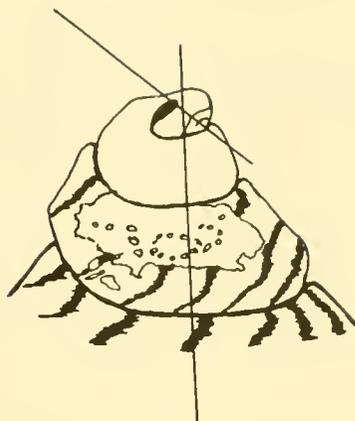


FIG. 3. Early whorls of the hyperstrophic *Littorina lineolata*. $\times 12$.

and orthostrophic but became abnormally hyperstrophic near the time of metamorphosis.

Shell. There are two major shell characters which attest to the hyperstrophy of this specimen: the location of the major spiral cords relative to the shoulder, and the direction of the brown axial bands relative to the columella. Normal specimens are characterized by having 11 or 12 major spiral cords on the apical side of the shoulder and a variable number of very fine spiral threads on the adapical side of the shoulder. This situation is reversed in the hyperstrophic specimen, the fine spiral threads being located on the apical side, while 11 major spiral cords are located on the adaptical side of the shoulder. When viewing the orientation of the brown axial lines relative to the columella, it can be seen that in normal individuals the brown bands approach the columella tangentially, while in the hyperstrophic specimen the bands appear to be almost perpendicular to the columella.

It should be noted that the actual shape of the aperture relative to the animal is not very drastically changed, the left side being more spacious than the right. This would have decreased the compression of the ctenidium, which would have been a serious impediment to the survival of the organism.

I thank Dr. Robert Robertson (Academy of Natural Sciences of Philadelphia) for reviewing the manuscript.

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FOUR OPISTHOBRANCHS LIVING ON MARINE ALGAE
FROM WEST MEXICO

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ABSTRACT

Field notes on Lobiger souverbii, Oxynoe panamensis, Berthelina chloris, and Phyllaplysia padina, all from West Mexico, are summarized. This includes descriptions of the living animals and observations on their habits and habitats. Range extensions northward into the Gulf of California are recorded for the first three species. Geographical ranges in the Tropical Eastern Pacific are given for all four species.

The last several years have presented opportunities for intensive collecting and observation of Panamic opisthobranchs. Collecting stations ranged from Cabo Tepoca, Sonora, to Manzanillo, Colima, Mexico. Several stations on the east coast of Baja California at Bahía de Concepción and Bahía de Los Angeles were visited. Opisthobranchs were observed and photographed in the field and in aquaria. Numerous species were preserved and are on deposit at the Natural History Museum, Los Angeles County, California. Copies of 35 mm slides are also on deposit.

A review of our field notes reveals some interesting information on four of the opisthobranchs living on marine algae. We believe that these notes and comments will be of some interest and will stimulate further field observation.

Lobiger souverbii Fischer, 1857

On February 17, 1974, during a series of low tides, we were collecting at Bahía de Tenacatita, Jalisco. On *Caulerpa racemosa* var. *turbinata*

(type 1), which resembles bunches of tiny grapes (Keen & Smith, 1961), we found 25 specimens of *Lobiger souverbii* Fischer, 1857. Several were crawling over the surface of the *Caulerpa*; but most were in nests along the lower edge of the algae, usually adjacent to sand. Sometimes, as many as five animals were in the same nest. A number of specimens were kept alive in an aquarium for several days for observation and photographing. The living animal is well-figured in Keen, 1971.

Lobiger souverbii has four parapodia which are lateral extensions of the foot and are not to be confused with cerata which are dorsal appendages containing diverticula associated with digestion. The parapodia are extensions of the foot below the four corners of the shell and curl upward. The branches are like long narrow leaves with ruffled edges. They are a lighter green than is the body, which is the green of the algae. On approximately half of the animals observed, there was an orange band on the upper side of each branch, inset slightly from the margin. The

parapodia were normally extended upward at an angle of 45° and were partially rolled inward. When disturbed, the animals flexed and recurled these in a rapid cyclic sequence. When oxygen was depleted, the animals became lethargic and the parapodia were completely extended horizontally.

The caplike shell is on the dorsum, exactly between the four branches of the parapodia. Mottled green of the internal organs and a strong blue veining shows through. When removed from the animal, the shell is clear but became translucent when dry.

While the animals were in the tank, autotomizing of the parapodia was observed. Several individuals had previously discarded one or more of the lobes. No instance of regeneration was observed.

This species appears to be very social. Not only did several animals share a common nest, but when 25 specimens were placed in an aquarium, they at once formed a close group. Within minutes, sexual activity was observed, involving two or more individuals at the same time. Within hours, the algae was covered with gelatinous strings containing thousands of microscopic, spherical yellow eggs.

In December, 1975, we found one specimen of *Lobiger souverbii* sharing a common nest with two other opisthobranchs. They were on a different type of *Caulerpa* (type 3) at Bahía de Algodones, Guaymas Area, Sonora. This is a northward range extension for the species. The known range is now from Bahía de Algodones, Sonora, to Bahía de Tenacatita, Jalisco, on the mainland of Mexico. It is also recorded from Cabo San Lucas, Baja California Sur (Larson & Bertsch, 1974) and from the Galapagos Islands, Ecuador (Sphon & Mulliner, 1972).

***Oxynoe panamensis* Pilsbry & Olsson, 1943**

A single specimen of *Oxynoe panamensis* Pilsbry & Olsson, 1943, was found on the *Caulerpa* at Bahía de Tenacatita. Like *Lobiger*, it had the ability to cling to the algae by suction of the foot. When attempts were made to remove the animal from the algae, a greenish white mucus was excreted from glands along the side of the

foot. This mucus seemed to have adherent properties for the animal. It is more probable that the mucus served as a defense mechanism (Sphon & Mulliner, 1974).

Oxynoe panamensis was described from a single shell in the beach drift on Isla Bocas, Golfo de Panama (7° 30' N, 80° 37' W). The living animal is figured in Keen, 1971. The body is long, slender, and slightly humped (30 x 4 x 4 mm). The first one-fourth of the body is made up of the head and neck. The second one-fourth comprises the shell, most internal organs, and two parapodia, one on each side. The posterior one-half of the body is the tail. The head is small and blunt with relatively large, nonretractable, inrolled rhinophores projecting horizontally from the lateral extremities. The angle between the rhinophores is 90-120°. The mouth is on the underside of the head and is preceded by two rounded lips.

The short neck extends back to the rounded anterior end of the shell. This is broad and caplike on the dorsum and contains most of the vital organs. Behind the shell, the body tapers narrowly into a sharp tail. There is a ridge extending from just behind the shell along the back to the posterior extremity.

The foot is extended laterally into two parapodia which rise upward over the shell to meet dorsally. Normally, the shell is completely covered except for the forward edge. The parapodia extend around the shell to the rear but do not quite meet until about 1 mm behind, where they fuse to form the ridge down the back. Except for the head, the body and parapodia are sparsely covered with sharp papillae.

Overall color of the animal is the green of the algae. The papillae are white and there are small white dots over the entire animal, most numerous along the lower edge of the foot and toward the extremities of the rhinophores. Black spots alternate with white dots along the foot margin and are scattered with white on the upper one-half of the rhinophores. Blunt papillae and white spots are concentrated along the posterior dorsal ridge.

When the parapodia are removed, the internal organs are revealed through the transparent shell. The organs are varying shades of green and clearly show a pattern of white dots.

In November, 1974, 32 specimens of *Orymoe panamensis* from 4 to 30 mm in length were collected from a feathery form of *Caulerpa* (type 2) at Tinajas, Bahía de Bachocibampo, Sonora. This algae resembled *Caulerpa racemosa* var. *sertularioides* reported by Keen & Smith, 1961, from Isla Espíritu Santo. One year later, the algae in the same region had greatly diminished in quantity and deteriorated in quality and only a few animals were found.

The collected animals were kept in an aerated aquarium for six weeks. Fresh algae was provided at intervals. The animals moved about freely on the algae and tank walls, exhibiting the same social habits as *Lobiger* except for the flexing of the parapodia. This species seems to be less excitable than *Lobiger*. When placed in the tank, the animals began sexual activity at once. Soon, the glass walls showed numerous spirally coiled egg masses containing microscopic, spherical yellow eggs. Actual laying of the eggs was observed and photographed through the glass as the egg mass was deposited. One animal moved along an irregular path with the gelatinous ribbon appearing from the broad front of the foot to be deposited on the glass. Two other animals crowded close on the right side and just behind the head of the animal that was depositing the egg mass.

We further noted that *Lobiger souverbii* from the southern part of the range was abundant, with the animals large, brightly colored, and vigorous; but that the specimen from Bahía de Algodones was in poor condition. In contrast to this, *Orymoe panamensis* was abundant at Guaymas. The animals were in fine condition compared to the single pale specimen from Bahía de Tenacatita.

Autotomizing of the parapodia, which is not uncommon with *Lobiger*, was not observed with *Orymoe*. However, the latter have been reported able to autotomize the tail section. The actual act was not observed in our tank; but several tail sections were found on the bottom of the tank and several animals without tails were observed. When dropped into alcohol, almost all of the animals separated the tail section from the body at a point just behind the parapodia and the shell.

The recorded range for *Orymoe panamensis* is at Isla Espíritu Santo, Gulf of California, (Keen, 1971), and from the Guaymas area, Sonora, Mexico, to Golfo de Panama (type locality).

Berthelinia chloris (Dall, 1918)

We were collecting at the south end of Bahía de Algodones on November 29, 1975. At low water, we were out on the reef, which is 2 or 3 acres in extent. The tangled mass of *Caulerpa* (type 3) was encountered for the first time. We picked up a small rock with a clump of the algae attached, thinking to examine the holdfast where we had previously found *Sulcoretusa*. Nestling among the branches was what seemed to be a small green bivalve. When the specimen was removed to a vial of sea water, a small green slug-like body emerged and began to crawl about. There were two valves inverted on its back with what appeared to be the hinge oriented upward and to the rear. Four small clumps of the algae yielded 13 specimens. We knew that we had found our first *Berthelinia chloris* (Dall, 1918). This is a range extension northward from Isla Espíritu Santo (Keen, 1971). The known range is now Abreojos to La Paz, Baja California Sur. Keen, 1971, states that the species possibly occurs at Guaymas. This is now confirmed. The species has also been reported from the Galapagos Islands, Ecuador (Sphon & Mulliner, 1972). The living animal was illustrated in Sphon & Bertsch, 1974.

When collected, all of the animals were withdrawn and with the shells closed. One nest in a cavity in the algae yielded eight specimens. Several very small individuals were in this nest and would have been overlooked except that they were clinging to the shells of the adults. As the animals were removed, they were found to be attached to the algae with the fine elastic threads which have been previously reported (Sphon & Mulliner, 1972). *Berthelinia* were subsequently observed to produce large amounts of mucus from glands along the posterior foot margin. The mucus soon sets, in the salt water, into elastic threads which the animal spins.

When first placed in the aquarium, the animals clung together in a tight ball. As they slowly dispersed, the young ones continued to cling to

the shells of the larger ones. Sexual activity was not observed. The presence of so many juveniles in November may indicate that reproduction is seasonal and occurs in late summer.

The largest specimen had a shell 9.5 mm long. When placed in sea water, the valves parted slightly and the narrow slug-like body appeared, oriented so that the shell would be supported by the branches of the algae. On the bottom, the animal could support the weight of the shell in an upright position for only a few seconds before it would fall to one side. The animal moved with an alternating motion between the front part and the back part of the foot. The animals in the tank tended to crawl up the sides to the surface where they would form a cup with the bottom of the foot and use surface tension to float upside down with the heavy shell hanging down.

Most of the internal organs appeared to be inside the heavy shell and gave it a mottled green color. The shell opened only about 1½ mm as the small green body extended in front about 4 mm and the tail showed only slightly behind. The body was about 2 mm in height and less in width. On the front of the head were two rolled, yellow-tipped rhinophores which were about 2 mm in length. The forepart of the foot was slightly extended and widened. Just above the extension of the foot was a flangelike lip. Behind the rhinophores on top of the neck was a small turretlike hump with two eye spots on the front. A slight ridge extended from this hump along the neck and into the shell. Under 20 magnifications, the body was clear and gelatinous, with horizontal rows of microscopic green nodules as inclusions. There was a row of small white dots along the margin of the foot and on the rhinophores.

When the animal withdrew, a sequence of events took place. The foot folded downward along a central line, the rounded cheeks folded inward, the rhinophores came together vertically, and the body disappeared into the shell which then closed.

The shell was translucent yellow-green with several clear rays extending from the umbones to the margins. Two dark rays were on either side of each umbone and extended laterally for about 1 mm. The tightly coiled nucleus of the embryonic shell was attached to the umbone of the

left valve and extended horizontally across the umbone of the right valve.

Phyllaplysia padina Williams & Gosliner, 1973

In March, 1975, a number of specimens of *Phyllaplysia padina* Williams & Gosliner, 1973 were collected from *Padina* in tide pools at Cabo Tepoca, Sonora. The animals were observed, photographed, and preserved. Several shells were extracted and photographed. Excellent drawings of the animal have been published (Williams & Gosliner, 1973a); but the living animal has not been figured.

Numerous specimens have since been taken from *Padina* intertidally in the Guaymas Area as far north as Bahía de Algodones. In May, 1975, and again in May, 1976, large numbers of these animals were observed at Bahía de Los Angeles, Baja California Norte. On Isla Smith in this region, there is a man-made turtle pond. When the tide is out, water pours over a six foot dam into a pool. There is some *Padina* in this pool. In 1975, six *Phyllaplysia padina* were taken from here but there were no animals found in 1976. At Punta la Gringa, across the channel on the mainland, the species was abundant on the algae from low water out to at least 10 meters. In May, 1976, high wind and rough water left large amounts of *Padina* at the high tide line. The algae was populated with this species. Twenty-four hours later, the algae was drying in the hot sun and wind. A few animals were still clinging to it and revived completely when placed in fresh sea water.

We did observe a previously unrecorded fact concerning the coloring of the living animal. When studied under 20 magnifications, the body was uncolored and clear. The apparent greenish brown color was due to inclusion in the tissue of longitudinal rows of microscopic nodules. Several photographs show this so clearly that individual nodules can be distinguished. Individual animals differed widely in the concentration of the nodules.

The normal habitat and range for this species seems to be wherever *Padina* will grow and from the head of the Gulf of California at least as far south as the Twenty-eight Parallel.

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THE MIOCENE BIVALVE *CUMINGIA MEDIALIS* (SEMELIDAE) FROM SOUTH CAROLINA

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Previous reports of the Miocene bivalve *Cumingia medialis* Conrad, 1866 have been almost entirely limited to North Carolina, Maryland and Virginia. Glenn (1904) reported *C. medialis* from the Miocene of Maryland and cited localities for specimens taken from Virginia and North Carolina. Shimer and Shrock (1944) also reported *C. medialis* from the Choptank Formation of Maryland and gave ranges of Maryland, Virginia, North Carolina and South Carolina without citing specific localities. Richards (1947) reported a specimen taken from a well, 18.3 m from the

surface, dug at Edenton, Chowan County, North Carolina. This specimen was placed in the collection of the Academy of Natural Sciences of Philadelphia (ANSP 16773) where the holotype and paratypes, from James River, Virginia, also reside (ANSP 18839). The present note reports the second locality in South Carolina from which *C. medialis* has been taken.

A right valve of *C. medialis* was found in sea-wrack at the high tide line at Crescent Beach, Horry County, South Carolina 18

August 1975. The shell was believed to be of recent origin and was sent to Dr. R. Tucker Abbott for confirmation. However, upon examination by Dr. Abbott at the Delaware Museum of Natural History, it was properly identified as a fossil or subfossil and accessioned DMNH 103141. It was suspected by Dr. Abbott that the shell may have washed up from a fossil outcrop offshore.

A specimen from the Peedee River, just south of the new locality, was reported by Glenn (1904). This specimen was the only such find of *C. medialis* in South Carolina prior to the present report.

Mr. Robert H. Schlutter (personal communication) has noted that the specimens reported by Glenn (1904) from Maryland are most probably not from Maryland but from

Virginia. Thus, the possibility that *C. medialis* is a Maryland form is doubtful and its citation as a representative bivalve of Maryland dubious. This was pointed out by Glenn (1904) but later references to the species place it in Maryland without noting this possibility.

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LATITUDE, HABITAT, AND HATCHING TYPE FOR MURICACEAN GASTROPODS

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ABSTRACT

Among rocky shore and oyster-reef muricaceans, all high latitude species hatch as young snails, while all tropical species hatch as veligers. In contrast, species from other habitats at all latitudes generally hatch metamorphosed. Among prosobranchs in general, more species of both hatching types are found at low latitudes than at high latitudes and, in Europe, on continental sites rather than on islands.

INTRODUCTION

One of the most intriguing generalizations of prosobranch ecology is that in some places most species hatch as planktonic larvae, while in other places most species hatch as fully formed snails. The predominant hatching type varies both with latitude and with habitat. Typically many species have planktonic larvae at tropical sites and in

shallow waters, while in the deep sea or in the arctic, most hatch metamorphosed (Thorson, 1950). These generalizations raise two questions: (1) are species that hatch metamorphosed in cold water areas replaced by ecological equivalents with planktonic larvae in warm-water areas; and (2) is one hatching type replaced more completely in some habitat types than others?

The latitudinal change in prevailing hatching type does not require species replacements. The change parallels a large change in community diversity. As long as most species added along the latitudinal gradient have swimming larvae, the prevailing hatching type will change, whether species with metamorphosing larvae are replaced or are about equally numerous everywhere. In the data presented by Thorson (1965) for European prosobranchs, about equally many species with metamorphosed hatchlings are found at all latitudes, while the diversity of species with swimming larvae rises abruptly between 30°N and 60°N (Fig. 1). Thorson's data (Fig. 1) include 50-60% of the total fauna and therefore

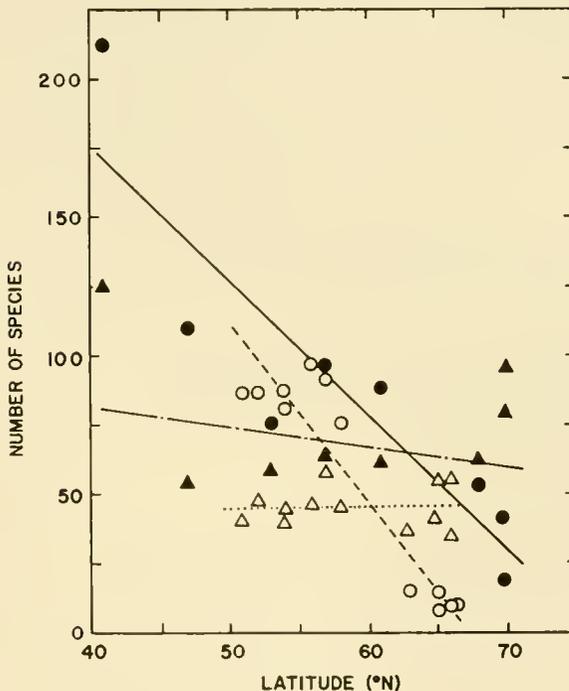


FIG. 1. Plot of estimated number of species of prosobranch snails hatching metamorphosed (triangles) and hatching as swimming larvae (circles) for various European localities as a function of latitude. Each point is obtained by multiplying the estimated total number of prosobranchs for the site by the fraction of species for each hatching type, as based on a sample of 40-60% of known hatching types. Data from Thorson (1944 and 1965). Solid figures and solid lines, mainland sites; open figures and dotted or dashed lines, island sites. The lines are fitted by linear regression and have the following r^2 values: metamorphosed, mainland 0.04, island 0.01; swimming larvae, mainland 0.81, island 0.87.

estimates of faunal composition based on these are both relatively unbiased and comparable to each other. Within the 40-70° latitudinal range, and among prosobranchs as a whole, species hatching metamorphosed are supplemented rather than replaced by species with planktonic larvae. Figure 1 also demonstrates an additional habitat variable: isolation. At all latitudes, island sites have fewer species of both hatching types.

Frequencies of the larval types also vary from one habitat to another. Most tropical shore species have planktonic larvae (91% of 21 species, Lewis, 1960; 100% of 13 species, Ostergaard, 1950), while in deeper waters (here "deep" refers to waters in the range of 10-100 m) many species hatch metamorphosed (25%, Thorson, 1940a; 69%, Knudsen, 1950). Hatching types were obtained for relatively few species in these studies, and the selection undoubtedly reflects the particular taxonomic groups these authors chose or were able to study. To confirm the habitat-larval type relationships, further data are required.

Larval types of many species have been reported incidentally, and these can be used to confirm the pattern of changes observed in the regional faunal studies. With this in mind, I have reviewed the published data on members of one major group, the superfamily Muricacea (including the thaidids).

METHODS

The available habitat descriptions (obtained from the papers cited or from standard works) fall into 4 major categories: intertidal rocky shores, oyster reefs, shallow-water sand bottoms, and deeper waters (10-100 m, as opposed to the deep sea). *Thais coronata*, found on mangroves, fits into none of these categories, and is arbitrarily included with the oyster reef species. The oyster reef species appear to be found on more kinds of substrates than the other species are; individuals of most of these species can be found feeding on clams on muddy bottoms or barnacles on rocky shores as well as on oysters.

Larval types are summarized by wide latitudinal bands (Table 1). Latitudinal bands were chosen to approximate equatorial, tropical, subtropical, temperate, and boreal areas. Too few

TABLE 1. Percentage of species of Muriceans hatching as long-term veligers (more than 1 week) as a function of latitude and habitat. Number of species in parentheses.

Latitude °N or S	Rocky Shore	HABITAT		
		Estuary	Shallow-water Sand	Deep-water
0-15	100%(6)	100%(1)	0%(2)	0%(3)
16-24	100%(1)	-	33%(3)	-
25-35	75%(12)	100%(1)	25%(8)	100%(2)
35-45	20%(5)	50%(4)	50%(2)	0%(3)
46-90	0%(6)	0%(3)	-	0%(3)

data are available to identify local patterns, and therefore no attempt was made to accommodate more subtle features of species distributions.

The latitudinal band for each species was obtained from the site at which observations were made rather than from the species range. Single sites were used to avoid the bias of including wide-ranging species in more than 1 band. However, of 6 species studied by more than one author, 3 were studied in different latitudinal bands (*Cuma turbinoides* = *Thais carinifera*?, *Ocenebra japonica* = *Tritonalia japonica*, and *Thais floridana* = *Thais haemastoma floridana*) and are entered twice in Table 1. Three species were studied by two authors within the same latitudinal band: *Thais fasciata* (*T. rustica*), *Acanthina lapilloides* (*A. spirata*), *Favartia cellulosus*. These 3 species are entered only once in Table 1.

HATCHING TYPES IN THE MURICACEA

Each species is listed as given by the original author, together with the approximate latitude of the original author's observations.

Intertidal Rocky Shores

Hatch as veligers: *Thais bufo* (Lamarck) 8°N (Natarajan 1957), *Thais tissoti* (Petit) 8°N (Natarajan 1957), *Vitularia salebrosa* (King and Broderip, 1832) 9°N (D'Asaro 1970b), *Thais deltoidea* Lamarck 13°N (Lewis 1960), *Thais floridana* Conrad 13°N (Lewis 1960), *Thais patula* Linnaeus 13°N (Lewis 1960), *Cuma turbinoides* Blv. 22°S (Risbec 1935), *Thais rustica* Lamarck 25°N (D'Asaro 1970a), *Thais carinifera* (Lam.) 27°N (Thorson 1940a), *Jopas francolinum* Bruguière 27°N (Gohar and Eisawy 1967), *Thais*

hippocastaneum (Lam.) 27°N (Thorson 1940a), *Dieathais aegrota* (Reeve 1846) 32°S (Phillips 1969), *Thais fasciata* Rve. 32°N (Lebour 1945), *Ocenebra poulsoni* Carpenter 33°N (Fotheringham 1971), *Shaskyus festivus* (Hinds) 33°N (Fotheringham 1971), *Morula marginalba* (Blainville) 33°S (Anderson 1967), *Bedevena birileffi* (Lischke) 33°N (Amio 1957), *Concholepas concholepas* (Bruguière) 39°S (Gallardo 1973).

Hatch as snails: *Favartia cellulosus* (Conrad) 25°N (Raeihle 1966), *Favartia nuceus* (Mörch) 32°N (Lebour 1945), *Thais dubia* 34°S (Bokenham and Neugebauer 1938), *Bedevena hanleyi* (Angas) 35°S (Anderson 1967), *Acanthina lapilloides* 36°N (Hewatt 1934), *Acanthina spirata* (Blainville), 37°N (personal observations), *Nucella calear* 39°S (Gallardo, 1973), *Ocenebra lumaria* Yokoyama 41°N (Luckens 1970), *Ocenebra aciculata* Lamarck 43°N (Franc 1940), *Ceratostoma foliatum* (Gmelin) 48°N (Spight et al. 1974), *Thais canaliculata* (Duclos) 48°N (original), *Thais emarginata* (Deshayes) 48°N (original), *Thais lamellosa* (Gmelin) 48°N (original), *Nucella lapillus* (Linnaeus) 54°N (Pelseneer 1910), *Thais lima* (Gmelin) 51°N (original).

Oyster Reefs

Hatch as veligers: *Thais coronata* Lam. 6°N (Knudsen 1950), *Thais haemastoma floridana* (Conrad) 26°N (D'Asaro 1966), *Purpura clavigera* Kuster 37°N (Amio 1963), *Purpura bronni* Dunker 41°N (Amio 1963).

Hatch as snails: *Eupleura caudata* (Say) 37°N (MacKenzie 1961), *Ocenebra japonica* (Dunker) 43°N (Amio 1963), *Ocenebra japonica* 47°N (Chapman and Banner 1949), *Ocenebra erinacea* (L.) 52°N (Hancock 1960), *Urosalpinx cinerea* (Say) 52°N (Hancock 1959).

Shallow-water Sand Bottoms

Hatch as veligers: *Chicoreus brunneus* Link 22°S (Risbec 1932), *Hexaplex kosterianus* Tapp. 27°N (Thorson 1940a), *Leptoconchus cumingi* (Deshayes) 27°N (Gohar and Soliman 1963), *Rapana thomasi* Crosse 37°N (Hirase 1928).

Hatch as veliconchas and/or snails: *Murex trapa* Röding 8°N (Natarajan 1957), *Chicoreus virgineus* var. *ponderosa* Sowerby 8°N (Natarajan 1957), *Chicoreus incarnatus* (Röding) 27°N (Gohar

and Eisawy 1967), *Chicoreus ramosus* (Linné) 27°N (Gohar and Eisawy 1967).

Hatch as snails: *Chicoreus torrefactus* (Sowerby) 18°S (Cernohorsky 1965), *Torvamurex territus* (Reeve) 22°S (Murray and Goldsmith 1963), *Chicoreus florifer* Reeve 26°N (D'Asaro 1970), *Chicoreus pomum* Gmelin 26°N (D'Asaro 1970a), *Calotrophon ostrearum* (Conrad) 30°N (Radwin and Chamberlin 1973), *Urosalpinx perrugata* (Conrad) 30°N (Radwin and Chamberlin 1973), *Hexaplex trunculus* (Linné) 43°N (Fioroni 1966).

Deeper Waters

Hatch as veligers: *Hexaplex fulvescens* (Sow) 28°N (Moore 1961), *Rapana bulbosa* Sol. 28°N (Thorson 1940a).

Hatch as snails: *Chioreus quadrifrons* (Lam.) 5°N (Knudsen 1950), *Chicoreus senegalensis* (Gmel.) 5°N (Knudsen 1950), *Murex fasciatus* Tryon 1880 10°N (Knudsen 1950), *Muricopsis blainvillei* (Payraudeau) 41°N (Fioroni 1966 after Franc 1948), *Murex brandaris* Linné 43°N (Fioroni 1966), *Ocenebra* spec. 43°N (Fioroni 1966), *Trophon muricatus* (Montagu) 50°N (Lebour 1936), *Trophon truncatus* (Strøm) 57°N (Thorson 1946), *Trophon clathratus* (L.) var. *Gunneri* Lovén 65°N (Thorson 1940b).

CONCLUSIONS

The predominant type of hatching changes more markedly among rocky shore muriceans than it does among prosobranchs as a whole (Fig. 1). In this habitat, all high-latitude species metamorphose before hatching, and all tropical species have planktonic larvae. The rocky shore fauna is relatively well known, because it is accessible at all latitudes; therefore further work is unlikely to change this generalization. Species of one hatching type are completely replaced by ecological equivalents of the other along the latitudinal gradient. The two hatching types are mixed between 25-30° (Table 1), and studies at these latitudes should reveal the relative advantages of the two hatching types, and possible instances of competition between them. A parallel latitudinal trend is observed among oyster reef species.

Hatching types for shallow-water sand species and deep-water (10-100 m) species do not change

in the same manner. Species with metamorphosed hatchlings prevail at most latitudes in both of these habitats. In the shallow-water sand habitat, one also finds an intermediate hatching type, a non-feeding Veliconcha that metamorphoses a few days after hatching.

Considering all habitats, diversities of both hatching types are probably greatest at low latitudes. According to available data, the latitudinal gradient in hatching type is striking (Milekovsky, 1971) and might imply a low number of tropical species that hatch metamorphosed. However, a disproportionately large number of the tropical observations are on rocky shore species. Species from other near-shore habitats are likely to have metamorphosed hatchlings at all latitudes. When these are included, species with metamorphosed hatchlings will probably be shown to be most diverse at lower latitudes. In the only whole-fauna available to date (Fig. 1), species with metamorphosed hatchlings are more diverse at the lowest latitude (Portugal, 41°N) than at the highest.

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CONUS VIOLA, A NEW NAME FOR *C. VIOLACEUS* REEVE

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ABSTRACT

The new substitute name Conus viola is here proposed for the homonymous C. violaceus Reeve, from the tropical West Pacific region.

Conus viola Cernohorsky, new name

Figs. 1-3

1844. *Conus violaceus* Reeve, *Conchologia Iconica*, vol. 1, pl. 44, fig. 241; 1858 Sowerby, *Thesaurus Conchyliorum*, vol. 3, p. 45, pl. 208, fig. 537; 1875 Weinkauff, *Martini & Chemnitz Syst. Conchyl. Cabinet*, ed. 2, vol. 4, pt. 2, p. 76, pl. 46, fig. 11; 1937 Tomlin, *Proc. Malac. Soc. London*, vol. 22, p. 328 (erroneously synonymized with *C. luteus* Sowerby) [*non C. violaceus* Gmelin, 1791]
1884. *Conus violaceus* Reeve (*pars*), Tryon, *Manual of Conchology*, vol. 6, p. 88, pl. 28, fig. 82 (only)
1964. *Conus luteus* var. Sowerby, Marsh & Rippingale, *Cone shells of the world*, p. 124, pl. 18,

- fig. 7 (*non* Sowerby, 1833)
1972. *Conus* species Hinton, *Shells of New Guinea and the central Indo-Pacific*, p. 82, pl. 40, fig. 6.
1975. *Conus violaceus*, *C. tendineus* or *Conus* sp.? Leehman, *Hawaiian Shell News*, vol. 23, No. 6, p. 6, text figs.
- Type locality*: Matnog, Island of Luzon, Philippines.
- Type specimens*: The three syntypes of *C. violaceus* Reeve, accompanied by a label which bears Tomlin's remark = *luteus* Broderip, are in the British Museum (Nat. Hist.), London. The specimen measuring 41.0 mm in length and 15.0 mm in width, is here selected as the lectotype of *C. violaceus* (= *C. viola* new name).
- Conus violaceus* was first described in literature by Reeve (1844), who based his



FIGS. 1-2. Lectotype of *Conus violaceus* Reeve (= *C. viola* Cernohorsky, new name; B.M.N.H., length 41.0mm, width 15.0 mm. 3. Specimen of *C. viola* from Bathurst Id., Nth.

Australia; length 55.8 mm, width 21.4 mm. 4-5. Topotype of *C. luteus* Sowerby, from Anaa Id., Tuamotus; B.M.N.H., length 38.0 mm.

diagnosis on three specimens from the Cuming collection. Reeve's *C. violaceus*, however, is a primary homonym of *C. violaceus* Gmelin, 1791, which is an earlier name for the Indian Ocean species *C. tendineus* Hwass in Bruguière, 1792. Tomlin (1937) did not propose a replacement name for the homonymous *C. violaceus* Reeve, as he considered this species to be synonymous with *C. luteus* Sowerby, 1833.

C. viola and *C. luteus* are similar but quite distinct species, with *C. viola* known only from an area between the Philippines and North Australia, whereas *C. luteus* is widely distributed throughout the tropical Pacific. The average size of *C. viola* is about 50 mm, the shell is cylindrical, the first 2-3 post-embryonic whorls are finely nodulose, the penultimate whorl is inflated and telescopic in appearance, sutures are firmly but irregularly adpressed, the outline of the body whorl is cylindrical with the first two-thirds of the body whorl descending almost vertically before tapering towards the base, the aperture is narrow at the start but slightly flaring basally, and the sculpture consists of 6-10 spiral threads on the spire whorls, obsolete spiral threads on the body whorl and up to a dozen close-set cords at the base. Fresh specimens are pale violet and ornamented with brown spots on the spire whorls, three broad but often dilacerated brown bands on the body whorl which are usually interrupted in the centre of the whorl by a pale band, and spiral rows of small brown spots, aperture pale violet.

C. luteus is considerably smaller, averaging about 30 mm in length, the spire is short and convex, whorls are not inflated but tight, the 2-3 post-embryonic whorls are smooth, the sutures are narrowly canaliculate, the shoulder is moderately broad, smooth and sloping and the body whorl tapers rapidly toward the slender base; shell glossy, obsolete spirally striate on the body whorl, the arcuate axial striae on the spire whorls are crisper and spiral threads fewer and the aperture is uniformly narrow and does not flare basally. The colour is yellow, orange, pink or rose-red, the centre of the body whorl has a narrow white band or blotches which are bordered by quadrate, irregular and distinctly smudged dark brown spots, and spiral rows of dark brown interrupted lines are present in some individuals.

Dark coloured specimens of *C. viola* have been illustrated by Leehman (1975) and the banded form by Hinton (1972). The lectotype of *C. viola* is a form where the brown bands are dilacerated into longitudinal zones.

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IS *THAIS CANALICULATA* (GASTROPODA: MURICIDAE)
EVOLVING NURSE EGGS?

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ABSTRACT

Thais canaliculata appears to be in the course of evolving from one reproductive mode (100% fertility) to another (provision of nurse eggs for embryos). In some populations, all eggs are fertile. In other populations, as few as 16% in each capsule may be fertile and the infertile eggs are used as nurse eggs by the embryos. If *T. canaliculata* is to complete the transition to nurse-egg feeding, two major adaptive problems must be solved: fertility must be regulated, and new larger hatchlings must become much more likely to survive to maturity.

Some *Thais canaliculata* (Duclos, 1832) females produce infertile eggs, and these are used by the embryos as nurse eggs, while other females produce only fertile eggs (Lyons and Spight 1973). These variations in reproductive mode may indicate that *T. canaliculata* is in the process of abandoning one mode in favor of another. This paper will examine available data on fertility in order to evaluate this hypothesis.

METHODS

Egg capsules were collected at Cattle Point and South Beach (on the southeast tip of San Juan Island, Washington) during May, 1970, at Cattle Point during May, 1972, and near Friday Harbor during May and August, 1972. One of the Friday Harbor clusters was attended by a 44-mm female, and one by a 31-mm female. Capsules were opened shortly after collection, and contents (eggs and/or embryos) were counted. The 44-mm female continued to deposit capsules while kept in a laboratory aquarium. Some of these capsules were kept to obtain embryo counts.

RESULTS

Capsules from Cattle Point and South Beach do not contain infertile eggs. The capsules collected during 1970 contained cleaving eggs or early embryos, and all eggs were developing. The average

1970 capsule was 8.23 mm long ($N = 23$, $SD = 0.53$) and contained 28.1 embryos ($SD = 8.35$). The 1972 capsules, which contained embryos nearly ready to hatch, were slightly smaller (8.04 mm, $N = 17$, $SD = 0.72$), and contained 16% fewer embryos (23.5, $SD = 4.39$). Therefore, embryo numbers do not decline significantly during development (Fig. 1, open vs. solid circles).

Capsules from Friday Harbor do contain infertile eggs. Several capsules from the 44-mm female were opened, and of these, 8 contained embryos that had almost reached the feeding stage. From 16% to 92% of the eggs in these capsules were developing (mean, 56%). I found feeding embryos, nurse eggs, and debris of broken nurse eggs in each of the capsules deposited by another female. Only 35% of the intact eggs were developing. Actual fertility must have been even lower, since some of the nurse eggs had already been torn apart and consumed.

The number of eggs per capsule is significantly correlated with capsule size (capsule length, excluding the stem; Fig. 1). When all counts from Cattle Point and South Beach capsules, and counts of eggs plus embryos from Friday Harbor capsules are included, the logarithm of capsule height (X) accounts for 34% of the variation in the logarithm of egg count (Y), and the following

linear regression between these variables is obtained:

$$Y = 1.7299 X - 0.1527$$

for a total of 55 capsules ($F_{1,53} = 27.0891$, $P < 0.01$). Almost all of the embryo counts for the Friday Harbor capsules fall well below this common line (solid triangles, Fig. 1).

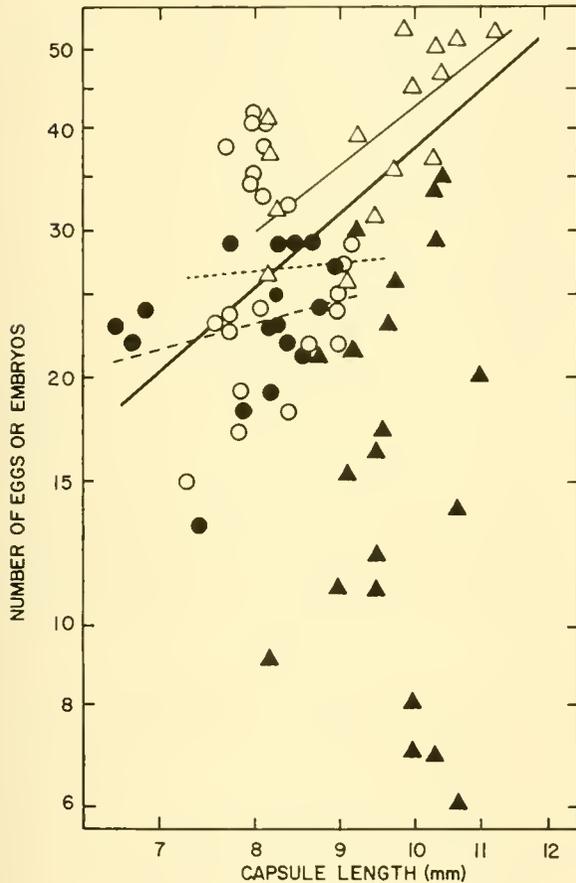


FIG. 1. Contents of capsules of *Thais canaliculata* from San Juan Island, Washington. Circles indicate capsules from Cattle Point and South Beach. Open circles and the dotted line indicate early embryos, while solid circles and the dashed line indicate late embryos. Triangles indicate capsules from Friday Harbor. Open triangles and the thin solid line represent eggs, while solid triangles represent embryos. The heavy line is the calculated regression for all data (except solid triangles). Individual capsules from Friday Harbor are represented by 2 triangles (one empty, one filled) when both egg and embryo counts were obtained. All lines are fit by least-squares linear regression.

DISCUSSION

Fertility of *Thais canaliculata* eggs varies strikingly around San Juan Island, Washington. In some populations, virtually all eggs become hatchlings. Counts of early and late embryos differ by only 16% at South Beach and Cattle Point. Larger developmental mortalities have been reported for most other muricid species without nurse eggs (14-58%; Cole 1942, Federighi 1931, Hancock 1959, Phillips 1969). In other populations, many eggs are infertile, and these are used as nurse eggs by the embryos. The *T. canaliculata* populations of Fig. 1 may be at different stages of the process of changing from one reproductive mode (100% fertility) to another (provision of nurse eggs).

If reproductive mode is changing, what is the direction of the change? *T. canaliculata* embryos possess a feeding mechanism unlike any other that has been described (Lyons and Spight, 1973). Firstly, this mechanism could have been inherited, but if so, the ancestor has no mid-latitude species that produce nurse eggs among its descendants. Secondly, *T. canaliculata* may have evolved a low-fertility reproductive mode early in its history and is now abandoning this mode. A third explanation is most simple because it postulates the fewest evolutionary changes: some *T. canaliculata* populations are utilizing nurse eggs for the first time.

If the reproductive mode is changing, how far has the change progressed? The fertility data provide a kind of measure of progress because as fertility varies from capsule to capsule, hatching size also varies, and females whose fertility is variable will in the long run be less fit than those with constant fertility and offspring of the optimum size. If large hatchlings are much more likely to survive through the post-hatching period than small ones are, then females that produce small hatchlings will be at a disadvantage; if not, females that produce small hatchlings will be the most fit because they produce more offspring. Among the Friday Harbor capsules, some contained only a few embryos (which would become large hatchlings), while nearly all of the eggs in others were fertile. Fertility varies much more than it does among *Acanthina spirata* capsules,

although *A. spirata* has about the same average fertility (Spight, 1976). Fertility is unregulated in Friday Harbor populations, but selection favoring regulation should be strong and therefore reproductive characteristics should be changing rapidly at the present time.

Each infertile egg reduces its parents' fecundity. Since only 35-56% of the eggs are fertile, Friday Harbor females are producing less than half as many embryos as females from Cattle Point are (compare the filled triangles of Fig. 1 with other symbols). If the number of surviving offspring per parent is to be similar at the two sites, then each Friday Harbor offspring must have a greater chance of surviving. Larger hatchlings are generally more likely to survive through the post-hatching period than small ones are (Spight 1972). *T. canaliculata* eggs range from 590 to 650 μm and eggs from Cattle Point become hatchlings of 1150 to 1300 μm . When only 56% of the eggs are fertile, the average embryo will have nearly twice as much yolk as would an embryo without nurse eggs, and therefore Friday Harbor hatchlings should weigh twice as much as those from Cattle Point. The large Friday Harbor hatchlings should be more likely to survive than the small ones from Cattle Point. However, if survival is dependent on size alone, then the optimum hatching size is the same for all parents of *T. canaliculata*, and an increase in hatching

size will result in a net decrease in the number of hatchlings surviving through the critical post-hatching period (Smith & Fretwell, 1974). If nurse-egg feeding, accompanied as it is by decreased fecundity, is to be evolutionarily successful, then the optimum hatching size must be altered. Further work will be required to determine whether necessary changes are in progress for *T. canaliculata*.

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THE CHINESE APPLE SNAIL, *CIPANGOPALUDINA CHINENSIS*, ON ORCAS ISLAND, WASHINGTON¹

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ABSTRACT

A very large population of Cipangopaludina chinensis (Gray, 1834) is reported from Lake Cascade on Orcas Island in the Puget Sound region of western Washington.

Various authors have reported the establishments of populations of the freshwater

¹ Part of a larger study supported by Sigma-Xi-Resa and Institutional grants.

viviparid snail, *Cipangopaludina chinensis* (Gray, 1834), in widely separated sections of North America, assigning several specific epithets to the snails (Dundee, 1974), including *Viviparus*

malleatus Reeve and *V. stelmaphorus* Bourguignat. Previous reports of the species from the state of Washington are restricted to a population in Green Lake at Seattle (Hanna, 1966).

The population reported here was thriving in 1973 in Lake Cascade at Moran State Park on Orcas Island, the largest and most highly tourist-oriented body of land in the San Juan Island off the Washington coast. Although I made no attempt at estimating population size, 56 individuals were secured in approximately 30 minutes from an area no larger than two square

meters. The smallest individual is 7.0 mm in total length, and the largest 44.0 mm, indicating, of course, that reproduction was occurring at that time. One shell and operculum were deposited at the Delaware Museum of Natural History (no. 106584) as a voucher specimen.

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THE POLYGYRID GENUS *McLEANIA* IN HISPANIOLA

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Mcleania is a genus of medium-sized depressed helicoid land snails in which the species are characterized by having a series of nodelike serrations along the peripheral keel of the shell. Until now the genus was thought to be monotypic and endemic to Puerto Rico (see van der Schalie, 1948:70) where the type species, *M. darlingtoni* Bequaert and Clench was discovered by Philip J. Darlington, Jr. in 1938. Bequaert and Clench (1939:283-284) tentatively placed *Mcleania* in the Cepolidae (= Xanthonichidae, see Baker, 1956) because of resemblances in size and shell shape to some *Hemitrochus*. Baker (1940: 55-57) demonstrated that the reproductive anatomy of *Mcleania* is similar to that of *Thysanophora*. Currently *Mcleania*, *Thysanophora*, and allied genera are placed in the Thysanophorinae, a subfamily of the Polygyridae.

During June, 1974, and January, 1976, I collected shells of two undescribed land snails from the Barahona Peninsula, Dominican Republic. One species is described in this paper. The second

remains undescribed because it is represented by a single immature shell that does not show definitive characteristics of its species. These two snails are tentatively assigned to *Mcleania* because of similarities in shell structure to *M. darlingtoni*. They differ from *M. darlingtoni* in important characteristics of the sculpture, as well as several other traits. No live specimens of the two new taxa were found, and a more satisfactory basis for relating them to *M. darlingtoni* cannot be given at this time.

Field work in the Dominican Republic was sponsored by the Florida State Museum and the National Geographic Society, Committee for Research and Exploration. I am grateful to officials of both organizations for making this field work possible.

Mcleania tumidula new species

(Fig. 1, A-C)

Shell.—Depressed helicoid, about 0.53-0.67 times as high as wide; medium sized, being about

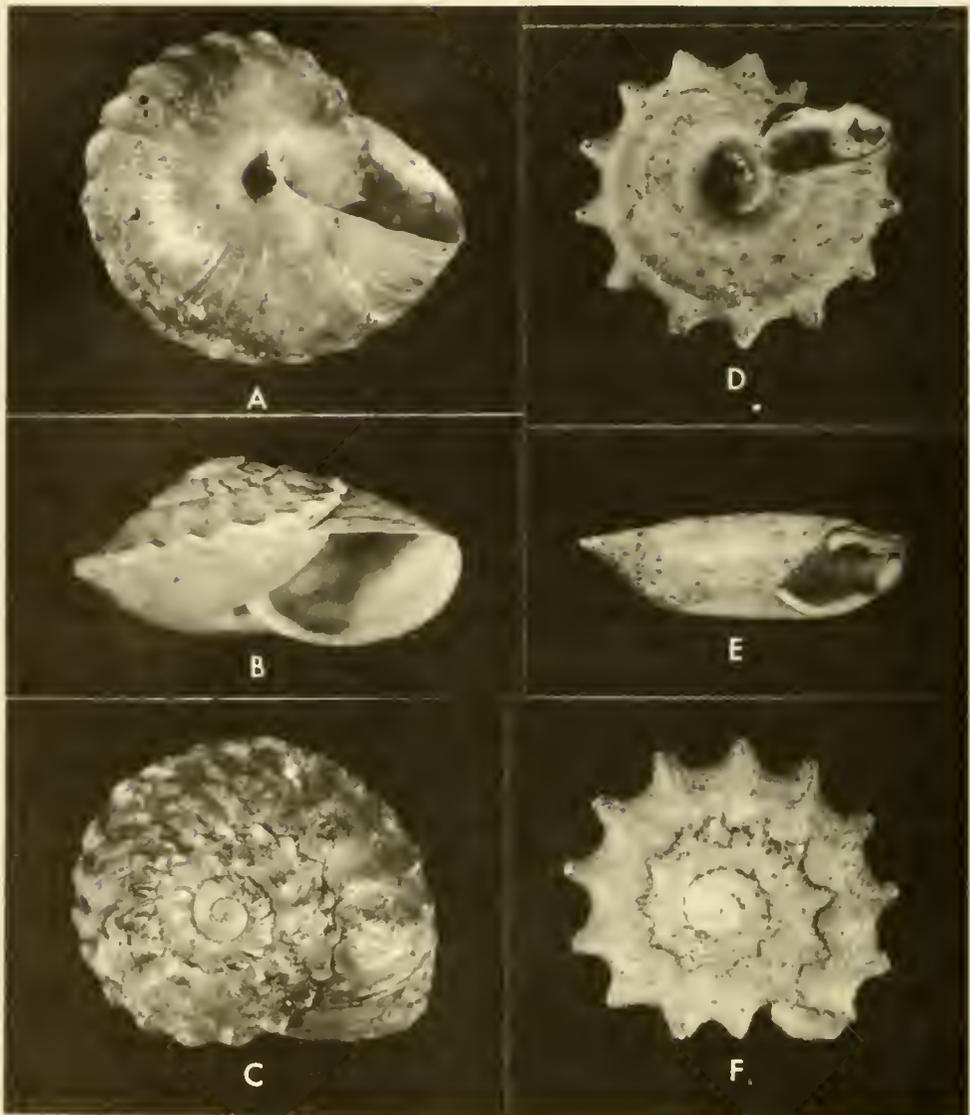


FIG. 1. A-C *Meleania tumidula* new species, holotype (UF 22736). 14.6 mm in width. D-F *Meleania darlingtoni* Be-

quaert and Clench; 30 km. N.N.W., 3 km E. Ponca, Puerto Rico, 1000-1150 m. alt. (UF 22738).

15 mm wide. Color uniform light brown. Shell opaque. Spire low, obtuse, nearly flat sided, slightly convex in outline. Base inflated. Whorls rapidly increasing in size, keeled, with about 19-21 obliquely compressed knobby serrations along the periphery that form a scalloped fold around the shell. The peripheral interior of the shell is indented beneath the knobs. Body whorls nearly flat above the periphery, strongly inflated

below; descending very slightly along its last quarter. Umbilicus narrow, about 1/25 the diameter of the shell. Umbilicus partially obscured by reflected columella. Adult shell with 3.6 whorls, and having 1.4 embryonic whorls. First embryonic whorl smooth. Subsequent embryonic portion with weak incremental growth wrinkles. First quarter of post-embryonic whorl with fine incremental thread-striations that are

replaced rapidly by heavy cord-like folds extending halfway across the whorl from the suture. Folds more or less alternating with compressed knobs along the periphery. Superimposed on the cords is an oblique series of irregular, fine zig-zag striations that tend to become corrugated near the periphery and on the knobs. Base of shell with fine, irregular, incremental striations bearing superimposed and finer, short, scattered, zig-zag striations that tend to corrugate the base. Aperture broadly auriculate, deeply indented by previous whorl. Peristome simple, thin, weakly reflected, incomplete across parietal wall. Dorsal lip nearly straight. Columellar margin moderately reflected over umbilical area. Parietal callus thin, transparent, strongly recurved near umbilicum, nearly straight otherwise.

Measurements in mm of the three known specimens are:

	Height	Width	Aperture H	Aperture W	Whorls
Holotype	7.7	14.6	4.6	8.3	3.6
Paratype	6.8	10.6	5.0	6.5	3.5
Paratype	5.9	8.8	4.5	5.7	3.3

Type Locality—Dominican Republic, Barahona Prov., Loma Caña Brava, 6 km. E, 6 km. NNE Polo, 1370 m. alt. Holotype: UF 22736; collected 18 January, 1976 by Fred G. Thompson. Paratypes: UF 22735(2); same locality as the holotype.

The type locality is in a wet mountain forest at the crest of the mountain Loma Caña Brava. The microhabitat occupied by the snail was not determined for live specimens were not encountered. The shells comprising the type series were found on the ground under limestone slabs on densely shaded moss and lichen covered knolls.

Remarks—*Meleania tumidula* can be compared with two other species, *M. darlingtoni* from Puerto Rico and another undescribed species from Hispaniola to which it is more closely related. It differs from *M. darlingtoni* in numerous details. The shell is much larger, attaining a major diameter of about 15 mm. It has a broadly obtuse raised spire, resulting in a height/width ratio of about 0.53-0.67. The whorls are much more inflated, and have more (19-21) but much weaker

serrated nodes per whorl along the periphery. The umbilicus is much narrower, being about 1/25 the width of the shell. The peristome is incomplete across the parietal wall, and the outer lip is only slightly reflected. The periostracum is nearly smooth, having weak incremental striations and poorly defined oblique anastomosing wrinkles. The embryonic whorls are smooth initially, with weak incremental sculpture following the first whorl.

M. darlingtoni is characterized by numerous peculiarities (Fig. 1, D-F). It attains a major diameter of about 12 mm, and is planispiral with a height/width ratio of about 0.36-0.38. The whorls are relatively small in caliber and have about 12-16 strong protruding nodes along the periphery. The umbilicus is very broad and funnel shaped, being about 1/3 the width of the shell. The peristome is complete and the aperture is slightly free from the preceding whorl. The lusterless periostracum bears numerous course incremental threads and fimbriations that form scattered tufts on the base and apex. The peripheral serrations are coarsely marked with radial periostracal fimbriations. Finally, the embryonic whorls have rather course, strongly oblique anastomosing wrinkles.

The differences between *M. tumidula* and *M. darlingtoni* are numerous and of such a magnitude that a congeneric assignment of the two species is only provisional. Most fundamental of these differences is the sculpture. Until the soft anatomy of *M. tumidula* is investigated the systematic relationships and biogeographic implications must be interpreted with caution.

An additional undescribed *Meleania* occurs in the Sierra de la Salle north of Pedernales, Pedernales Prov., Dominican Republic. A single immature shell (UF 22737) was collected 1 km. south of Altigracia, at 750 m. altitude in a cacao grove. Compared to *M. tumidula* this other species has course, irregular radial sculpture on the spire, is nearly planispiral, and has a wide umbilicus that is about 1/6 the diameter of the shell. In other aspects it is more like *M. tumidula* than *M. darlingtoni*.

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RECENT DEATHS

Alberto Carcelles, well-known and leading malacologist of Argentina, died January 23, 1977, in Alta Gracia, Córdoba, Argentina, at the age of 81. Dr. Carcelles taught at the University in Buenos Aires and was for years Chief of the Invertebrate Section, in the Museo Argentina de Ciencias Naturales. He was born in Buenos Aires on July 18, 1897. He authored many works on the marine mollusks of Uruguay and Patagonia. Among his students was Dr. J. J. Parodiz of Pittsburgh, Pa.

John Dyas Parker, malacological archivist for the Delaware Museum of Natural History and long-time assistant to Henry A. Pilsbry at the Academy of Natural Sciences of Philadelphia, died February 2, 1977, of a heart attack, in Pennsylvania, at 61. He stimulated interest in mollusks among amateurs who funded the Pilsbry Chair of Malacology, and was a co-founder of the Philadelphia and Wilmington Shell Clubs. He was active in paleontological field work and cave exploration. Jack was born June 5, 1915, in Woodhaven, Long Island, N. Y. where he is now buried.

Willard Lee Mohorter, former publisher and private shell collector, died October 19, 1976, in Cincinnati, Ohio, at the age of 88. He and his late wife travelled extensively from 1936 to 1975 in search of mollusks. He was honorary curator of mollusks at the Cincinnati Museum of Natural History and donated part of his collection to that institution. He was born in Kiamensi, Delaware,

October 4, 1888. A short, posthumous biography of "Mr. Mo" appeared in the *Hawaiian Shell News*, February 1977.

Esther Brooks Hadley, well-known shell dealer in Newton, Massachusetts since 1936, died in North Adams, Massachusetts, on September 9, 1976 at age 87. Formerly, she worked for the Veterans Administration in Boston. She and her late husband, F. Knight Hadley, operated a shell mail order business for forty years. Her collection is for sale by her son, Norman, of Jacksonville, Vermont 05432.

Kenneth R(ichard) H(odgson) Read, biochemist and marine biologist at Boston University, died February 24, 1977, at 48, in Boston, Mass. He was well-known for his underwater photography, and published on myoglobins in mollusks. He was born September 9, 1928, in Dinas Powis, Wales, and obtained a Ph. D. at Harvard University in 1963.

Albert B(ernhard) Kettell, for years a pastor of the United Church of Christ in New England, an Army Chaplain during World War II, and an ardent shell collector, was born in Somerville, Mass., March 7, 1896. He was a member of the A.M.U. for 25 years and a former President of the Connecticut Valley Shell Club. Reverend Kettell amassed a large collection of shells, and retired to Clearwater, Florida, where he died December 30, 1976, at the age of 81. He is survived by his wife, Clara Dito Kettell. See *American Malacologists*, 1975 supplement, p. 555.

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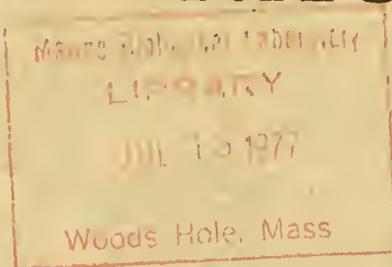
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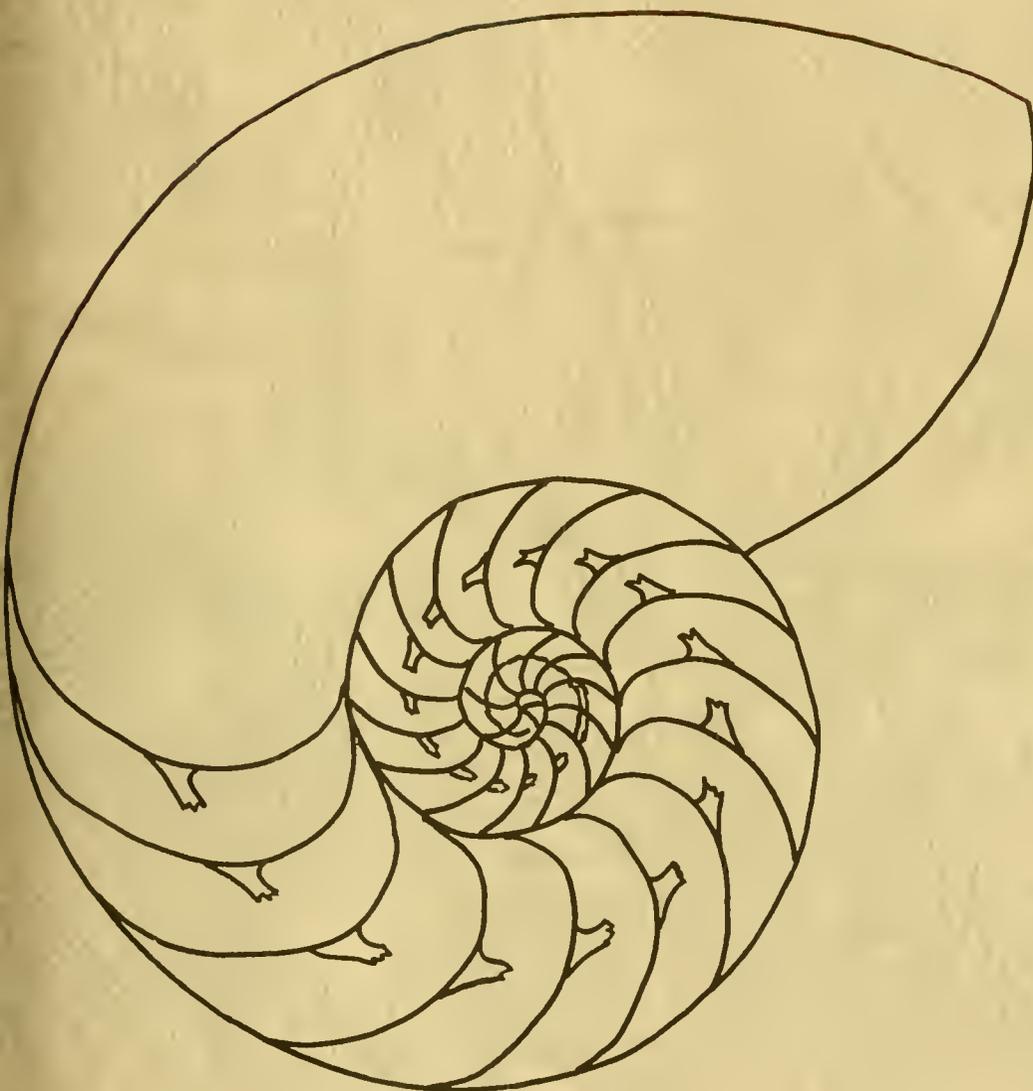
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NOTES ON SOME INDO-PACIFIC SPECIES OF *MORUM*
(GASTROPODA: TONNACEA)

William K. Emerson

American Museum of Natural History
New York, New York 10024

ABSTRACT

Descriptive and distributional data are given for three poorly known and misunderstood species of Morum from the Indo-Pacific. Additional specimens of Morum (Oniscidia) exquisitum are reported from the Sulu Sea, and records other than those from the Philippines are rejected. Morum (O.) praeclarum, a species previously reported from deep water off Natal and Zululand, South Africa is reported from four stations in the western Indian Ocean. The recorded range of Morum (Herculea) ponderosum is extended to include New Caledonia and the Pitcairn Islands.

Specimens of two poorly known Indo-Pacific species of the genus *Morum*, namely: *Morum exquisitum* (Adams and Reeve, 1848) and *M. praeclarum* Melvill, 1919, have recently come to the attention of the writer. *Morum exquisitum* was described from a unique specimen obtained by Arthur Adams in the Philippines during the celebrated voyage of the HMS *Samarang* to the western Pacific and Indian Oceans, from 1843 to 1846. Despite the fact that this species, based on the type specimen dredged in the Sulu Sea, was well-described and illustrated by Adams and Reeve (1848, 1850) and by Reeve (1849), the identity of this taxon has remained uncertain owing to its extreme rarity in collections. Most subsequent workers followed Tryon (1885) who considered it to be conspecific with *Morum ponderosum* (Hanley, 1858), a distinct species originally described from an unknown provenance. The two species were finally separated by Melvill (1919), and he correctly recorded *M. ponderosum* from Japanese waters.

Through the good offices of Dr. Joel Greene of San Francisco, California, a mature, live-taken specimen of *Morum exquisitum* (figures E, F, J) was recently brought to my attention. This specimen, together with a dead one, was taken by divers in shallow depths off Laminusa, Sulu, Philippines. Now in the collection of the American Museum of Natural History (cat. no. 183926),

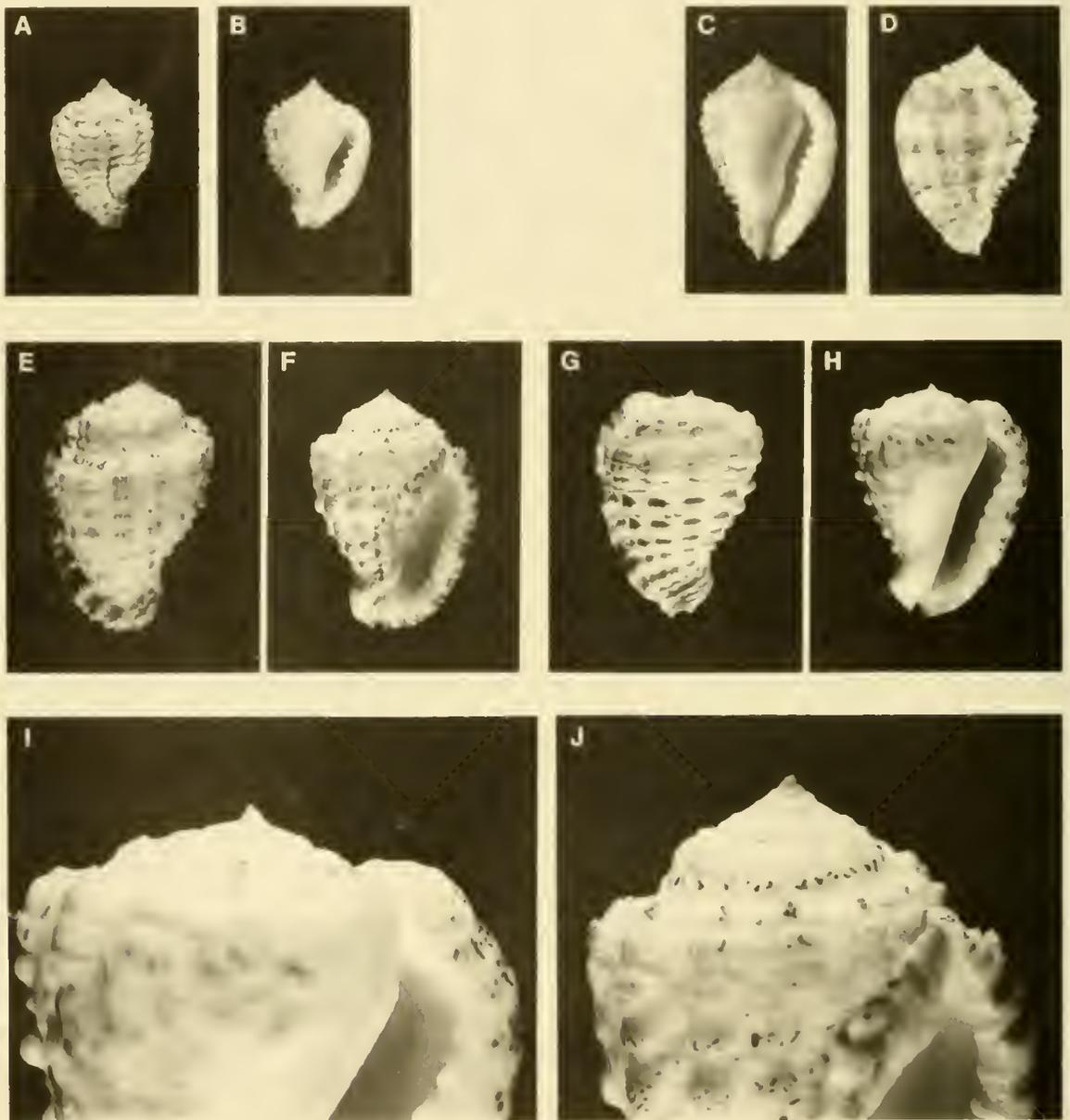
this specimen compares favorably in all details with the figured holotype, except it is slightly larger with 5 post-nuclear whorls, and has 12 axial ribs on the body whorl. The apex is colored a pale pink, whereas the parietal shield and the blotches on the outer lip are a light purple-pink. Of the living species of *Morum*, it appears to be most closely related to the New World "twin species," *M. veleroae* Emerson, 1968, from the eastern Pacific, and to *M. dennisoni* (Reeve, 1842), from the Western Atlantic. Attesting to the rarity of *M. exquisitum*, I was able to locate only two other specimens in institutional collections.

Compared to *M. exquisitum*, *M. ponderosum* (figures G, H, I) has a heavier shell, which is more triangular in outline, with coarser ornamentation and a much lower spire. The parietal wall is heavily callused and the non-pustulose, flattened shield covers most of the apertural side of the body whorl. Numerous weakly formed, irregular folds extend down the parietal wall into the aperture. The outer lip is thickened and the inner margin is dentate; the lip extends posteriorly to the penultimate whorl to form a deep sulcation. The shell, including the apex, is colored creamy white with occasional streaks and blotches of reddish brown, which are especially prominent on the reflected surface of the outer lip. The parietal shield is suffused with creamy tan and is variegated with reddish brown markings.

Perhaps one of the reasons Tryon (1885) erroneously concluded that *M. exquisitum* and *M. ponderosum* were the same species was the result of the artist's lapsus in coloring the original figures (Hanley, 1858) of *M. ponderosum* reddish

purple, instead of the natural reddish brown coloration that is characteristic of this species.

Morum praeclarum Melvill, 1919 was described from a unique specimen lacking locality data obtained from the collection of J. J. MacAndrew,



FIGS. A-D *Morum* (O.) *praeclarum* Melvill; A-B Faqhuar Group, Seychelle Islands, in 80 m., NMNH no. 71862. C-D Holotype, Melvill-Tomlin Coll., NMW (Courtesy of National Museum of Wales); A-D about 3/4 natural size. E, F, J *Morum* (O.) *exquisitum* (Adams & Reeve); Laminusa, Suba Sea, Philippines, in 6 m., AMNH No. 183926; E, F about 3/4 natural size; J spire greatly enlarged to show protoconch. G, H, I *Morum* (H.) *ponderosum* (Hanley); Oeno Island, Pitcairn Islands, off reef, NMNH No. 731601; G, H about 3/4 natural size; I spire greatly enlarged to show protoconch.

for whom *Morum macandrewi* (Sowerby, 1889) had been named 30 years previously. Although the type specimen of *M. praeclarum* was illustrated recently in color (Dance, 1971), no additional material had been recognized until Kilburn (1975) reported it from South Africa. Dr. Joseph Rosewater uncovered five specimens in the National Museum of Natural History collections. An additional specimen was located in the Delaware Museum of Natural History by Dr. R. Tucker Abbott. These specimens were dredged by the "Anton Bruun".

The newly discovered specimens of *M. praeclarum* (figures A, B) are more diminutive than the holotype (figures C, D), the largest being 30.3 mm in length, compared to 40 mm for the type specimen. Otherwise they agree well in essential characters with the description and illustrations of the holotype (Melvill, 1919; Dance, 1971). Melvill believed this species to be "nearest" to *M. exquisitum*, but he also compared it to *M. macandrewi*, to which it is actually more closely related. It differs, however, from *M. macandrewi* in several respects. The shell is smaller, proportionally more robust and less pyriform in outline; the axial ridges are more delicate and they form sharp, scalelike spines at the intersections of the spiral ridges; the parietal shield is thickly enameled, finely ornamented with pustules anteriorly and lineations posteriorly, and the denticles on the outer lip are confined to the apertural surface. Dance's illustration (1971, p. 119) suggests that the brownish spiral bands are well-developed on the holotype. In the present specimens, these bands are more diffused and are most prominent on the reflected surface of the outer lip and the adjoining portion of the body whorl. In these specimens, the surface is suffused in buffish cream and the spiral bands form streaks of light brown. As in the holotype, the aperture, outer lip, and parietal shield are a milky white.

TAXONOMY

In a revision of the southwestern Pacific species, Beu (1976) reviewed the taxonomic status of the genus *Morum* Röding, 1798, type species by monotypy: *Morum purpureum* Röding, 1798

(=*Strombus oniscus* Linnaeus, 1767). In addition to the nominate subgenus, he recognized two subgenera: (1) *Oniscidia* Mörch, 1852, type species by monotypy: *Oniscia cancellata* Sowerby, 1824; (2) *Herculea* Hanley, in H. and A. Adams, 1858, type species by monotypy: *Oniscia ponderosa* Hanley, 1858.

The attribution of the first valid use of *Oniscidia* to Mörch, 1852, by action of the International Commission of Zoological Nomenclature (Opinion 1040), precludes the use of *Cancellomorum* Emerson and Old, 1963, type species by original designation: *Oniscia grandis* A. Adams, 1855, and *Onimusiro* Kira, in Kuroda, Habe, and Oyama, 1971, with the same type species and method of designation. Both of these rejected taxa, which are currently widely used respectively in the American-European literature and in the Japanese literature, thus become junior subjective synonyms of *Oniscidia* Mörch. Beu (1976) also referred *Pulchroniscia* Garrad, 1961, type species by monotypy: *Pulchroniscia delecta* Garrad, 1961 (= *Oniscidia bruuni* Powell, 1958, *vide* Beu, 1976), to the synonymy of *Oniscidia* Mörch. Because generic synonymies of *Morum sensu lato* are given by Beu (1976), they are not repeated here.

INDO-PACIFIC SPECIES

In addition to the three species discussed below, the following nominal species of *Morum* are known from the Indo-Pacific: *M. (Oniscidia) cancellatum* (G. B. Sowerby, I, 1824); *M. (O.) grande* (A. Adams, 1855); *M. (O.) macandrewi* (G. B. Sowerby, III, 1889); *M. (O.) bruuni* Powell, 1958; *M. (O.) teramachii* Kuroda and Habe, in Habe, 1961; *M. (O.) uchiyjamai* Kuroda and Habe, in Habe, 1961; and *M. (O.) watsoni* Dance and Emerson, 1967: *quod vide* for citations to the original descriptions.

Morum (Oniscidia) exquisitum (Adams and Reeve, 1848)

Figures E, F, J

Oniscia exquisita Adams and Reeve, in Adams, 1848, p. 35 [text p. 35, issued in May, 1850], pl. 5, figs. 3a, 3b, [References To Plates, p. x and pl. 5, issued in November, 1848], "Sooloo [Sulu] Archipelago; outside a coral reef near the city

of Sooloo [Jolo] in about sixteen to twenty fathoms, sandy mud." Reeve, 1849 [issued in August], vol. 5, *Oniscia* pl. 1, fig. 3, "Sooloo [Sulu] Archipelago" [repeats data of Adams and Reeve, 1850].

Oniscia exquisita Reeve, Küster, 1857, p. 58, pl. 55, fig. 10 (after Reeve, 1849, fig. 3), "Soulou-Archipel von Belcher entdeckt."

Oniscia (Oniscidia) exquisita Adams and Reeve, Tryon, 1885, p. 282, pl. 8, fig. 100 (after Reeve, 1849, fig. 3), "Sooloo [Sulu] Sea; Australia."

Morum (Oniscidia) exquisitum, Melvill, 1919, p. 72, "Sooloo [Sulu] Archipelago [etc.], Philippine Isles (Hidalgo), Japan (Hirase), Saya de Malha Banks, S. Indian Ocean (J. Stanley Gardiner)."

Morum exquisitum Adams and Reeve, Abbott, 1962, p. 66, color illus., "Philippines, rare."

Type depository: not known (Melvill, 1919, p. 72; Dance and Emerson, 1967, p. 95). The specimen figured by Reeve (1849), the apparent holotype, was sold in 1865 when the famous collection of John Dennison was disposed by public auction in London (Melvill, 1919; Dance, 1966, p. 210). The holotypic specimen is apparently lost.

Type locality: off Jolo [Sulu City], Sulu Island, Sulu Archipelago, Philippines, in 30 to 36 meters.

Verified geographic range: Known only from the Sulu Archipelago, Philippines, in 6 to 36 meters.

Material examined: Philippines: 6 meters, Laminusa, Sulu Archipelago, 1 specimen, 46.7 mm in length, 27.4 mm in width, *ex* Joel Greene, AMNH 183926; Tawi-Tawi, Sulu Archipelago, 1 specimen 30.3 mm in length, 19.5 mm in width, *ex* Mrs. P. Bautista, ANSP 218411, illustrated in Abbott (1962, p. 66); Zamboanga, Mindanao, 1 specimen, 32.4 mm in length, 22.5 mm in width, NSMT 54630.

Remarks: The early citations in the literature to records from Japan, Australia, and the Indian Ocean appear to be erroneous. Dr. Habe (personal communication) has no knowledge of specimens from Japanese waters. The specimen in the British Museum (Natural History) reported by Melvill (1919) from the Indian Ocean was sent to me on loan. It is apparently referable to *Morum praeclarum* Melvill, being a badly worn, broken and discolored juvenile shell. The Japanese and Australian records were based most likely on

misidentified specimens of *M. (H.) ponderosum*. At the present time *M. (O.) exquisitum* is known only from the Sulu Sea.

Oniscia exquisitum Adams and Reeve dates from November 1848, when the name was applied to figures 3a, 3b of plate 5 in the "References To Plates, Mollusca" of the Zoology of the Voyage of the H.M.S. *Samarang*. The description appeared subsequently, in May 1850, when the text was issued.

Morum (Oniscidia) praeclarum Melvill, 1919

Figures A—D

Morum praeclarum Melvill, 1919, p. 69, text fig. "Hab.[itat]?" J. J. MacAndrew Coll. Dance, 1971, p. 119, fig. 5, "locality unknown"; 1975, Kilburn, p. 49, "off Mvoti River, 56 fms., and off Durban, South Africa, 160 fms."

Type depository: holotype, here illustrated, figures C—D, Melvill-Tomlin Collection, National Museum of Wales, Cardiff (Dance and Emerson, 1967, p. 95); N.M.W. accession No. 55.158, *teste* June Chatfield.

Type locality: 11 mi. off Port Shepstone, South Africa in 250 fathoms. (Kilburn, 1975).

Verified geographic range: western Indian Ocean; off Somali Republic and Mozambique, Africa; Seychelle Islands, in 78 to 132 meters off South Africa.

Material examined: Africa; 80 miles E. of Ras Maber, N.E. Somali Republic; 78-82 meters, 1 specimen, 28.6 mm in length, 20.1 mm in width, "Anton Bruun," Sta. 9-445, 09°36' N. Lat., 51°01' E. Long., *ex* Harold Vokes, DMNH 117851; off Mozambique; ca. 40 miles E. Quissico, 132 meters, 2 specimens, 30.3 mm in length, 21.1 mm in width, 30.1 mm in length, 19.1 mm in width, "Anton Bruun," Cruise 7, Sta. 371-E, NMNH 761345. Seychelle Islands: ca. 80 meters, Faquhar Group, 1 specimen, 26.7 mm in length, 17.2 mm in width, "Anton Bruun" Cruise 9, Sta. 444, 09°36' N. Lat., 51°01' E. Long., NMNH 718962; ca. 90 meters, Faquhar Group, 2 specimens, 24.8 mm in length, 17.2 mm in width, 23.2 mm in length, 16.4 mm in width, "Anton Bruun" Cruise 9, Sta. 437, 09°25' N. Lat., 50°54' E. Long., NMNH 718953.

Remarks: At my request, Dr. June Chatfield kindly compared the holotype of *M. praeclarum* with the illustration of the type specimen in Dance (1971, p. 119, fig. 5). She concluded that the

figure is fairly accurate in color, but it is perhaps a little darker than the holotypic specimen. The East African provenance of this species has been revealed through the dredging operations of the "Anton Bruun" in the Indian Ocean. Additional unrecognized specimens of this species probably exist in the extensive collections made in recent years from this region.

Morum (Herculea) ponderosum (Hanley, 1858)

Figures G, H, I

Oniscia ponderosa Hanley, 1858, pp. 255, 256, pl. 42, fig. 9, 10, "Hab[itat]?", Cuming Coll. Tryon, 1885, p. 282, pl. 10, fig. 22 (after Hanley, 1858, fig. 10), [incorrectly cited as a synonym of *Morum exquisitum* (Adams and Reeve)]. Stearns and Pilsbry, 1895, "Yaeyama" [Ryukyu Islands], incorrectly cited as "*Oniscia exquisita*," which, following Tryon, was considered to be a synonym of *Morum ponderosum*.

Morum ponderosum (Hanley), Hirase and Taki, 1951, pl. 98, fig. 2, "Amami-Ôshima," Ryukyu Islands. Kuroda and Habe, 1952, p. 68, Range: 0-29° North Latitude. Oyama and Takemura, 1961, pt. 5, *Morum* pl. 2, figs. 4, 5, "Amami-Oshima Isl."

Morum (Herculea) ponderosum (Hanley), H. and A. Adams, 1858, p. 621. Melvill, 1919, p. 71, "Japan (Stearns)." Shikama, 1963, p. 59, pl. 42, fig. 4 "Amami-Ôshima, Ryûkyû Group, Japan." Habe, 1964, p. 69, p. 21, fig. 1, "rare, Amami and Ryûkyû Islands, wide-ranging in the Indo-Pacific regions." Shikama, 1964, p. 114, fig. 193. Ponder, *in* Beu, 1976, p. 224, "Herald Cay and Lady Elliot Island, Queensland."

Type depository, Lectotype: BM(NH) No. 1966724, *ex* Hugh Cuming Collection, selected by Dance and Emerson (1967, p. 94); syntype BM(NH) No. 196625, *ex* Hugh Cuming Collection.

Type locality; Amami-Oshima, Ryukyu Islands, here designated.

Verified geographic range: Ryukyu Archipelago, Japan; Queensland, Australia (*vide* Beu, 1976); New Caledonia; and the Pitcairn Islands.

Material examined: Japan: Ryukyu Islands: "Oshima Osumi" [Amami-Oshima], 2 specimens,

47.8 mm in length, 31.5 mm in width, 34.5 mm in length, 21.6 mm in width, Hirase Coll., NMNH 34938; Amami-Oshima, 1 specimen, 31.7 mm in length, 21.8 mm in width, Hirase Coll., MCZ 43262; Amami-Oshima, 2 specimens, 45 mm in length, 28.5 mm in width, 32 mm in length, 22.8 mm in width, Hirase Coll., ANSP 98020; Amami-Oshima, 1 specimen, 22 mm in length, 18.2 mm in width, A. R. Cahn Coll., ANSP 275543; Okinawa, Onna sand flat, 1 specimen, 38.6 mm in length, 26.7 mm in width, Bernice Albert, leg., ANSP 276387; Okinawa, Kadena, 1 specimen, 36.6 mm in length, 24 mm in width, Rose Burch Coll., AMNH 114571; Okinawa, Kadena, 1 specimen, 37.3 mm in length, 25.8 mm in width, W. A. McCarty, leg., AMNH 183950.

New Caledonia: 1 specimen, C. T. Trenchmann Coll., BM(NH) 1964504, *teste* A. F. Blake.

Pitcairn Islands: off reef, N. coast of atoll, Oeno Island, 1 specimen, 41 mm in length, 27.8 mm in width, H. A. Rehder leg., NMNH 731601; Henderson Island, 1 specimen, J. R. Jamieson and D. K. Tait leg., BM(NH) 1913.7.28.90, *teste* A. F. Blake.

Remarks: According to Dr. Tadashige Habe (personal communication) specimens from the Hirase Collection bearing the locality Oshima Osumi are from Amami-Oshima of the Amami Group in the Ryukyu Archipelago. Early records attributed to "Japan" are actually referable to the Ryukyus and Okinawan Islands. The disjunct distribution of the uncommon species apparently represents gaps in collecting in the intermediate areas, rather than a relict distributional pattern.

ACKNOWLEDGMENTS

I am indebted to the following curators for professional courtesies of various kinds: Drs. R. Tucker Abbott, Delaware Museum of Natural History (DMNH); June Chatfield, National Museum of Wales (NMW); Kenneth J. Boss, Museum of Comparative Zoology, Harvard University (MCZ); George M. Davis, Academy of Natural Sciences of Philadelphia (ANSP); Tadashige Habe, National Science Museum, Tokyo (NSMT); Joseph Rosewater, National Museum of Natural History, Smithsonian Institution (NMNH); and John Taylor and Miss A. F.

Blake, British Museum (Natural History) (BMNH). I thank my colleague, Mr. William E. Old, Jr., for technical assistance.

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A NEW ABYSSAL AMAEA (GASTROPODA: EPITONIIDAE) FROM THE NORTH EASTERN PACIFIC OCEAN

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ABSTRACT

Amaea siapnoi new species, a deepwater epitoniid, is described from a location about 540 nautical miles southwest of Islas Revillagigedo, Mexico.

Species of *Amaea* are rare in the North Pacific Ocean. Until now, no species of this genus has been reported from the south eastern portion of the North Pacific Ocean. Recently, I have received, on loan, a live-collected specimen of a new species of *Amaea* s. s. for purposes of identification. Deepsea Ventures, Inc., May 1975, retrieved this mollusk from 14,521 feet (4428.60 meters), approximately 540 nautical miles southwest of the Islas Revillagigedo, Mexico.

Superfamily Epitoniacea

Family Epitoniidae

Genus *Amaea* H. and A. Adams, 1853

[Type species (SD, deBoury, 1909:

Scalaria magnifica Sowerby, 1844]

Subgenus *Amaea* H. and A. Adams, 1853

***Amaea (Amaea) siapnoi* DuShane, n. sp.**

(Figs. 1 and 2)

Shell medium in size, off-white in color; nuclear and early postnuclear whorls missing, six whorls remaining, gradually expanding to the last whorl; sides of the whorls more perpendicular than in most *Amaea*, giving it a columnar outline; suture well-defined; costae curved and retractive, lamellar near the distinct suture, worn on the whorls, not continuous from whorl to whorl; with a change of slope in the outline of the whorls just below the suture, causing the costae to curve rather abruptly; axial costae on the last whorl 85, of varying thickness, sometimes fusing with adjoining ones, continuous over the

base to the simple lip (outer lip partially fragmented); with a poorly defined basal thread, below which the sculpture is the same as that above; spiral sculpture of approximately 16 to 22 uneven but mostly extremely wide ribs, separated by narrow incised lines that cross the close-set axial costae and impart to the shell a somewhat beaded appearance; aperture round, lip thin; umbilicus lacking; operculum dark, round, horny. Length 34 mm, width 12 mm (holotype).

Type Locality—Approximately 540 nautical miles southwest of Isla Clarión, Islas Revillagigedo, Mexico (14°50' N, 124°29' W), from a depth of 4428.60 meters.

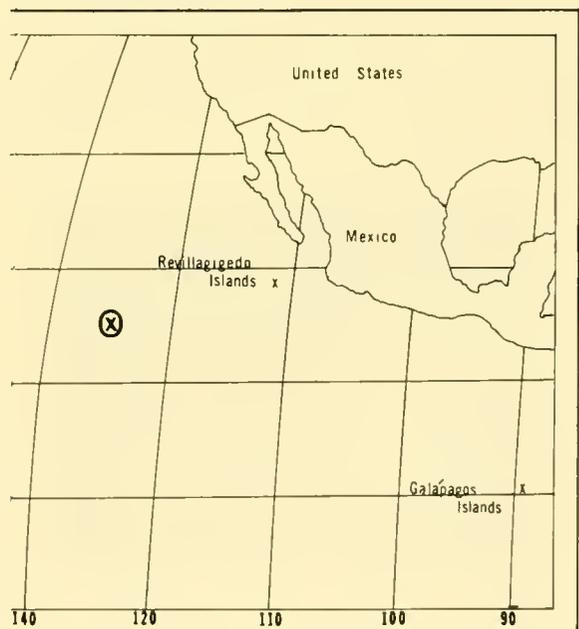


FIG. 1. Map showing approximate location where *Amaea (Amaea) siapnoi* DuShane, n. sp. was taken in a dredge haul from a depth of 4428.60 meters.

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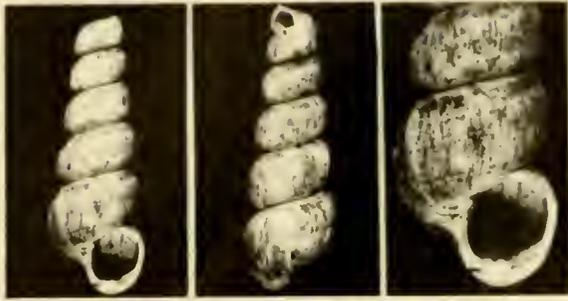


FIG. 2 *Amaea (Amaea) siapnoi* DuShane, n. sp. Left: Ventral view. Length 34 mm, width 12 mm. Center: Dorsal view. Right: Anterior portion enlarged to show poorly defined basal thread. $\times 2$

Type Material—Holotype, Department of Marine Invertebrates, San Diego Natural History Museum, San Diego, California: SDSNH 65482.

Etymology—The species name honors the chief scientist of Deepsea Ventures, Inc., William Siapno.

DISCUSSION

Deepsea Ventures, Inc., working out of San Diego, California, is involved in exploratory mining for manganese nodules. William Siapno, chief scientist of Deepsea Ventures, Inc., collected this new species in May 1975. Other material in the dredge haul included coarse, gritty manganese that still adheres to the shell, manganese nodules, large *Carcharodon* teeth, pelagic shark teeth (probably of Miocene age), a whale ear-bone, small brittle stars, and worm tubes.

The nuclear and immediate post-nuclear whorls of the holotype are missing. One can only conjecture that the live-taken specimen was damaged in the dredge as it was retrieved.

Among the other *Amaea* collected in deep water are *Amaea (Scalina) ferminiana* (Dall, 1908) from 118 to 1333 m off the coast of Peru by the SEPBOP Program on the vessel ANTON BRUUN (DuShane, 1974: 55); *Amaea (Scalina) pompholyx* (Dall, 1908) collected in 1485 m near the Galapagos Islands by the ALBATROSS (station 2807) in ooze (DuShane, 1974: 56). These are

the only two records of *Amaea (Scalina)* from deep water in the tropical eastern Pacific; these depths do not approach the depth from which the present species was taken. Comparison with *Amaea luxus* Okutani, 1964, collected 56 miles off Aogashima Island (32° 20' N, 140° 55.5' E), in from 3,150 to 3,350 m, shows the two species to be congeneric, each with an usually large number of costae. The live-taken specimen of *luxus* differs by having 140 (instead of 84) close-set costae on the last whorl, a very elongate shell with 15 whorls, and a hardly distinguishable basal disk.

ACKNOWLEDGMENTS

To the following people I am indebted in many ways: Drs. Myra Keen, Professor Emeritus, Stanford University and George Radwin, Department of Marine Invertebrates, San Diego Museum of Natural History, for reading preliminary drafts of the paper and providing constructive criticism; to Bertram Draper, Museum Associate, Los Angeles County Museum of Natural History, for the photographs; to Anthony D'Attilio, Department of Marine Invertebrates, San Diego Museum of Natural History, for the map; to William Siapno, Deepsea Ventures, Inc., and Dr. Hugh Bradner, University of California, San Diego, for their help in obtaining the holotype for examination and description.

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EPITONIUM TEXTIMATTUM, A NEW GASTROPOD
FROM THE WEST COAST OF MEXICO

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ABSTRACT

Epitonium (*Asperiscala*) *textimattum* DuShane, n. sp. (Gastropoda) is described from sublittoral water off the west Mexican states of Nayarit, Jalisco, and Colima. It resembles *E. walkerianum* Hertlein and Strong.

Family EPITONIIDAE

Genus *Epitonium* Röding, 1798 [*Scala*
of authors; *Scalaria* Lamarck, 1801]

Subgenus *Asperiscala* deBoury, 1909

Species referable to the subgenus *Asperiscala*, with its type species of *Scalaria bellastrata* Carpenter, 1864, are relatively common constituents of the Panamic-Galapagan fauna, there being 21 recognized species. The new species is known only from the sublittoral zone, 7 to 18 meters, in a mud substrate, dredged from 4 stations off the states of Nayarit, Jalisco, and Colima, Mexico.

Epitonium (*Asperiscala*) *textimattum* n. sp.

(Figs. 1-8).

Description: Shell medium to large in size, elongate-conic, white, sturdy; nuclear whorls 3 to 4, horn-color, rounded, glassy, with a brown sutural line, first two whorls small, subsequent ones much larger and more bulbous with no noticeable sculpture; fifth whorl down with minute indentations and small axial ribs; post-nuclear whorls 5 to 10, rounded, slightly sloping; suture distinct; axial sculpture of 10 to 12 low, rounded, chinalike ribs, inverted V-shaped on early whorls, flat-topped and of varying widths on later whorls, with fine axial grooving and widely-spaced spiral sculpture on the sides (magnification of 20X), without angulation, curving into the sutures, not continuous from whorl to whorl, with an occasional one twice the width of the others; channels between ribs twice the width of the ribs; axial and spiral sculpture striolate (magnification of 40X) between ribs, carrying over the ribs as fine indentations; aper-

ture ovate, outer lip but slightly thickened by the last rib, with faint traces of spiral impressions; peritreme complete, narrower on the columellar portion; umbilicus lacking; operculum light horn color, paucispiral. Length, 12 mm; width, 4 mm (holotype).

Discussion: This epitoniid from the Panamic-Galapagan fauna has an elongate-conic shape combined with a matte texture and sturdy ribs with faint, irregular spiral impressions. Sizes vary from 9.5 to 17 mm in length, with from 10 to 12 costae. (See Figs. 1, 2, 3)

At first it was thought that this species might be the enigmatic *Epitonium* (*Asperiscala*) *regulare* (Carpenter, 1856), type locality, Panama. The original description of *E. regulare* mentions 3 syntype specimens; Keen (1965) photographed 4 specimens labeled with this name, but the label [BM(NH) Reg. No. 1950. 4. 18. 13/16] is not in



FIGS. 1-3—*Epitonium* (*Asperiscala*) *textimattum* DuShane, n. sp. 1—Holotype (LACM, Malacology Type Collection, no. 1846). Length, 12 mm; width, 4 mm. 2 and 3—Paratypes (DuShane Collection). Smaller specimen: length, 11 mm; width, 5 mm. Larger specimen: length, 15.5 mm; width, 5 mm.



FIG. 4—*Epitonium regulare* (Carpenter, 1856): syntype specimens, IBM(NH) Reg. No. 1950. 4. 18. 13/16]. The smallest specimen in the photograph, which may be the broken top of the first specimen to the left, has been lost (teste Dr. John Taylor). Specimen to the far right was erroneously considered by Palmer to be the holotype. $\times 3.14$

Carpenter's handwriting (teste Keen). It is doubtful if any of the specimens shown (Fig. 4) are *E. regulare* of Carpenter, therefore, I do not choose to select a lectotype from among them. Compared to *E. textimattum* the left hand specimen has prominent spiral sculpture between the whorls and very thin costae. The smallest specimen from the left (lost, *fide* Dr. John Taylor, BM(NH)), might well be the upper broken portion of the lefthand specimen. The largest specimen has more convex whorls, a less contracted suture and twice the number of costae (20-22), with narrow interspaces between costae. The right hand specimen has many strong costae, crowded on the whorls, with fine spiral threads between.

The brief description given by Carpenter (1856: 164) makes identification of his nominal species difficult, if not impossible; therefore, their type status is questionable. Palmer (1963: 332) unwisely cited the last specimen mounted on the right as the holotype, which being figured by her, is tantamount to a type selection. This specimen does not fit Carpenter's original description. Because of the uncertainty of the identity of Carpenter's taxon it must stand as a *species inquirenda*.

Pilsbry and Lowe (1932: 120) reported having taken *Epitonium regulare* at Acapulco, Mexico, but examination of the two specimens in the Lowe collection (SDMNH 26442), at San Diego, California, proves them to be *Epitonium (Asperiscala) eutaenium* Dall, 1917. Except for this one reference there seems to be no other cita-

tions to *E. regulare* other than to the syntypic specimens at the BM(NH).

Epitonium (Asperiscala) textimattum is closer to *Epitonium (Asperiscala) walkerianum* Hertli and Strong, 1951 (3.7 to 8 mm in length), than to any other species in the Panamic-Galapagan fauna. It differs from the latter by having much finer spiral threads, fewer and discontinuous ribs, with an occasional heavier rib, and by having a larger shell (9.5 to 17 mm in length). The range for *E. walkerianum* is from San Felipe, Gulf of California, along the west coast of Mexico as far south as Nicaragua, taken from the intertidal zone down to 23 meters, whereas *E. textimattum* is known only from off the west Mexican states of Nayarit, Jalisco, and Colima.

The soft parts, when live, show through the shell as coral-pink in color. The color fades to a peach-tan within a few weeks. Sixty specimens of this species were dredged just beyond the wave line at Playa Los Angeles, Jalisco, Mexico, mud substrate, at a depth of 7 to 18 meters in association with the sand dollars, *Encope fragilis* Clark, 1948 and *Encope perspective* Agassiz, 1841, August 1975, by Carol and Paul Skoglund. Dredging repeated at the same locality in December, 1975 revealed only two specimens of the new species and only a few specimens of *Persicula* sp. and *Kurtziella* sp. that were so numerous in



FIG. 5—Map taken from the U. S. Hydrographic Survey showing the coastline along which *Epitonium (Asperiscala) textimattum* DuShane, n. sp. occurs. The solid triangle indicates the type locality.

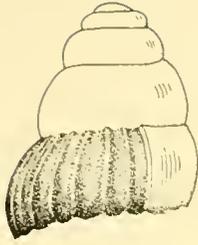
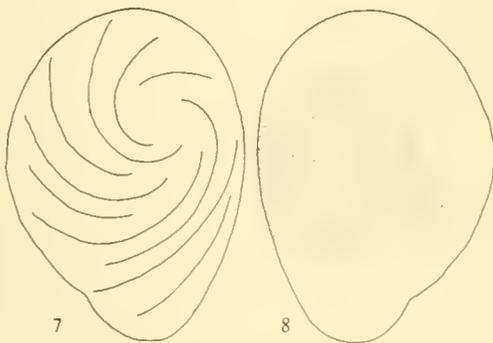


FIG. 6—*Epitonium (Asperiscala) textimattum* DuShane *n. sp.* Nuclear whorls showing sculpture on the fifth whorl down of minute indentations and small axial ribs (white portions).

August. In addition, few sand dollars were present in the December dredgings.

Type locality—Playa Los Angeles, Tenacatita Bay, Jalisco, Mexico (Lat. 19° 18' N; Long. 104° 50' W), at depths of 7 to 18 meters. (See Map)

Type material—holotype, Los Angeles County Museum, Malacology Type Collection, No. 846. Paratypes (1): To each of the following institutions, American Museum of Natural History, British Museum (Natural History), Delaware Museum of Natural History, Los Angeles County Museum of Natural History, National Museum of Natural History (Smithsonian Institution), Academy of Sciences of Philadelphia, Santa Barbara Natural History Museum, San Diego Natural History Museum; (2) DuShane Collection; remainder in the Bennet and Skoglund Collections. Additional paratypes.—Lo de Marcos, Nayarit; collected by the Bennets and Skoglunds, September, 1974, dredged from 7 to 18 m, 1 specimen; Cuastecomate, Jalisco; collected by the Skoglunds, August, 1975, dredged from 11 to 27



FIGS. 7 and 8—*Epitonium (Asperiscala) textimattum* DuShane, *n. sp.* 7—Operculum showing growth lines. Actual size 2 mm. 8—Attachment side of operculum showing muscle attachment scar.

m, 2 specimens; Santiago Bay, Colima; collected by the Skoglunds, August, 1975, dredged from 11 to 18 m, 1 specimen.

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To Dr. William K. Emerson I am most indebted for having read the manuscript and offered useful suggestions and corrections, as well as the species name; to Dr. George E. Radwin for the loan of two specimens from the Lowe Collections; to Dr. Myra Keen for her photograph of syntypic specimens of *E. regulare* in the BM(NH) and to Bertram Draper for photographs of the new species; to Dr. John Taylor for comparison of species involved; to Merton Goldsmith for the drawings and the map; to the Skoglunds (Carol and Paul) for the privilege of naming this new taxon.

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THE EFFECTS OF GRAZING BY PHYSID AND PLANORBID FRESHWATER SNAILS ON PERIPHYTON

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ABSTRACT

Populations of Physa heterostropha (Say) (Physidae) and Promenetus exacuus (Say) (Planorbidae), were used in two-week experiments in controlled laboratory microecosystems. Comparison of chlorophyll extracts from periphyton in snail-less aquaria with those containing snails were used to determine relative grazing efficiency. Snail population density was inversely correlated with periphyton standing crop in all situations, except for pure cultures of P. exacuus.

Studies of this kind have application in natural areas where decimation of snail populations has effects on the species composition of the algal flora, and therefore, water quality and resource utilization.

The effects of grazing by snails and other aquatic invertebrates on periphyton (benthic algae) is poorly known. Logically, one would expect the standing crop of periphyton to decrease in the presence of grazing invertebrate populations. Indeed, Douglas (1958) suggested that the caddis fly larvae, *Agapetus fuscipes*, controlled the population size of the diatom *Achanthes* during the spring and summer in a small stream in England. She noted a strong inverse relationship between the numbers of the caddis fly larvae and numbers of diatoms during that time. A study along the Oregon coast by Castenholtz, (1960) demonstrated how a heavy diatom population in the upper half of the intertidal zone was held in check by limpets and littorines during summer periods. Kehde and Wilhm (1972) noted how snail grazing affected the community structure of periphyton in laboratory streams. They exposed the periphyton to grazing by the snail *Physa gyrina* Say for three months and measured a significant increase in the chlorophyll *a* concentration and a slight reduction in the standing crop of the periphyton. Beyers, (1963) in a laboratory microecosystem, showed that when the large herbivorous snail *Marisa cornuarietis* (Linné) was added to the system, it severely overgrazed the macrophytes and associated periphyton.

The following pilot study was undertaken to determine: (1) the effect that selected freshwater pulmonate snails have on periphyton standing crop, (2) the effects the population density of these snails has on the grazing ability of individuals, and (3) whether one species has effects on the other's grazing ability when both are in the same laboratory microecosystem.

MATERIALS AND METHODS

Individuals of *Physa heterostropha* (Say) about 13 mm. in length and with an average wet weight of .06 gm. and those of *Promenetus exacuus* (Say) about 4.5 mm. in length and with an average wet weight of .01 gm. were used for the experiment. Both species are commonly found in central New York State (Harman and Berg, 1971). The individuals used for the study were taken from coexisting populations in Rat Cove, a partially protected bay along the southwestern shore of Otsego Lake, the headwaters of the Susquehanna River in east-central New York. The lake is morphometrically oligotrophic but chemical characteristics are typical of eutrophic waters. It has a surface area of 1,725 ha (6.7 sq. miles) and a maximum depth of 51 m (166 ft.). Rat Cove has a littoral area roughly .4 x .2 km. in size, up to 6 m. in depth and has a bottom

TABLE 1. Characteristics of gastropod populations, algal populations and water utilized for the study.

Habitat	Number of snails		(gms.) wet weight of snails	% of controls trans- mittance	Chl <i>a</i> liter	Physical and Chemical Parameters					
	<i>P. heter- ostropha</i>	<i>P. exacuous</i>				Alkal. (ppm)	Dissolved Solids (ppm)	pH	O ₂ conc. (ppm)	O ₂ sat. (%)	Temp. °C
Rat Cove	10*	4*	.64*	—	—	125.0	142.0	7.8	9.4	111.0	22.5
Controls	—	—	—	100	42.17	93.0	129.3	8.3	7.2	90.3	27.3
	5	—	.3	70	14.06	92.0	121.0	8.3	7.6	92.5	26.0
	10	—	.6	30	9.37	89.0	108.5	8.1	7.5	94.5	27.5
	15	—	.9	25	9.38	76.0	106.0	8.0	7.6	93.0	26.0
	—	2	.12	60	23.43	96.0	137.5	8.4	7.3	93.5	28.5
Laboratory Microecosystems	—	4	.04	75	28.12	102.5	134.5	8.4	7.6	94.5	26.5
	—	6	.06	70	30.46	96.0	130.5	8.2	7.4	93.0	27.5
	5	2	.32	30	14.06	84.5	124.0	8.3	7.2	93.5	29.5
	5	4	.34	40	14.06	84.5	120.0	8.2	7.2	93.5	29.5
	10	2	.62	60	23.43	83.0	108.0	8.3	7.6	96.0	28.5
	10	4	.64	15	7.03	82.0	125.0	8.1	7.2	93.5	29.5
	10	6	.66	35	14.06	90.0	124.5	8.3	7.2	92.0	29.5
	15	4	.94	10	7.03	87.5	124.0	8.3	7.5	94.5	28.0
	15	6	.96	20	9.37	90.5	124.0	8.1	7.6	94.0	26.5

* estimates per unit area equal to one laboratory microecosystem.

composed of deep organic muds (Herrmann and Harman, 1975).

Laboratory microecosystems were set up in twenty-nine covered, rectangular plastic "mini-tanks" (18 x 25 x 10 cm). Each was sterilized with 95% ethanol and then rinsed thoroughly with tap water. Three liters of lake water from Rat Cove, filtered through a screen with a .5 mm filter mesh to remove macroinvertebrate grazers, were added to each tank to provide a potential snail grazing surface area of 1250 cm². Three microscope slides, each with a surface area of 19 cm² were placed in each container. Various population densities of snails (Table 1) were used, some with one species present and others with both species coexisting. A density of 10 individuals of *Physa* and 4 individuals of *Promenetus* was considered an estimation of the population density of each respective snail population in Rat Cove. With this as a basis, we arrived at the densities shown in Table 1 by lowering or increasing the number of snails per tank proportionally. The complete series was duplicated and the control (no snails in a container) was repeated three times.

Aquaria were arranged in rows 25 cm below continuously illuminated 20 watt naturescent and gro-lux fluorescent lights. Each tank was furnished with continuous aeration. Half the water was removed twice a week from each container

and replenished with filtered lake water to provide a regular turnover of nutrients. At these times dead snails were replaced with living individuals from Rat Cove.

To ascertain if conditions varied among the tanks and between natural and laboratory conditions, various chemical and physical characteristics of the water were determined in each aquaria and the snail collection site in Rat Cove. Water was analyzed for pH using a Beckman pH meter. Dissolved oxygen determinations (mg/l) employed the Winkler method-azide modification (APHA *et al.*, 1970). Total alkalinity (as CaCO₃ in mg/l) was determined by titration with .02N H₂SO₄ using methyl orange as an indicator (APHA *et al.*, 1970). Temperature and dissolved oxygen were utilized to determine oxygen saturation from a nomograph (Hutchinson, 1957). Dissolved solids were determined by a Myron Dissolved Solids Meter.

Snails were allowed to graze two weeks in the tanks. At the end of that time all slides were removed. The three slides from each aquaria were collectively placed in flasks with 200 ml of 90% acetone for 72 hrs. at 5° C to extract chlorophyll. In a 2.54 cm spectrophotometer cell, chlorophyll transmittance was read at the 665 mμ setting of a Bauch & Lomb (Spectronic 20) spectrophotometer. Results, expressed as a percentage of the

transmittance exhibited by the chlorophyll extracted from the controls, were utilized as measurements of the standing crop of periphyton. Thus, low values indicated that periphyton populations were greatly reduced by grazing snails. We consider these to represent efficient grazing abilities. The μg of chlorophyll *a* per m^2 was also utilized for comparative purposes because it is a potentially more definitive index. The results are given as $\mu\text{g Chl } a/\text{m}^2 = 937.01$ (Optical Density at $665 \text{ m}\mu$), which assumes the absence of degradation products and interfering pigments in the chlorophyll extract.

There was a significant size and weight difference between specimens of *Physa* (.06 gm/individual) and those of *Promenetus* (.01 gm/individual). In order to give an accurate picture of the relative grazing abilities of the two species, total weight of the populations were used as a measure of population density. Since individuals of *P. heterostropha* weighed six times more than those of *P. exacuou*s, it was assumed that six individuals of *P. exacuou*s would have grazing abilities comparable to one individual of *P. heterostropha*.

PHYSICAL AND CHEMICAL PARAMETERS

Limnological characteristics of the tanks containing *Physa* are illustrated in Table 1 as are

characteristics of aquaria supporting populations of *Promenetus* and limnological features of tanks containing populations of both species. Also illustrated are physical and chemical characteristics of the water in Rat Cove at the time the snails were initially collected on August 4, 1974.

The chemical and physical characteristics of the tanks containing *P. heterostropha* tend to exhibit reduced values as population density increases, except for oxygen saturation and the related parameters of temperature and oxygen concentration. All values peaked at intermediate population densities when only *Promenetus* was present. When the two species coexisted, the values appeared to remain stable as density increased. A series of t-tests indicated that significant differences between aquaria occurred in alkalinity and dissolved solids despite continual addition of lake water. All statistical analyses were performed at the 0.05 level.

Water from Rat Cove and in the experimental aquaria differed greatly. Both environments were provided with the same amount of nutrients, but the tanks were completely enclosed and exhibited the characteristics of high eutrophy in a short time under continuous illumination. This is apparently related to the great surface area per unit substrate in Rat Cove that absorbs the nutrients, only slowly releasing them, compared

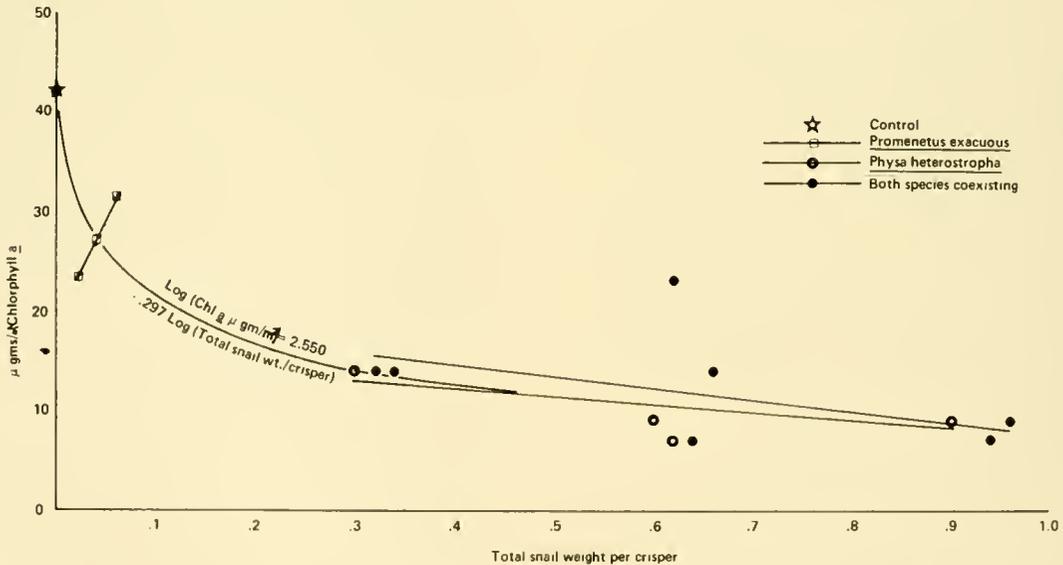


FIG. 1. Grazing efficiency of snails expressed as $\text{Log (Chl } a \mu \text{ gms}/\text{m}^2) = 2.550 - .297 \text{ Log (total snail weight per crisper)}$.

to their immediate availability in the tanks. The result is a buffering of the eutrophication process in Otsego Lake when enrichment is not too severe.

Limnological parameters measured in each container were well within the limits for the two species measured by Harman and Berg (1971) in their survey of freshwater snails of central New York, indicating that the chemical conditions in the tanks were not atypical and the results can be applied to natural populations.

SNAIL GRAZING

Table 1 indicates the grazing efficiency of both mixed and pure cultures of *P. heterostropha* and *P. exacuouus*. The grazing efficiency of all snail populations was represented by the equation ($\text{Log } Y = 2.550 - .297 \text{ Log } X$) where Y equals the chlorophyll *a* content in $\mu\text{gm}/\text{m}^2$ (extracted from slides placed in the aquaria) and X equals the total snail weight per tank, a measure of snail population density. The negative correlation, shown in Figure 1, clearly illustrates the fact that as snail population density increased, standing crop of periphyton (chlorophyll *a* content) decreased.

Physa heterostropha had a grazing ability efficient enough to reduce the standing crop of periphyton at all population densities studied (Fig. 1). The positive correlation between population density of *P. exacuouus* and periphyton chlorophyll concentration illustrates the fact that this species is unable to limit growth of algae (Fig. 1). The increase in periphyton population density with increase in snail population density may be due to the increased availability of nutrients brought about by the presence of snails in the crispers. However, equally possible are effects of competitive interactions between algal species resulting from differences in the grazing characteristics of the snail species involved.

The grazing ability of coexisting snail populations is not significantly different from that of pure cultures of *P. heterostropha* (Fig. 1). This is what was expected, since *P. exacuouus* added very little biomass in the experiments utilizing coexisting populations.

The sides and bottom of the snail-less control tanks were thickly covered with attached algae,

but those with snails in them appeared relatively free.

CONCLUSIONS

It is an overgeneralization to state that periphyton standing crop is decreased by the presence of snail populations. Although this is often the case, as shown by our data collected from pure cultures of *P. heterostropha* and mixed cultures of *P. heterostropha* and *P. exacuouus*, situations can arise when algal standing crops increase in size.

When a particular species of gastropod grazes it undoubtedly alters competitive interactions between various species of algae by more efficiently cropping one species than another. In a natural environment these alterations could be extremely significant. In this study it was not determined whether this kind of phenomenon caused the periphyton standing crop to increase as the population density of *P. exacuouus* increased. These results may have come about because of "inefficient" grazing of *P. exacuouus*, in combination with the effects of continuous illumination and added nutrients associated with the presence of the snails.

In many localities great effort has been expended on the eradication of freshwater snail populations because they are intermediate hosts of economically important trematode parasites. The harvesting of rooted aquatic plants, with concomitant removal of gastropods, is taking place in more and more situations where the plants have become nuisances. If snails have important effects on the standing crops of benthic algae in those ecosystems, studies such as this could determine how well snails control algal population densities, and therefore, maintain the quality of natural waters.

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A FURTHER NOTE ON GEOLOGIC CHANGES IN THE RELATIVE SIZE OF BIVALVE SHELLS

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At the 1965 meeting of the American Malacological Union, I challenged the conclusions of E. S. Morse who published various reports from 1879 to 1925 showing differences in the proportion (length-width) of bivalve shells between those found in native shell-heaps and living specimens from the same locality. He believed that the difference was due to climatic change. However, it was demonstrated that the ratio of *Mya arenaria* L. depends upon the nature of the substratum in which the clams developed. Without a knowledge of the substratum, comparisons cannot be made (*Annual Reports*, A.M.U. for 1965, p. 18).

In studying the correspondence of naturalists at the Museum of Science, Boston, Massachusetts, I encountered a similar situation. Apparently, Sameul H. Scudder, Curator at the Boston Society of Natural History, believed he could detect a difference in shell size between fossil and recent shells of the quahog (*Mercenaria mercenaria* L.) and, like Morse, had assumed an evolutionary change. Addison E. Verrill, at Yale University, however, realized the differences could be due to local environmental conditions. He wrote to Scudder 9 October 1875 as follows:

"You are perfectly correct in regard to the peculiarities of the *majority* of the fossil quahogs with the *average* specimens seen in our markets. I had noted the same differences, but *they*

are not constant in the fossils, for in my lot there are some of good size that are as thin and smooth as ordinary New Haven specimens of the same size and they have the same form also. We have a large number (50 or more) of good, large (3-4½ in.) Nantucket quahogs obtained from a native. They are remarkable for their massiveness, for their strong concentric rings and most of them are rather rounded and the disk violet color extends in a broad zone entirely across the shell (the same is true of some of the fossils that retain traces of color), and in the totality of their characters they are more like the average fossil quahogs than are those from any other locality yet examined, but *in the same lot* are some of the thin, elongated ones nearly smooth in the middle like the ordinary sort and others that are intermediate. I imagine that such differences as occur are due to local causes and were in ancient times as now, inconstant. I presume that localities might now be found where the quahog would be precisely like the fossils."

Permission to quote Verrill's letter was kindly given by the Museum of Science, Boston, Mass.

BUOYANCY CHANGES AS RELATED TO RESPIRATORY BEHAVIOR IN AN AMPHIBIOUS SNAIL, *POMACEA URCEUS* (MÜLLER), FROM VENEZUELA

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ABSTRACT

The ampullariid Pomacea urceus uses its ctenidium and lung in respiration. The snails reach the surface with their siphon and ventilate their lung by withdrawing their head-foot in a pumping action. The lung gas also serves to change the buoyancy of the snails. After a ventilation a snail does not necessarily return to the same buoyancy level. They may achieve overall specific gravities of <1 to >1 after a ventilation. They may remain submerged (s.g. >1) or float (s.g. <1) for long periods. In the field many P. urceus are found floating during periods of low oxygen tension. Underwater weights were recorded over 24 hr and five day periods. Weight changes are representative of gas volume changes in the lung. The most rapid changes take place over the first six hours. Adult snails normally ventilate their lung within the first two hours of submersion. Juvenile P. urceus ventilate their lung more frequently than adults. Pomacea falconensis and P. luteostoma are similar to juveniles of P. urceus in size and show similar ventilation rates. The rate differences probably reflect the difference in lung capacity to total tissue in relation to metabolic rate.

Considerable significance attaches to any observations on the structural and functional adaptations shown by "primitive" lung-fish. This is also true for amphibious snails. Such observations, especially physiological data from whole animals, can be of interest in two ways. First, at the level of mechanistic physiology, they help establish our concepts of how such an "unlikely" animal machine as one built on the basic molluscan plan — of great efficiency in an aquatic environment — can maintain itself on land. Secondly, it is possible that hypotheses on the evolution of the major land stocks can be modified as a result of physiological investigation of amphibious stocks (whether they involve "partially adapted" or "doubly adapted" forms).

The remarkable physiological plasticity shown by amphibious and freshwater snails of the major class Pulmonata has been discussed elsewhere (Russell-Hunter, 1964). The mantle-cavity converted as a "lung" can be used in rhythmic "div-

ing" (Russell-Hunter, 1953a, b, 1957), or be water-filled, or have its gas used as a "physical gill" for the underwater uptake of oxygen (Russell-Hunter, 1953b; Henderson, 1963), or principally to provide buoyancy (Jacobs, 1941; Russell-Hunter, 1953b; Henderson, 1963).

Among the amphibious prosobranchs are several genera and species in the family Ampullariidae (superfamily Viviparacea). It has long been known (Troschel, 1845; Pelseneer, 1895) that ampullariid snails possess unusually "amphibious" respiratory structures, one part of the mantle-cavity containing a ctenidium and another part being modified as a gas-filled lung cavity. Significant anatomical studies on ampullariids have been reviewed (Fretter and Graham, 1962; Demian, 1965; Andrews, 1965a, b) and the physiology of aestivation has received attention (Meenakshi, 1956, 1957, 1964; Visser, 1965; Burky, Pacheco, and Pereyra, 1972). The behavior of lung ventilation has been discussed by Robson (1922), Prashad (1925, 1932), and Andrews (1965b), and examined in greater detail by McClary (1964) and Demain (1965). Until recently there has been

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little modern physiological and ecological work on populations of ampullariids, but now there are extensive data on *Pomacea urceus*, which is abundant over vast areas of the Venezuelan savannah. These include data on growth and biomass turnover (Burky, 1973, 1974) and on temperature, water, and respiratory regimes (Burky, Pacheco, and Pereyra, 1972). This paper reports work on buoyancy changes in relation to respiratory behavior in *Pomacea urceus* (conducted by the senior author in Venezuela in 1970, along with some comparative notes on other aspects of respiration in *P. urceus*, and with limited comparative data on three other species of ampullariids.

MATERIALS AND METHODS

The snails were initially maintained in large outside tanks and then moved to aquaria in the laboratory. Caracas tap water was used but only after it had been allowed to stand for 24 hr or longer. When changing the water (at least twice a week), 25%-50% of the used "conditioned" water was usually retained. Snails were regularly fed lettuce.

The weighing apparatus used in this investigation (Fig. 1) was designed after that used by

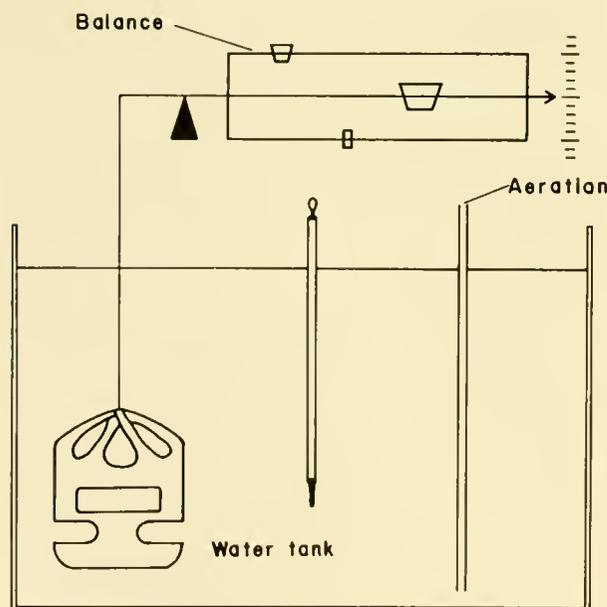


FIG. 1. Weighing apparatus.

Henderson (1963). A triple-beam balance and a plastic weighing cage (made from a two liter bottle) with a volume of about 1.25 l were used. Lead weights were added to the naturally buoyant plastic cages until an underwater weight of 9-10 g was reached and this weight is referred to as the zero weight. This could easily accommodate the range of buoyancy changes in *P. urceus*. When the underwater weight of a snail is greater than the zero weight, it has an overall specific gravity of greater than one. It follows that underwater weights of less than or equal to the zero weight will correspond to specific gravities of less than one and one respectively. Snails were taken from aquaria at ambient room temperature (about 20-25° C) and placed in constant temperature tanks (maintained near 29° C) two days before each experiment. Eighteen to 24 hr before an experiment, a snail was placed in an experimental cage with lettuce. The cage was suspended from the balance by coated copper wire a few centimeters below the water surface. On the morning of each experiment uneaten lettuce was removed and the snail was observed until it ventilated its lung by reaching the surface with its siphon. It was immediately lowered to a depth of more than double its shell length so it could not reach the surface with its siphon to ventilate, and weighed. Subsequent weighings were made at various intervals depending on the experiment. The water was continuously aerated throughout each experiment; all snails were starved throughout each experiment; and all experimental temperatures were in the range of 28.75-29.75° C, since this is near the natural field temperature during the rainy season (Table 1).

The weight of a snail is reduced by a force equal to the mass of the water displaced when submerged. The submerged weight reduction in grams (without gas in the lung) is equal to the volume of water displaced (milliliters), since one gram of water can be assumed to have a volume of one milliliter. It follows that the weight of a submerged snail will be further reduced by one gram per milliliter of gas (weight of the gas is disregarded) in the lung. Therefore underwater weight changes give an accurate picture of the gas volume changes in the lung. Since milliliters

TABLE 1. *Physical data from the natural habitat of Pomacea urceus during the rainy season.*

Date	Time	Temperature °C			pH	Water O ₂ ppm (mg O ₂ /l)
		Bottom Water	Surface Water	Air		
11 Aug. 70	1100	29.2	30.1	28.3	6.8	1.7
	1200	29.4	30.4	24.4	6.8	1.7
	1400	29.6	31.5	25.2	7.1	4.5
	1600	30.0	32.8	27.0	7.0	5.5
	1800	31.2	31.5	26.8	7.1	4.1
	2000	30.4	30.5	25.6	7.1	3.2
	2200	30.2	30.3	24.5	7.0	2.1
	2400	30.2	29.8	25.6	7.1	3.4
12 Aug. 70	0200	29.7	29.6	26.7	7.0	2.6
	0400	29.5	29.4	25.6	7.0	1.6
	0600	29.2	29.1	25.3	7.1	1.6
	0800	29.0	28.8	25.0	7.1	1.1
	1000	28.8	28.6	24.0	7.1	1.0

and grams are equivalent, the gas in the lung at the start of each experiment can be estimated. The volume of a contracted snail in milliliters (determined by displacement of water) was subtracted from the weight of the snail (in air) in grams to give the underwater weight of the snail without any gas in the lung. It follows that the difference between the underwater weight without gas and the underwater weight of the snail immediately after ventilation will give the milliliters of air present in the lung. It is necessary to estimate the initial gas volume since it is not possible to force these snails to expel all gas for an underwater weight (without gas) at the end of an experiment. It also follows that the volume measurement of a snail is not accurate and will include the volume of any retained gas. Therefore, initial gas volumes are underestimates but make reasonable comparisons between snails possible.

Observations on the interval between successive ventilations and the number of pumps per ventilation were made on adults and juveniles of *Pomacea urceus*, and on adults of *P. falconensis* and *P. luteostoma* (Swainson). Some general observations were also made on *Marisa cornuarietis* (Linné).

Field measurements were taken hourly over a 24 hr period. Temperatures were recorded with a YSI Tele-thermometer; oxygen tensions were recorded with a YSI portable oxygen electrode; and

pH values were recorded with a portable pH meter.

RESULTS

It is important to know the weight and volume of body parts for *Pomacea urceus*. This information is partly based on the data of Burky, Pacheco, and Pereyra (1972) and is given for a hypothetical snail of 100g in Table 2.

Volume reductions over twenty-four hours of submersion—Observations of underwater weight changes were made over 24 hr periods of continuous submersion. Periods of submersion started immediately after ventilation of the lung. Under experimental conditions a snail usually reduces its overall specific gravity without becoming buoyant. The results of such an experiment are illustrated in Fig. 2 and given in Table 3.

The weight increases (volume reductions) are brought about smoothly with time. The most rapid changes take place during the first six hours. The weight increase in the first hour is equivalent to a 6.7% reduction in the volume of gas. The rate decreases to 1.1% of the initial volume in the sixth hour. In the first six hours,

TABLE 2. *Estimated weight and volume of body parts for a hypothetical snail with a maximum live weight of 100 g (shell length, about 85 mm).*

Body part and condition	g*	(ml)* Without gas volume of lung
Whole live active snail (includes shell)	100.0	73.0
Water retained in mantle cavity	2.1-4.2	2.1-4.2
Wet tissue of active snail	52.6	52.6
Dry tissue of active snail	7.0	—
Whole live aestivating snail at end of dry season (includes shell)	81.0	52.0
Wet tissue of aestivating snail at end of dry season	35.6	35.6
Dry tissue of aestivating snail at end of dry season	6.4	—
Shell	45.4	16.2

* The above values are based on weights from 59 active and 15 aestivating snails, and from the extensive data on the rate of weight loss during aestivation (Burky, Pacheco, and Pereyra, 1972). The shell volume is based on a compromise specific gravity (2.8) between calcite and aragonite since the crystalline structure is not known. Also, the shell contains organic compounds. It is assumed that the specific gravity of wet tissue is 1.0.

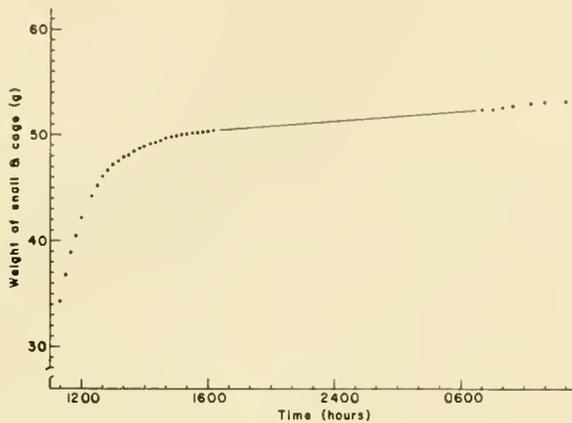


FIG. 2. Underwater weight changes during a twenty-four hour period of submersion. Experimental snail No. 1. Zero weight, 9.72 g.

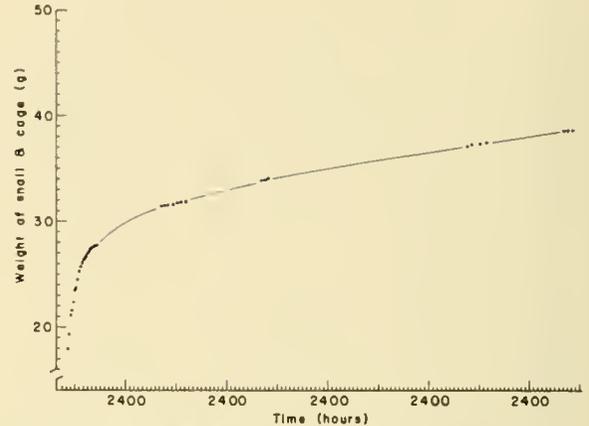


FIG. 3. Underwater weight changes during a five day period of submersion. Experimental snail No. 3. Zero weight, 9.72 g.

19.6% of the initial volume has been lost while at the end of 24 hr, a 28.3% reduction was observed.

Volume reductions over five days of submersion—Table 4 gives the results from experimental snails which were maintained under experimental conditions for an additional four days. Figure 3 illustrates the results for one of these snails. The smooth weight increase (volume reduction) continues but at a reduced rate. The weight increase for the first day is equivalent to a gas volume reduction of 28.3% (Table 3) or 29.5% (Table 4). The rate decreases to 4.0% of initial volume on the fifth day (equivalent to 0.17% of initial volume per hour). The total volume reduction after five days is 46.2% of the initial volume. Although these snails were without food or access to air they appeared to be in good condition throughout the five day period. Each snail was active and tried to ventilate throughout the

experiment by reaching upwards with its siphon. This behavior was characteristic of all experimental snails.

Buoyancy of snails—It has already been pointed out that these snails usually do not become buoyant under experimental conditions. The results of the one experiment in which the snail became buoyant is illustrated in Figure 4. The results presented for the snail of Figure 4 are not given in either Tables 3 or 4. The snail of Figure 4 was neutrally buoyant after about 3 hr of submersion. At the end of nearly three days the snail was allowed to ventilate and it returned to its original buoyancy level. Following this ventilation, the weight increase with time was reduced. This rate reduction may be a result of starvation, respiratory stress, and other undetermined experimental conditions.

TABLE 3. Gas volume changes in the lung during a 24 hour period of submersion.

Exp. No	Shell Length (mm)	Estimated Gas Volume at Start of Exp. (ml)	Underwater Volume Reductions on Successive Hours (ml/hr)						Total Volume Reduction After 6 Hours (ml)	Percentage Reduction After 6 Hours	Total Volume Reduction After 24 Hours (ml)	Percentage Reduction After 24 Hours
			1st	2nd	3rd	4th	5th	6th				
1	113	73.38	7.88	3.87	1.91	0.96	0.74	0.43	15.79	21.5	18.91	25.8
2	105	91.53	5.04	3.17	2.08	1.78	1.32	1.50	14.89	16.3	27.78	30.4
3	109	59.82	3.71	2.16	1.93	0.80	0.69	0.46	9.75	16.3	13.69	22.9
4	107	43.53	2.32	1.93	1.38	0.78	0.87	0.56	7.84	18.0	12.51	28.7
5	112	77.15	2.98	4.90	4.68	2.50	1.98	1.16	18.20	23.6	27.25	35.3
6	98	43.35	4.06	3.69	1.00	0.35	0.21	0.09	9.40	21.7	11.60	26.8
Mean	107									19.6		28.3

TABLE 4. Gas volume changes in the lung during a five day period of submersion.

Exp. No.	Shell Length	Estimated Gas Volume at Start of Exp.	Underwater Volume Reduction on Successive days (ml/day)					Total Volume Reduction After 5 Days	Percentage Reduction After 5 Days
			1st	2nd	3rd	4th	5th		
2	105	91.53	27.78	7.37	5.97	3.04	3.04	47.21	51.6
3	109	59.82	13.69	2.51	1.67	1.67	1.31	20.84	34.8
5	112	77.15	27.25	4.91	4.08	4.08	4.58	44.89	58.2
6	98	43.35	11.60	1.30	1.34	1.34	1.85	17.43	40.2
Mean	106								46.2

It should be pointed out that flotation is common in these snails. On numerous occasions over 50% of these snails have been observed to float in laboratory tanks. At other times all are submerged. In the field most of the snails collected are those which are floating. Collecting snails is easiest in the early morning because of the large numbers which are buoyant. By mid-day conditions have changed and floating snails may be difficult to find.

Pomacea urceus is either buoyant or has a specific gravity of greater than one after each ventilation. Therefore these snails do not always return to the same specific gravity after each ventilation. However, one must ask if a level is maintained while floating or while submerged. Figure 5 gives the results of a snail (specific gravity greater than one) which was allowed to ventilate at will. This individual may return to the same weight level; it may go to a much lower specific gravity; or it may decrease the total gas

volume during the process of ventilation. On two occasions this snail ventilated three successive times before a smooth weight increase was recorded. This type of ventilating activity has been observed frequently in laboratory tanks.

Siphonal ventilation in *Pomacea urceus*, *P. falconensis*, *P. luteostoma*, and *Marisa cornuarietis*.—During ventilation the tip of the siphon is brought into contact with the surface to form an air tube to the lung. The head of these ampullariids is then observed to contract in a pumping action. Adults of *P. urceus* are gigantic and are capable of extending their siphon by at least 1.5 times their shell length. A large snail of 125 mm can easily extend its siphon about 200 mm and makes little effort to reach the surface of shallow laboratory tanks. The juveniles of *P. urceus* and the adults of *P. falconensis*, *P. luteostoma*, and *Marisa cornuarietis* all had maximum shell dimensions of about 30 mm.

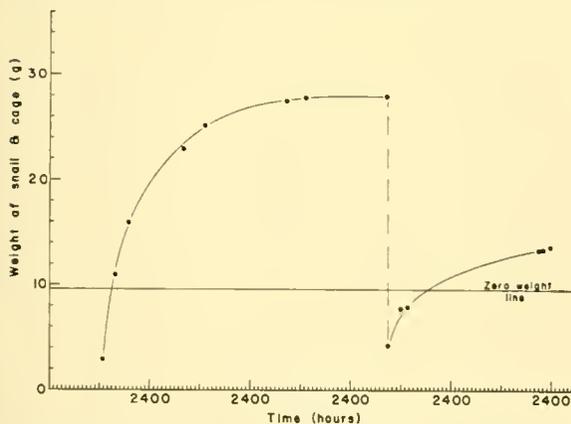


FIG. 4. Underwater weight changes of a snail which was buoyant after ventilation of its lung. Broken line indicates a decrease in weight when snail was allowed access to air after a period of nearly three days.

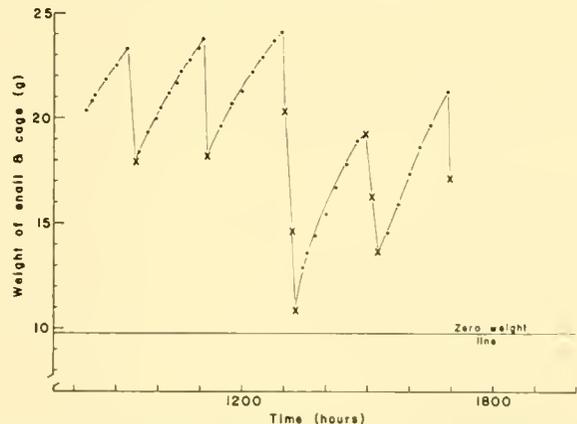


FIG. 5. Underwater weight changes after successive ventilations of the lung. Those weights marked by an X indicate the weight immediately after completion of a ventilation. Zero weight, 9.75 g.

Adults of *P. urceus* ventilate their lung every 62 min with about 18 pumps per ventilation (Table 5). Juveniles of *P. urceus* ventilate every 20 min with about eight pumps per ventilation (Table 5). The difference between the adults and juveniles of *P. urceus* undoubtedly reflect size. The adults of *P. falconensis* and *P. luteostoma* were similar to juveniles of *P. urceus* in the interval between ventilations and in the pumps per ventilation (Table 5). In addition to the snails of Table 5, *Marisa cornuarietis* was also maintained in aquaria. All the ampullariids regularly surface and actively ventilate their lung by extending and withdrawing their head-foot. They have all been observed to release from the bottom and float to the surface. They may also float for prolonged periods as well as release gas at the surface and sink to the bottom.

DISCUSSION

Unfortunately there are no published data on the underwater weights of ampullariids. Therefore many comparisons must be made with the extensive data of Henderson (1963) on freshwater pulmonate snails.

This investigation has shown that *Pomacea urceus* regularly surfaces and ventilates its lung. This snail may become buoyant and float or maintain a specific gravity of greater than one. Ventilation normally occurs during the period of

greatest weight change. This is also true of the pulmonates studied by Henderson (1963). For Henderson's pulmonates, the buoyancy level is apparently used as a very sensitive signal for surfacing. This is not the case for *P. urceus*, which ventilates at various buoyancy levels (Fig. 5). Environmental oxygen tension is probably a more important signal for surfacing. McClary (1964) showed that the buoyancy in *P. paludosa* is reduced before surfacing, but believes that oxygen tension is probably the critical stimulus. *Pomacea urceus* maintains an overall specific gravity of greater than or less than one for periods of activity while continuously submerged or while floating. The apparent greater variability of surfacing behavior in *P. urceus* may well be accounted for by the presence of a functional ctenidium. This provides an alternative: aquatic respiration with its gill or aerial respiration with its lung. Henderson (1963) points out that *Lymnaea stagnalis* and *Planorbarius corneus* are very sensitive to disturbances and such will cause an increased amount of gas to be taken in at the surface. In *P. urceus* there is a sensitivity to vibration, movement near aquaria, and light changes. Such irritations may cause a snail to retract and remain inactive for long periods. However, there is no evidence that disturbances cause an increase in the amount of air taken in during ventilation. This sensitivity increased as

TABLE 5 Frequency and intensity of siphonal ventilation of the lung in adults and juveniles of *Pomacea urceus*, and in *P. falconensis* and *P. luteostoma*.

Description	adult	juvenile	<i>P. falconensis</i>	<i>P. luteostoma</i>
	<i>Pomacea urceus</i>	<i>Pomacea urceus</i>		
Number of snails involved in observations	24	12	8	5
Shell length (mm)				
Mean	—	28.3	32.8	28.0
Range	about 90-125	22-32	15-53	17-35
Live weight (g)				
Mean	—	3.7	7.81	7.4
Range	about 140-400	2.0-5.6	0.6-22.2	1.2-13.3
Interval between ventilations (min.)				
Number of observations	30	27	26	49
Mean	62.4	19.9	17.8	12.6
Range	3-190	2-78	1-54	1-42
Standard Error	8.413	3.069	2.545	1.519
Pumps per ventilation				
Number of observations	70	46	28	51
Mean	18.3	8.1	10.6	9.8
Range	3-36	4-16	4-22	5-19
Standard Error	0.762	0.432	0.690	0.551

the breeding season neared. During November when copulating pairs are common, experiments are impossible to perform. Therefore, these results are not representative of snails at all times. Further, *P. urceus* aestivates during the dry season and remains buried in the dry ground surface where aerial respiration is obligatory (Burky, Pacheco, and Pereyra, 1972; Burky, 1973, 1974).

Over periods of 24 hours, Henderson (1963) reports that for *L. stagnalis* and *P. corneus*, 56.7% and 52.2% of the gas bubble has been lost, respectively. For *P. urceus*, only 28.3% of the gas bubble has been lost for the same period. At the end of five days these pulmonates have lost 93.5% and 91.5% of the gas respectively, while *P. urceus* has only lost 46.2%. The lower percentages for *P. urceus* probably represents a lower respiratory rate for this large snail. However, the ratio of gas volume to body tissue, as well as the presence of a gill are also involved.

On occasion the interface of the gas at the pulmonary opening was observed. However, this opening is relatively small in the genus *Pomacea* (Andrews 1965b) and is probably not suitable as a diffusion interface. Further, there is no evidence that *P. urceus* uses the pulmonary gas as a physical gill. After ventilation some snails have been observed to retract and remain inactive on the bottom until just before the next ventilation. In these snails the pulmonary gas must be used as an oxygen store.

It is known that the rate of aquatic respiration of snails decreases with oxygen tension (Berg and Ockelmann, 1959). Similarly it follows that the volume reductions for *P. urceus* represent reduced rates of gas consumption with time. This has also been claimed for pulmonates by Henderson (1963) who points out that the weight changes, although representative of volume reductions, cannot be converted to oxygen consumption rates. There is a constant loss of nitrogen and other gases to the surrounding water. However, the rates reported by Henderson are of the same order as oxygen consumption rates reported by others for pulmonates. In *P. urceus* the weight changes can be assumed to be even less representative of oxygen consumption rates since apart from cutaneous respiration there is a functional

gill. Regardless, the initial hourly volume change for *P. urceus* is of the same order as the oxygen consumption rates of active adults (Burky, Pacheco, and Pereyra, 1972).

It was observed that juveniles of *P. urceus* ventilate their lung more frequently than adults. This probably reflects a higher metabolic rate in the smaller snails. Significantly, these juveniles show ventilation frequencies which are similar to those for adults of other species with the same approximate size (*P. falconensis* and *P. luteostoma*, from Table 5; *P. paludosa* from McClary, 1964; *Marisa cornuarietis* from Demain, 1965). The difference between juvenile and adult *P. urceus* may also reflect differences in the ratio of lung capacity to total tissue in relation to metabolic rate.

It has been pointed out that more snails are observed to float during the morning in the field. Over vast areas of the savannah, greater than three meters of water may cover the savannah during the rainy season. Significantly the oxygen tension is lowest during the morning hours (Table 1). At times of high oxygen tension, in the afternoon and evening, there may be "less" dependency on aerial respiration. Andrews (1965b) points out that the ctenidium of ampullariids is relatively smaller than in other prosobranchs and that the genus *Pomacea* has a relatively large lung when compared to other ampullariids. The relative proportions of gill to lung support the field observations in relation to oxygen tensions and floating activity.

Willmer (1934) studied the relation between the mode of respiration and the gas content of the water in a tropical fish, the yarrow. At low oxygen tension aerial respiration is used; at high oxygen tension and specific carbon dioxide tensions aquatic respiration is used; and at intermediate gas concentrations both means of respiration are employed. It would be interesting to know the specific responses of *Pomacea urceus* to varying tensions of oxygen and carbon dioxide as well as the characteristics of its haemocyanin.

Ampullariids possess a typical prosobranch ctenidium and it is unlikely that this could be of secondary origin (Andrews, 1965b). The development of the lung in ampullariids is unlike that of

pulmonates (Ranjah, 1942) and is a new secondarily derived structure (Ranjah, 1942; Demain, 1964 discussion and references therein). This supports the primary ctenidial origin and the secondary pulmonary structure and physiological mechanisms in ampullariids. As indicated in the introduction and above, more information on respiratory behavior and physiology will give a better basis to our concepts of the evolution of this prosobranch group and the structural-functional basis for the colonization of amphibious-terrestrial habitats by these snails.

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THE ELECTROCARDIOGRAM OF THE FRESHWATER BIVALVE *LAMPSILIS RADIATA* (BIVALVIA: UNIONIDAE)

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ABSTRACT

The electrocardiographic configuration of the freshwater mussel Lampsilis radiata was investigated and described using three standard leads, three augmented leads, and one unipolar lead. Electrocardiograms demonstrated depolarization complexes for both the atria and the ventricle. Longitudinal mean electric axis of the ventricle revealed anterior-to-posterior depolarization and repolarization from posterior-to-anterior. Heart rates were irregular and bradycardic due to the electrocardiographic measurement while the valves of the mussels were closed.

Electrocardiographic studies in Bivalvia have been employed mainly as a measure of the animals response to various environmental stimuli (Crozier and Stier, 1924; Pickens, 1965; Helm and Trueman, 1967; Trueman, 1967; Coleman and Trueman, 1972; Trueman, et al., 1973). The majority of these studies used marine bivalves, freshwater species being almost completely ignored. Further, most molluscan electrocardiographic studies have only one lead which results in presentation of "rhythm strips" which provide information only on heart rates and their regularity. The present paper describes the electrocardiographic configuration of the North American freshwater mussel, *Lampsilis radiata* (Lamarck, 1819), as revealed by a seven lead system.

METHODS

Electrocardiograms (ECGs) were made for 10 specimens (6 males and 4 females) of *L. radiata* taken from Beech Fork of Twelve Pole Creek, Wayne County, West Virginia. The mussels were maintained in an aquarium for two weeks prior to recording the ECGs. Weight, water displacement, and shell dimensions were measured before each ECG was made.

Two 25 gauge hypodermic needles were placed such that one needle entered between the margins of the valves 2 cm from the anterior and the other 2 cm from the posterior margins of the umbral ligament. In this manner, electrodes were

thus located at the anterior and posterior margins of the pericardium. A third 25 gauge needle was placed in the foot, directly beneath the umbo (Fig. 1). All recording equipment was manufactured by Harvard Apparatus. The needles were connected to a model 369 EKG lead selector with a model 354 bioamplifier input module such that the anterior needle was connected to the left arm input, the posterior needle was connected to the right arm input, and the foot needle was connected to the left leg input. ECGs were preamplified with a model 371A preamplifier with a gain control variable to over 100 and a bandwidth of 0.2 Hz to 12.0 kHz at a gain of 100 and a bandwidth of 0.2 Hz to 4.5 kHz at a gain of 1000. A 10-speed chart mover (0.005 cm/sec to 5 cm/sec) equipped with a model 283 event/time marker module (1 min/ 10 sec/ 1 sec intervals) and a model 350 recorder were used.

Leads measured were I, II, III, aVR, aVL, aVF, and a single unipolar lead recorded by connecting the foot electrode to the chest input jack. ECGs were measured at a variable speed and amplification. Once amplitude was established for a mussel, the entire ECG was run at that amplitude. ECGs were run continuously, using lead II, for one hour intervals to determine rhythmicity. All ECGs were obtained while the mussels were lying on their left valve in a wooden pan of water at 22°C and a pH of 7.5.

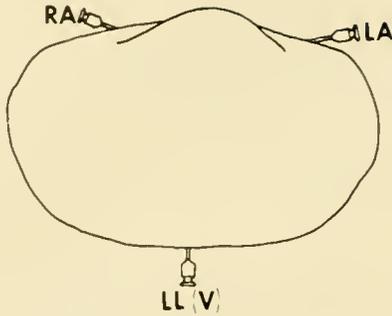


FIG. 1. Placement of the needle electrodes in *L. radiata*. The left arm electrode (LA) was placed in the anterior end of the mussel and the right arm electrode (RA) was placed in the posterior end. The left leg electrode (LL) was placed in the foot and was used to record the single unipolar lead (V). Electrodes were connected to appropriate input jacks on an EKG lead selector.

Electrocardiographic intervals analyzed were the QRS complex (which measures the time elapsed during contraction (depolarization), and the strength on contraction), the T wave (which measures the elapsed time during which the heart prepares for the next contraction (repolarization)), and the QT interval which measures the total elapsed time between depolarization and repolarization. The mean electrical axis, which is a measure of the general direction of depolarization and repolarization, was determined by taking the algebraic sum of R waves (+) and S waves (-) of leads I and III and plotting the result on a triaxial reference system. The axis was measured in the longitudinal plane due to the placement of the needle electrodes and was measured for both depolarization and repolarization of the ventricle.

The bivalves were identified by Dr. David H. Stansbery of the Ohio State University Museum of Zoology, The Ohio State University, Columbus, Ohio, where voucher specimens were placed in the collections. Other voucher specimens are in the Marshall University Malacological Collection (MUMC 17), Marshall University, Huntington, West Virginia, and the Delaware Museum of Natural History, Greenville, Delaware (DNMH 107101).

RESULTS AND DISCUSSION

Interpretation of the ECG wave components of *L. radiata* was complicated by the presence of

two distinct QRS complex forms (Fig. 2). These complexes could not be related to each other in terms of duration or sequence timing. As the heart of *L. radiata* is composed of a single ventricle and two smaller atria, connected to the ventricle by small vessels, and the ventricle is the largest chamber of the heart, the strongest QRS deflections were interpreted as being ventricular in origin and the smaller complexes as originating from the atria. This phenomenon was best seen in leads I, aVL, and the unipolar foot, or V lead, in the majority of tracings. The QRS of the ventricle (QRS_v) had a mean duration of 1.4 sec (range 0.8-2.0 sec) and the mean duration of the atrial QRS complex (QRS_a) was 0.6 sec (range 0.6-0.8 sec). The smaller size of the QRS_a is to be expected as the atria are smaller and the amount of work necessary to pump blood to the ventricle is less than that required to pump blood to the entire body. The shorter duration of contraction periods of the atria support this supposition. Also, the longer contraction periods of the ventricle may be necessary to pump the molluscan

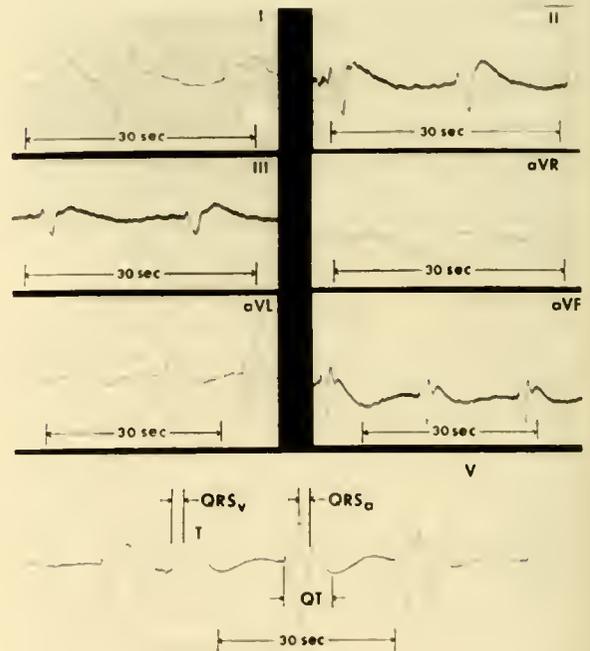


FIG. 2. Representative electrocardiogram of *L. radiata* demonstrating the independently occurring ventricular (QRS_v) and atrial (QRS_a) depolarization complexes.

blood by a "milking" action of the ventricle. Ventricular QRS complexes were seen to be positive deflections only in a *Vr* and were negative in all other leads.

No T waves could be demonstrated for the QRS_v as they occurred during the repolarization of the ventricle. This is explained by the fact that the repolarization signal of the ventricle, being stronger than the repolarization wave of the atria, will take precedence over weaker signals. Thus, the repolarization of signal of the atria was buried in the T wave of the ventricle. Ventricular T waves had a mean duration of 2.2 sec (range 1.3-4.6 sec). T waves were negative only in a*Vr* and were positive in all other leads.

The placement of the electrodes (Fig. 1) allowed measurement of the mean electrical axis in the longitudinal plane which was desirable, as the heart of *L. radiata* lies in this plane. The mean electrical axis of ventricular depolarization (Fig. 3) was -165° (range $-111^\circ - +54^\circ$) while the mean axis of ventricular repolarization was -21° (range $\pm 0^\circ - 60^\circ$). Thus the ventricle of *L. radiata* depolarizes, or contracts, in an anterior to posterior direction and repolarizes posterior to anterior. This may be visualized by superimposing Figure 1 over Figure 3.

The heart rate of *L. radiata* had a mean of 9.5 beats/minute (range 3-18). Rates were irregularly irregular and long periods of asystole were noted in some ECGs. Ventricular QT intervals

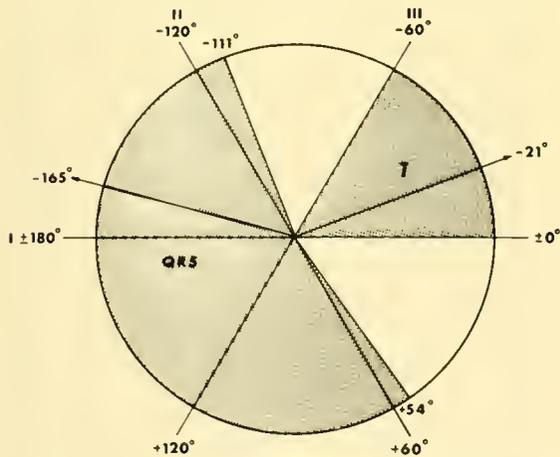


FIG. 3. Mean electrical axis and distribution for ventricular depolarization (QRS) and repolarization (T) in *L. radiata*. Arrows indicate the arithmetic mean of these axes.

had a mean duration of 3.5 sec (range 1.6-60 sec). Other studies (Coleman and Trueman, 1971; Trueman and Lowe, 1971) demonstrated bradycardia in the ECGs of marine *Bivalvia* recorded while the valves were closed. All of the ECGs of *L. radiata* were recorded under these conditions. The low heart rates may be due to reduced metabolic requirements when the valves are closed (Hill and Welsh, 1966; Coleman and Trueman, 1971), and our data suggests the same mechanism may be present in freshwater mussels. However, further studies are necessary to determine if the position in which the ECGs were recorded, which was different from the position normally assumed by the mussels in their natural habitat, plays a significant role in heart rate. Another aspect of interpretation of ECGs from mussels by the technique used in this study is the degree of change in "normal" ECG findings caused by the invasive method of electrode placement. No correlation between weight, size, or sex could be found for the electrocardiographic intervals measured.

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OBSERVATIONS ON THE VERONICELLID SLUGS
OF THE SOUTHERN UNITED STATES

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ABSTRACT

During the past decade veronicellid slugs have entered the United States. Some of them have become established and are spreading. These slugs are associated with the movement of plant materials and are affected by insecticides used on plants. Environmental factors which influence them are temperature, wind, light, pH and relative humidity. Two reproductive periods per year occur, with each slug depositing several (1-5) egg masses containing up to 15 ova per mass. A pathogenic disease, which might serve as a biological control, occurs when the individuals are crowded. The significance of these introductions cannot be underestimated in view of the problems encountered in past biological introductions in various parts of the world.

In 1960 a veronicellid slug was first found in the Gulf Coast area in Mobile, Alabama, and New Orleans, Louisiana. It had not been taken prior to that time in any of the extensive collections which had been made in connection with a molluscan survey (Dundee, 1970; Dundee, et al., 1965), nor had it been reported in the literature.

Here, then, was a perfect opportunity to work with an introduced species from the probable time of its introduction. Since then, its ever-widening distribution has been documented, its life cycle studied, its anatomy has been charted (Petrellis and Dundee, 1969), and study of its ecological requirements has begun.

This slug is *Veronicella ameghini* Gambetta. This identification is based upon comparisons of these slugs with types residing in European museums. For this I thank Dr. José Thomé of Port Alegre, Brasil, who is currently working on the nomenclature of the Veronicellidae. *V. ameghini* is endemic to Rio Grande do Sul, Brasil.

During the spring of 1970 another veronicellid, *Veronicella floridana* (Leidy) was reported in New Orleans and since then several other localities for it have been discovered in the city.

The United States Department of Agriculture has reported *Veronicella moreleti* (Crosse and Fischer) from Brownsville, Texas, and *Vaginulus*

occidentalis (Guilding) from McAllen, Texas, and state that a third unidentified species was taken from Raymondville, McAllen, Edinburg and San Benito.

Thus, it is obvious that veronicellids are moving into the south with rapidity, making it imperative that we have information on them.

DISTRIBUTION OF VERONICELLIDS
IN THE UNITED STATES

Veronicella floridana can be considered native in the south Florida area. Only recently has it begun to spread into other Gulf Coast areas (Figure 1).

Veronicella ameghini was first discovered in New Orleans and Mobile in 1960. Our last survey of the area (summer 1970) revealed its present distribution as shown in Figure 1.

The other records are those of slugs found in nurseries and/or greenhouses. Thus far they have not, to our knowledge, become established elsewhere, but it is probably only a matter of time until they do. The means of distribution is through the moving of plants by man. Most likely the egg masses deposited in the soil around the plants are the stage transported since nursery operators generally pick off and kill any visible

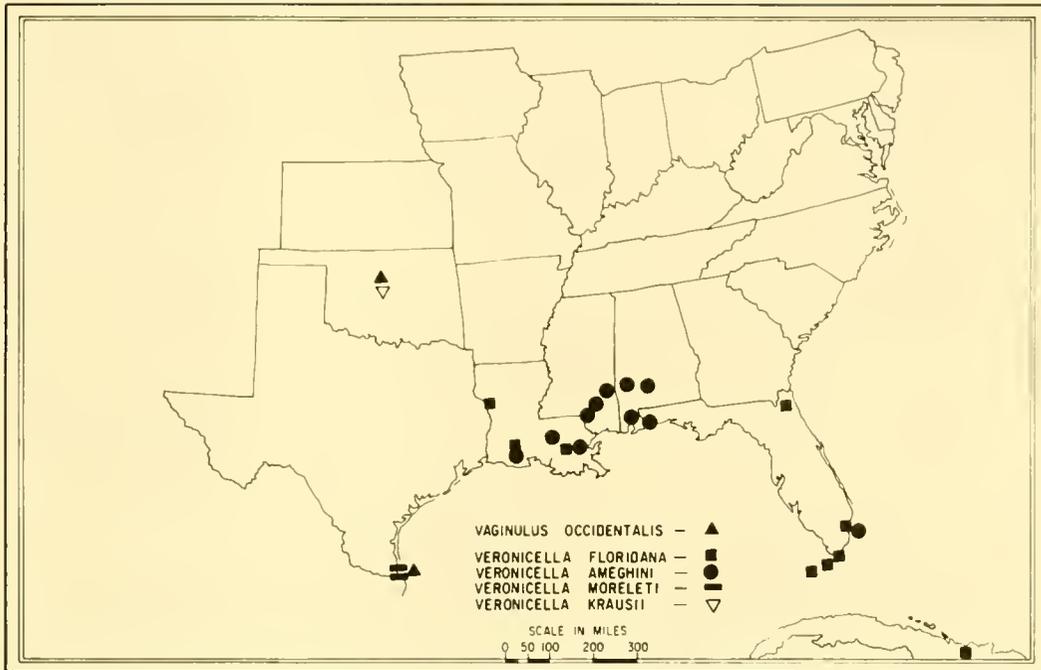


FIG. 1. Distribution of veronicellids in the United States.

adults or young. It is obvious that the Gulf Coast provides suitable habitats for these animals and we can expect to see more of them colonize the area as time goes by.

OBSERVATIONS ON ENVIRONMENTAL FACTORS

Population densities: Dundee, Stutts, Hermann (1965) provide an adequate description of a typical habitat. Population densities in these habitats fluctuate greatly. In the New Orleans area both slug populations, which are usually associated with the grass, *Stenotaphrum secundatum*, fluctuate tremendously. In peak seasons such as 1965, populations were very large; in one 375 sq. m. area we were able to collect the following number of slugs in a half hour period: July 13 (584), August 10 (454), September 15 (254). All slugs were returned to the habitat after collection.

During the next eight years the populations fluctuated considerably (Figure 2). By 1973, they were at the lowest ebb since introduction. In fact, they were so scarce that the author wondered if they were dying out in the area. Note that, while measurements of the population were made in

the one area routinely, casual observations were made in numerous areas since the author had some concern about the effects on the population of using the same area regularly. Those substantiated the measured results. As any collector well knows, one is well aware of relative population densities over a period of time, if one is collecting or observing in an area regularly.

Stenotaphrum secundatum (St. Augustine grass) used widely as a lawn grass, is subject to damage by chinch bugs, *Blissus leucopterus*. As a result, lawns throughout the south are routinely treated with various products: Ortho Malathion 50, Cygon, Ortho Dieldrin, and others. These directly affect the slugs living in the grass. During the summer of 1970, for example, in the New Orleans area the bug problem was severe and much spraying was done.

A simple experiment (Table 1) involving various easily obtainable insecticides and molluscicides was run to determine the effects of these on the slugs. Slugs were placed in a container identical to their usual laboratory housing: lightly moist sand on the bottom with part of it covered by a piece of paper toweling. The

TABLE 1. Results of lab tests with molluscicides and insecticides (10 slugs of each species were used in each trial)

Product	Concentration	How Applied	Amount of Kill
Snarol	Pellets	Set in container	all dead in 24 hrs.
Bug-Geta	Pellets	Set in container	all dead in 24 hrs.
Green Lite	Crushed form	Sprinkled in container	all dead in 24 hrs.
Dieldrin	Undiluted	Dog biscuit saturated and placed in container	all dead in 24 hrs.
Malathion 50	1 ml in 800 ml water sprayed		no deaths after 72 hrs.
	2 ml in 800 ml water sprayed		4 dead in 24 hrs.
	2.5 ml in 800 ml water sprayed		9 dead in 24 hrs.
	5.0 ml in 800 ml water sprayed		all dead in 24 hrs.
	Undiluted	Dog biscuit saturated and placed in container	all dead in 24 hrs.
	1 ml in 800 ml water	Sprayed	no deaths after 72 hrs.
Cygon -2E	2 ml		no deaths after 72 hrs.
	3 ml		no deaths after 72 hrs.
	6 ml		much writhing but alive after 72 hrs.
	Undiluted	Dog biscuit saturated and placed in container	all dead in 24 hrs.
	1 ml in 800 ml water sprayed		no deaths after 72 hrs.
	5 ml in 800 ml water sprayed		no deaths after 72 hrs.
	6,7,8 ml in 800 ml water sprayed		no deaths after 72 hrs.
	9 ml in 800 ml water sprayed		all dead in 24 hrs.

application of the chemicals was as shown in Table 1.

Three of these chemicals, Snarol, Bug-Geta, and Green Lite, are specific for snails and slugs. Snarol's active ingredients are tricalcium arsenate and metaldehyde. Green Lite has hexachlor - epoxy - octahydrodimethanonaphthalene (0.5% Dieldrin) and metaldehyde. Bug-Geta contains calcium arsenate and metaldehyde as active ingredients.

The others are insecticides. Dieldrin, designed to kill beetles, ants, grasshoppers, box elder bugs as well as "many other lawn and ornamental soil insects", is composed of dieldrin (see above) and an aromatic petroleum derivative solvent. Malathion 50 is designed "for use on evergreens, roses, ornamentals, shrubs, trees" and is meant to control red spiders, aphids, flies, mealybugs, scale insects as well as various other household pests. It is a choline esterase inhibitor. Active ingredients are

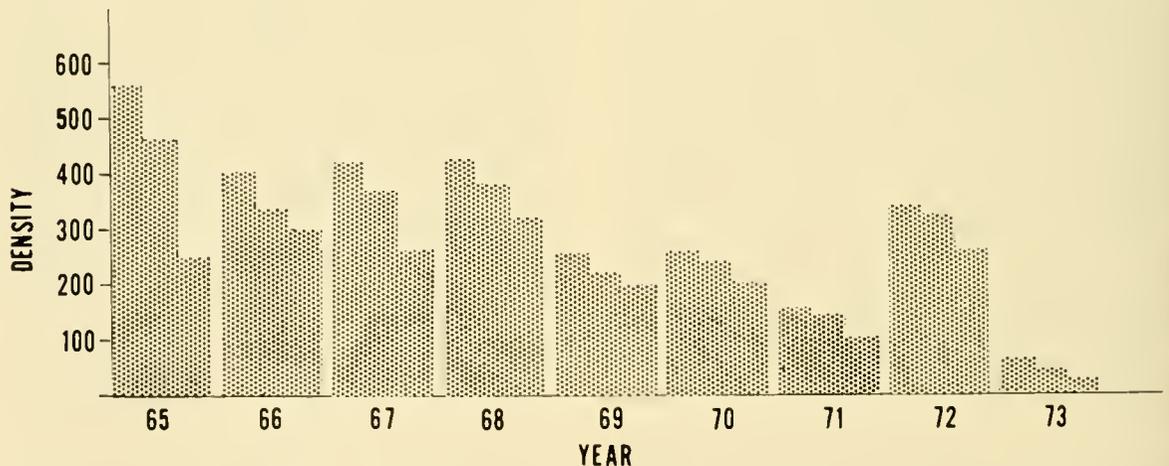


FIG. 2. Population densities of *V. ameghini* in one 375 sq. meter area. Left column of each year represents a mid-July collection, middle is mid-August, and right is mid-September.

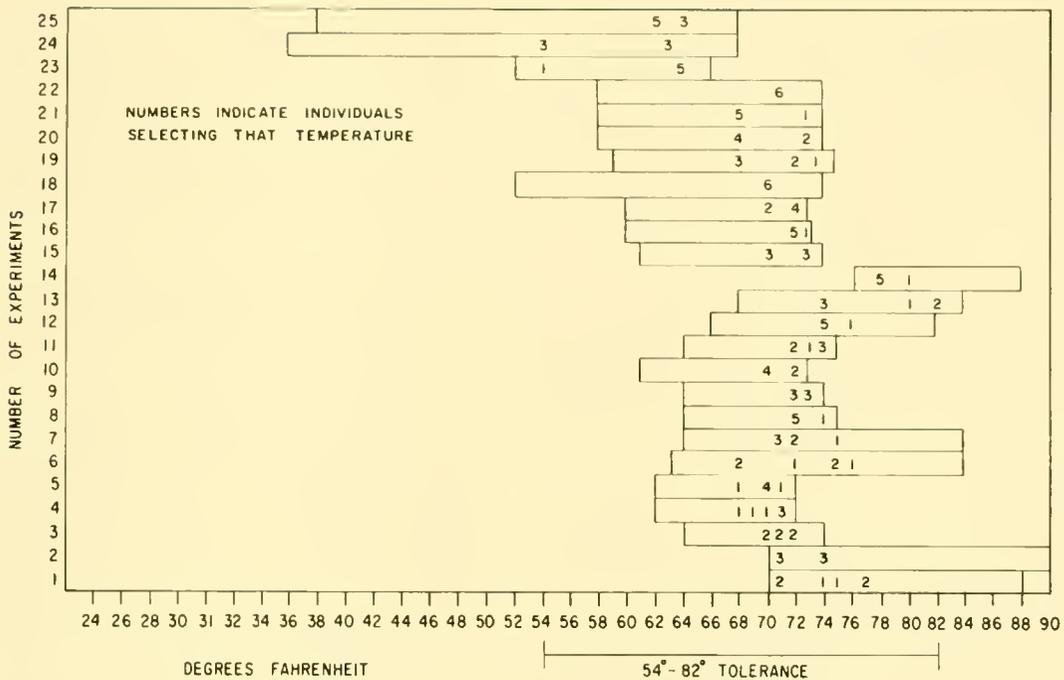


FIG. 3. Temperature tolerance in *Veronicella ameghini*. Bars indicate the temperature range to which the slugs were exposed in each experiment.

malathion (0, 0-dimethyl dithiophosphate of diethyl mercaptosuccinate) and an aromatic petroleum derivative solvent. Cygon 2-E has as an active ingredient dimethoate (0, 0-dimethyl S-(N-methyl-carbamoylmethyl) phosphoro-dithioate).

Although a much broader experiment with more variables such as size of area, moisture control, would, of course, be more desirable, it is apparent from Table 1 that, even with these simple tests, these insecticides used for lawns (as well as the molluscicides which are for sale) are very quickly detrimental to the slugs. This could be a significant factor in population fluctuations.

Temperature. Experiments patterned after Dainton (1954) were run numerous times to determine temperature tolerance. The temperature measured was that of the air immediately above the substrate upon which the slugs were resting. In each trial, except one, 6 slugs were used. No difference in species behavior was found. Repeatedly the results were shown in Figure 2 wherein the range of tolerance falls between 12 and 28°C (54-82°F) with the preference seeming to be 20-24°C (68-75°F). When the temperatures fall

below 12°C (34°F) inactivity prevails whereas if it rises beyond 28°C (82°F) and remains even for a short period of time, death ensues. In relating these data to the situation in nature, one must remember that the soil temperature in the micro-habitat is modified by other factors not involved here: shade, wind, humidity. For example, we have collected active slugs when the air temperature was 10°C, but simultaneously the relative humidity was 92% and the slug substrate was approximately 23°C due to a warm water sewer close by (see section on relative humidities).

Light. In another series of experiments involving a combination of temperature and light several factors were discovered. When air temperatures have been higher than 31°C (88°F) and begin decreasing, the slugs begin activity whereas when temperatures have been lower than 25°C (77°F) and are increasing, activity does not begin to occur until 25°C is reached even though this is above the preferred range (20-24°C) as demonstrated in the substrate studies. Since these temperatures approximate

the summer season daily temperature range (21-30°C) here, this leads us to superimpose light as a factor directing slug behavior. We discovered that slugs (in our experimental chamber) moving towards a cooler area, will, if a light (anywhere from 44 to 260 foot candles) is directed at their anterior ends, go in the reverse direction even if the temperature is intolerably high there. Several such experiments lead us to believe that temperature controls time of activity but that light determines the area of activity. All of these factors together could account for nocturnal activity which is seen normally. But, the further problem of desiccation must also be considered.

Wind. A series of experiments to test for effects of wind upon the slugs was done. Superimposed upon these experiments were additional conditions of heat, light and temperature.

The method of procedure was as follows: a clear, plastic box 25 cm wide \times 17.5 cm high \times 15 cm deep, with moist paper toweling on its floor and sides, was used as the light chamber. A similar box with all sides painted black served as the dark chamber. A partial barrier (15 cm high \times 5.5 cm wide) was taped upright in the right front side of each box. The box was turned so that the top faced frontwards to the path of the air from a small electric fan. Screen covered the top (front) of each box. Twenty slugs (the experiments involved each species) were placed in each chamber approximately 2.5 cm abeam of the plastic wind barrier. Exposure time was planned to be fifteen minutes per experiment; however, under certain conditions the animals were dying sooner so that results were obtained more quickly.

The animals were observed and responses recorded. A control set was maintained in a similar box for each experiment but without the variables (wind, hot, cold)—simply at room conditions. No behavior similar to that observed in the experiments was seen. Terminology used was as follows:

barrier area: that portion of the box behind the plastic barrier (the area sheltered from the wind)

exposed area: the rest of the box

aggregation: animals close together so as to form

a group; characterized by a mound-like appearance and complete or near complete absence of motion

random orientation: any motor activity not specifically directed towards the barrier area; includes extension-retraction of tentacles, motion of anterior body and/or actual movement into the barrier area

sheltered activity: activity occurring after the animal had reached the barrier area but which was not directed towards the outside of that area

temperature: room temperature was 22°C (72°F). Heat was introduced into the boxes by placing a hot-plate directly in front of the fan. Temperatures as high as 33°C (92°F) could be attained by this method; however, temperatures between 23 and 29°C (74-84°F) were used since it was determined that the animals would not survive above 28°C (84°F); again this verified previous experiments.

A summary of results follows:

Experiment 1 (repeated ten times with each species): light box—room temperature—wind (fan)

1. Animals initially stationary; no motion for first five minutes.
2. Random orientation on the part of three animals; others motionless or with only slight movement. Lasted 6-15 minutes.
3. By the end of twenty minutes, most animals had migrated to the barrier area.
4. Remaining animals aggregated.

Note: Attainment of barrier area did not necessarily indicate cessation of movement. On a number of occasions sheltered activity continued. In some cases, animals having attained the barrier area early would return to the exposed area to any clustered group. One time when a single slug attained the barrier area and the others clustered in the exposed area, that individual returned to the cluster. Under conditions of exposure all animals secreted mucus heavily unless clustered. This occurred in both the light and the dark.

Experiment 2 (repeated ten times with each species): Dark box—room temperature—wind (fan)

1. The same absence of activity for the first five minutes.
2. Much less activity for the first ten minutes than in the light.
3. Some random orientation leading to clustering by most; in some of the experiments several slugs had, by the end of fifteen minutes, attained the barrier area and ceased activity.

Note: There was much less activity in the dark than in the light when wind was applied.

Experiment 3 (repeated ten times with each species): Light box—heat—wind (fan)

1. Motion often leading to aggregation in first five minutes.
2. Random orientation leading to signs of shriveling accompanied by increase in activity for next ten minutes. Those reaching the barrier area often returned to the exposed area. Appearance of general discomfort; the higher the temperature, the greater the appearance of discomfort (in combination with wind)

Experiment 4 (repeated ten times with each species): Dark box—heat—wind (fan)

1. Aggregation was the response within the first five minutes with no other behavior occurring.

Experiment 5 (repeated ten times with each species): Light box—cold (whole experiment placed in 3°C (38°F)—wind (fan)

1. Immediate shriveling.
2. Moved into an aggregate within two minutes; appear “pinched”; very heavy mucus secretion.

Experiment 6 (repeated ten times with each species): Dark Box—cold—wind (fan)

1. Aggregation close to point of release followed by inactivity; same appearance and mucus as in light-cold.

Several interesting results were obtained from these experiments. First, it is obvious that veronicellids have a negative response to wind and either seek shelter or aggregate in the presence of it. The temperature of the wind seems to be of no more importance than temperature alone (based upon a comparison of these experiments with the previously-discussed tem-

perature experiments). The reason for less activity in the dark than in the light is as yet unexplained; it is the reverse of the situation without wind.

pH: the range in soil pH in areas where slugs are common is 7.2-7.8.

LIFE HISTORY

There are two periods of egg deposition by *Veronicella ameghini* in the Gulf Coast area. One is from March through June and another from September through mid-November. The same timing prevailed in the laboratory despite different experimental conditions.

Eggs are normally deposited in a shallow cavity which the slug makes in the soil. This usually occurs under leaf litter where a higher moisture level is likely to be maintained. The egg mass is coiled and the eggs are attached together by a gelatinous, fecal-containing strand. The slug deposits the strands while it is curled in the form of a circle. The curve of the body apparently helps form the coil-shaped egg mass. A single slug may deposit from one to five masses during each breeding season. Five to fifteen eggs are laid in this manner and the period of deposition is known to be at least five hours. Each egg is oval, 6 mm in length 3 mm wide, gelatinous without a hard cover. Once deposited, the eggs are not covered over with soil but are merely left to hatch.

Hatching occurs in approximately 20-28 days depending on the temperature. The average incubation period in the laboratory with a room temperature averaging 24°C was 21.4 days. The late spring masses hatch sooner than those laid in early spring, probably due to a higher temperature; likewise, the later fall eggs require a longer period to hatch.

Length of newly hatched slugs is about 3-4 mm. It is impossible to accurately measure living slugs; therefore, weighing was employed. Average weight of a newly hatched slug .016 g.

Growth rate in the laboratory is slow. Here they were maintained at room temperature (approximately 24°C or 76°F with air conditioning) and fed lettuce. The average rate was 0.28 g in six months. The average weight of hundreds of

slugs collected at random throughout the year was 0.523 g. It is suspected that the average growth rate in laboratory is well under that in the field.

The largest adult captured weighed 2.94 g. If the above-mentioned growth rate does occur in nature the calculated age would be approximately five years for this individual. Longevity is more likely around two years as it is with many other land molluscs. Laboratory maintenance is difficult for periods longer than six months. One has a constant die-off as time goes by. The problem is one which is being investigated in more detail—namely, that of a blistering phenomenon wherein the slugs become pitted, form blisters and gradually become weak and die. It is thought that the disease is caused by either a yeast or a bacterium (DeGravelle, 1971).

SIGNIFICANCE OF THE INTRODUCTIONS

Repeated checks in nature and in greenhouses of our local colonies of *Veronicella ameghini* and *Veronicella floridana* reveal no significant damage from them to native vegetation, crops, or property. The latest finding of veronicellids in southern Texas is new enough that no information is available on their activities. USDA does

report that damage has been done to greenhouse plants by these slugs. The author has received a picture of damage done to bananas in Honduras by *Vaginulus olivaceus* (courtesy of Div. of Trop. Res., Dept. Entomology, La Lima, Honduras). It shows holes and brown spots where the slugs have rasped the banana "peel", thus making the banana unmarketable.

With more introductions being reported recently, it is well that we stay alert and be prepared with knowledge in case of any major problems such as have been associated with introductions of *Achatina fulica*, the giant African snail (Mead, 1961).

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USE OF EMPTY GASTROPOD SHELLS (POLYGYRIDAE) BY PSEUDOSCORPIONS

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Marshall University
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Pseudoscorpions are noted for their phoretic associations with many living vertebrates and invertebrates (Muchmore, 1971). However, their associations with non-living animal remains for a survival advantage has not been documented. Specimens of *Chthonius tetrachelatus* (Preyessler) and *Apoththonius moestus* (Banks) have been collected by us from the empty shells of the terrestrial gastropods *Triodopsis albolabris* (Say and Mesodon *thyroidus* (Say) from Cabell, Kanawha, Putnam, and Wayne Counties, West Virginia. The empty shells were collected from mid-February to May, 1976, and the pseudoscorpions were collected in them up to April.

The use of gastropod shells by arthropods is not an uncommon occurrence in the marine and littoral environment, as demonstrated by several species of hermit crab. Indeed, the use of ter-

restrial gastropod shells by pseudoscorpions may have the same survival advantage in protecting the animal's soft parts during molting. However, this behavior may have other implications. The shells may offer protection from excessive cold, heat and desiccation.

We would like to thank Drs. Sigurd Nelson, Jr., SUNY at Oswego, New York, William B. Muchmore, University of Rochester, and C. Clayton Hoff, University of New Mexico, for their advice and assistance. Voucher mollusk specimens are in the Marshall University Malacological Collection and the Delaware Museum of Natural History.

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- Muchmore, William B. 1971. Phoresy by North and Central American pseudoscorpions. *Proc. Rochester Acad. Sci.* 12: 79-97.

VERONICELLA OCCIDENTALIS IN LOUISIANA

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A comprehensive review of introduced mollusks in eastern North America (North of Mexico) was recently published by Dundee (1974). The tropical veronicellid slugs introduced in the above area received attention in the review. In the summer of 1975 I collected veronicellids in New Orleans, in the uptown region of the city. These slugs fit the description of *Veronicella occidentalis* (Guilding). This is a new record for this slug in Louisiana. About twenty slugs were found under logs, garbage cans and leaves, and on side-walks.

Veronicella occidentalis was reported by Dundee (*loc. cit.*) to have been introduced into Oklahoma and Texas. The slug is believed to have originated in southern Mexico, northwestern South America and the Antilles. I have seen and examined specimens collected on the Caribbean Island of St. Lucia (E. A. Malek, 1976, in press), and the Louisiana material is quite identical to those from St. Lucia. These tropical slugs were probably introduced into the United States on several plants, judging from interceptions by the

U. S. Department of Agriculture, at ports in Florida, Louisiana, New York and Texas. Among the plants are bromeliad, caladium, *Dracaena* sp., *Ficus*, orchid, palm, pineapple, and philodendron.

Another veronicellid previously introduced in Louisiana, circa 1960, is *Veronicella ameghini* (Gambetta), and was reported upon by Dundee and Herman (1968). The latter slug occurs now in small numbers, that it is rarely encountered in New Orleans. It did, however, occur in large numbers in New Orleans in the early 1960's.

I am grateful to Dr. Dee Dundee of the University of New Orleans for having examined the slugs which I collected in New Orleans, and having confirmed my identification.

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NATIONAL MUSEUM OF NATURAL HISTORY

Department of Invertebrate Zoology—Mollusca

Several changes have occurred recently in the malacological staff of the Department of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560 (formerly known as Division of Mollusks, U.S. National Museum).

Dr. Arthur H. Clarke joined the staff in January, 1977, as Associate Curator of freshwater and land mollusks in the position created by the retirement of Dr. J. P. E. Morrison (1975). Dr. Clarke formerly was curator of Molluscs and later Head, Invertebrate Zoology Division at the National Museum of Natural Sciences, National Museums of Canada, Ottawa.

Dr. Richard S. (Joe) Houbrick became an Associate Curator in marine mollusks in March 1977, transferring from the Smithsonian Oceanographic Sorting Center (NMNH), where he supervised the benthic invertebrate sorting program. Dr. Houbrick occupies the vacancy created by the retirement of Dr. Harald A. Rehder (1976).

Dr. Rehder remains in mollusks as Zoologist Emeritus, Department of Invertebrate Zoology.

Dr. C. F. E. Roper and Dr. Joseph Rosewater continue to serve as Curators in cephalopods and marine mollusks, respectively.

Each department of the National Museum of Natural History (Anthropology, Botany, Entomology, Invertebrate Zoology, Mineralogy, Paleobiology and Vertebrate Zoology) is administered by a chairman. The Departmental chairmanship is a rotating position so that no individual Curator need have his research program permanently curtailed. Curatorial staff are administratively responsible to the Department Chairman, as divisional Head Curators no longer exist. The subject areas within the Department of Invertebrate Zoology are Crustacea, Echinoderms, Lower Invertebrates, Mollusca, and Worms. Administrative requirements within a subject area are attended to by a Supervisor, a position rotated among the curatorial staff every year or two. Requests should be directed to the Supervisor or to a specific curator.—C. F. E. Roper.

PUBLICATIONS RECEIVED

- Thompson, Fred G. 1977. The Hydrobiid Snail Genus *Marstonia*. Bull. Florida State Mus., Biol. Sci., vol. 21, no. 3, pp. 113-158. Eight species, of which five are new, are treated systematically. The genus, limited to Southeast and Central United States, is placed in the subfamily Nymphophilinae Taylor, 1966. \$1.75, Florida State Museum, Gainesville, Fl. 32611.
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C. M. Yonge and T. E. Thompson

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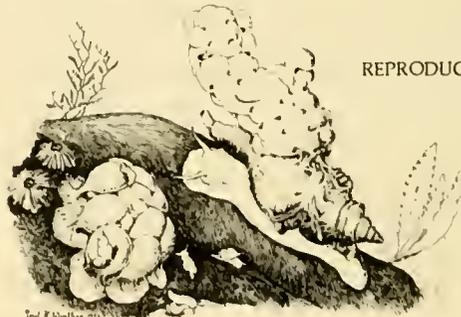
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PUBLICATIONS RECEIVED

- Andrews, Jean. 1977. *Shells and Shores of Texas*. xx + 365 pp. text figs., 12 colored photos. University of Texas Press, Austin, TX. 78712. \$19.95 (\$24.95 after Dec. 31, 1977). This is a greatly improved second edition of *Sea Shells of the Texas Coast*, and now qualifies as the best book on marine mollusks of any state. The book has been reset and much new material added. It will serve for years as an excellent guide to shore conditions and shells of Texas and beaches of neighboring states (R. T. Abbott).
- McMillan, Nora F. 1977. *The Observer's Book of Seashells of the British Isles*. 158 pp., 195 text figs., 8 colored pls. Frederick Warne, Ltd., London. About one of the smallest (3½ x 6 inches) hardback guides to shells ever published. Worth taking on field trips in the British Isles and northern France. \$2.00.
- Jacobson, Morris K. and William K. Emerson. 1977. *Wonders of Starfish*. 80 pp., illus. Dodd, Mead & Co., N. Y. \$4.95. An excellent coverage for 10-year olds and up.
- Gastropodia*. Edited by Glenn R. Webb. vol. 1, no. 10, pp. 97-112, pls. 42-46. Six articles on anatomy, hybridization and sexology of North American land pulmonates. Index to vol. 1. Published May 22, 1977.
- Jewell, C. B. 1977. *The Inception and Ascension of Man*. 93 pp. Hardback. Vantage Press, N. Y. Mentioned only because the author theorizes that man descended from mollusks. This should make malacologists feel special.
- Powell, A. W. B. *Shells of New Zealand*. Fifth revised edition. 153 pp., 45 pls. (2 in color). Hardback. Whitcoulls Ltd., N. Z. Checklist of 2256 New Zealand mollusks, with 555 now illustrated. Leading guide, up-dating Suter's *Manual*. \$12.00 N. Z. Obtainable in U. S. from *Seashell Treasures*, P. O. Box 730, Oakhurst, CA 93644.

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SMALL SPECIES OF NUCULIDAE (BIVALVIA) FROM THE
TROPICAL WESTERN ATLANTIC¹

Donald R. Moore

University of Miami,
Rosenstiel School of Marine and Atmospheric Science

ABSTRACT

Three small species of Nuculidae, two of which are the smallest known bivalves, are described from tropical western Atlantic sediments. *Nucula calcicola* n. sp. is a small, less than 2.0 mm, clam found in calcareous sediments over much of the Caribbean region. The other two species are placed in a new genus, *Condylonucula*, with *C. cynthiae* n. sp. as the type. *C. cynthiae*, mature at around 600 μ is found in the western Caribbean on atolls off the coast of Nicaragua. *C. maya* n. sp., mature at around 500 μ has been found at Cozumel and Arrowsmith Bank at the northwestern extremity of the Caribbean. Recent and Upper Cenozoic Nuculidae of the area are listed, and some are discussed.

A very small shallow-water species of *Nucula* is widely distributed throughout much of the Caribbean region. Specimens, when found, have apparently been identified as juvenile *N. proxima* Say or as *N. aegeensis* Jeffreys. However, *N. proxima* is a temperate species with a distribution from New England to Texas, and is a much larger species reaching a size of 10 mm. The small tropical species does not reach, at least in the material at hand, more than a length of two mm. *N. aegeensis*, in the western Atlantic, was identified by Dall in 1886, and this identification has not been challenged even though *N. aegeensis* was described from the Mediterranean. While most of the material ascribed to the species came from depths of more than 200 m, Dall (1889) gave a depth range of 5-464 fms (9-849 m). Later, Dall and Simpson (1901) reported a single worn juvenile valve from Mayaguez Harbor (Puerto Rico).

The American specimens of *N. aegeensis*, according to Dall, are fairly large, reaching a length of more than 10 mm. Dall did not give size or locality for the shallow water specimens, and apparently no one has studied them recently. Dall apparently considered small *Nucula* from shallow water to be either *N. proxima* or *N.*

aegeensis. This was probably due to the amount and condition of the material that he had to study. He apparently did not have any of the rather distinctive species from northern South America at the time. South Caribbean shallow water species are *Nucula dalmasi* Dautzenberg 1900, *N. surinamensis* Altena, 1968, and *N. venezuelana* Weisbord, 1964.

OBSERVATIONS

I first found the new species in a bottom sample collected at a depth of two m in Lameshur Bay, St. John, U. S. Virgin Islands (Moore, 1970). Thinking that these were very young specimens, I did not attempt to identify them at the time. Several years later, I found more specimens in bottom samples from Serrana Bank (Bock and Moore, 1971), an atoll in the western Caribbean (Milliman, 1969). It was not until I found that I had 72 specimens from two stations made at Courtown Cays, a small atoll east of Nicaragua, that I became convinced that I had a small shallow-water-dwelling species. The largest specimen measures 1.90 mm.

By this time I had also found several specimens of a much smaller species with a peculiar prodissoconch. This nuculid gave every indication of having attained full growth at a length of about 600 μ . Naturally, I wanted more material before attempting to describe either

¹Contribution from the University of Miami, Rosenstiel School of Marine and Atmospheric Science, and Contribution No. 5 from the West Indies Laboratory, Fairleigh Dickinson University.

species as there have been many cases of immature mollusks described as adults, often badly misclassified (Moore, 1966, Pilsbry, 1949). Searching through sediment samples from St. Croix, Virgin Islands, Key Largo in the Florida Keys, and from Bermuda all provided more material of the larger species.

Bottom samples from Chancanab Lagoon, Cozumel, Mexico, collected in November, 1971, provided a large suite of the largest species and over 30 specimens of another, very small species. The latter species was also found in sediments from Arrowsmith Bank, a flat topped bank about 34 km NNE of Cozumel. Since I now had well over 300 specimens of the largest species, and 52 of the two smaller ones, I felt that there was little doubt that all three species matured at a very small size. In the following descriptions, the largest species is assigned to *Nucula*, and a new genus is erected for the smaller two.

DESCRIPTIONS

Genus *Nucula* Lamarck, 1799

Type species by monotypy, *Arca nucleus* Linnaeus

Nucula calcicola new species

Description: A small species of *Nucula* maturing at a length of about 1.5 mm. The prodissoconch is about 220 μ long, somewhat flattened, pitted, and has a small knob near the posterior edge. The dissoconch is about 25% longer than high; thickness of an adult specimen is about one half the length. The anterior end is extended and rounded; posterior end truncate. The posterior margin forms a straight or nearly straight line. The ventral margin is well-rounded and weakly dentate. Both concentric and radial sculpture are present, but are exceedingly weak. A thin brownish periostracum is present on fresh specimens.

The resilifer is internal, short, and nearly at right angles to the hinge line. The anterior limb of the hinge is broad, and is widest distally between the last two teeth. Mature specimens usually have seven anterior teeth in the left valve, six in the right. The posterior limb of the hinge is short and broad with four teeth in the left valve,

four in the right. The adductor muscle scars are located at each end of the hinge. Shell structure in fresh specimens is transparent; there is no nacre, or at most, an extremely thin wash of this material.

Material: Holotype. Specimen collected alive, 1.74 mm long and 1.38 mm high. U. S. N. M. No. 758535.

Type locality: Chancanab Lagoon, depth 2 m, Cozumel, Quintana Roo, Mexico.

Paratypes and other localities: Courtown Cays, western Caribbean, Lagoon, depth 11 m, 59 separate valves. North end of the atoll, depth 2 m, 13 separate valves. Serrana Bank, western Caribbean: Lagoon, 14 valves, 2 complete specimens. St. John, Virgin Islands: Lameshur Bay, depth 2 m, 15 separate valves. St. Croix, Virgin Islands: West side of Cottongarden Point, depth 1 m, one valve. Tague Bay, depth 3 m, 3 valves and one complete specimen; depth 4 m, one complete specimen; station at inside edge of outer reef, 4 m, 3 valves and one complete specimen. Glovers Reef, Belize (British Honduras): depth 2 m, 3 valves, 2 complete specimens. Cozumel, Quintana Roo, Mexico: Chancanab Lagoon, depth 2 m, 74 complete, 98 separate valves, and 14 identifiable fragments: depth 5 m, one valve. Key Largo, Florida: Harry Harris Park, depth 2 m, 2 complete, 17 separate valves, some badly broken. Andros Island, Bahamas: one mile east of Wax Cut, depth 3 m, one complete specimen. Harrington Sound, Bermuda: notch at 4.6 m, 2 complete, 3 separate valves.

The paratypes range in length from 0.38 mm, for a complete specimen from Cozumel to 1.90 mm for a single valve from the same locality. One typical complete mature specimen from Cozumel measured 1.60 long by 1.24 mm high by 0.86 mm thick.

Paratypes have been placed in the following institutions: National Museum of Natural History, Smithsonian Institution (USNM 758537); Delaware Museum of Natural History (DMNH 120581); Academy of Natural Sciences Philadelphia (ANSP 344387); American Museum of Natural History (AMNH 183857); Museum of Comparative Zoology (MCZ); British Museum (Natural History); Rijksmuseum van Natuurlijke Historie, Leiden; Laboratoire de Malacologie,

Museum National d'Histoire Naturelle, Paris; University of Miami Marine Laboratory Museum (UMML 28-2812).

Name: From *calcis*, lime, and *cola*, dweller in, referring to the calcareous sediments the new species seems to prefer.

Remarks: At first I thought that *N. calcicola* should go into *Pronucula* Hedley, 1902, but I could not find any character in the new species, except lack of nacre, that was actually distinct from other species of *Nucula*. The one character that seems to set *Pronucula* off from other genera is the large smooth area surrounding the umbones, with the sculptured area coming in relatively late. Both *N. venezuelana* Weisbord, 1964, from the lower Caribbean and *N. exigua* Sowerby, 1833, in the eastern Pacific, have this feature, but no one has assigned these species to *Pronucula*. Furthermore, a species dredged by me in 45 m off Abidjan, Côte d'Ivoire, looks like a *Pronucula* with a size of 1.0 to 1.5 mm. The large prodissoconch, the arched hinge, and the teeth distant from the resilifer are all characters used by Hedley in forming his new genus. However, the largest specimen is 17 mm long, and has the characters of a typical *Nucula*. The above mentioned characters for *Pronucula* thus appear to be juvenile characters, at least in some species. Whether *P. decorosa* Hedley and its allies in Australian waters are described from immature specimens or are adults, I do not know.

The collection of 330 specimens of *N. calcicola* with a maximum size of 1.90 mm from nine localities in the western Atlantic left little doubt this was a distinct small species of *Nucula*. The only locality where a different *Nucula* was collected along with the new species was at Glovers Reef, Belize, where two specimens of another, perhaps undescribed, species were collected. Large specimens of *N. calcicola* (1.4 to 1.9 mm) were examined for signs of maturity, and in this material a thickening on the inside of the valves was noted as well as some irregularity of the inner surface. The adductor muscle scars were sunken, indicating that shell material had been deposited on the inner surface after growth had been completed. However, this is not the smallest species of *Nucula*. For instance, Powell (1939) described *Austronucula schencki* whose length

was 1.15 mm, and recently Marinovich (1973) described a 1.12 mm species as *Nucula interflucta*. Marinovich had more than 2,000 specimens.

The range of *N. calcicola* now extends from Courtown Cays and Serrana Bank, atolls off the coast of Central America, to Belize, to Cozumel off the east coast of Yucatan, and the Florida Keys. Far to the eastward, it is found in the Virgin Islands, and it almost certainly must live in the Greater Antilles between the two areas. It has also been collected at Bermuda.

This appears to be a very shallow-water-dwelling stenohaline species. All of the known localities are around coral reefs, in lagoons behind reefs, or where at least a few corals are living. Chancanab Lagoon, where *N. calcicola* was most abundant, is a small shallow landlocked body of water, Moore (1973), but it is connected with the open sea by a short underground passage. Several coral colonies were observed growing on rocks in the lagoon, and the other animals observed were all marine in habitat.

The greatest depth of any of the material of *N. calcicola* was 11 m in the lagoon of Courtown Cays. All of the specimens taken at this locality were rather worn separate valves making it a distinct possibility that the clams had been carried to that depth by water movement from nearby shallows. Live material was only collected in 2 m at Chancanab Lagoon; the depth range for empty valves is one to 11 m. Some of the Key Largo material (2m) was very fresh in appearance, but none were alive when collected.

N. calcicola has apparently been considered in the past to be young *N. aegeensis* Jeffreys. Our knowledge of this species in the western Atlantic stems mainly from Dall's (1886) discussion. There is a brief description of *N. aegeensis* in Dall and Simpson (1901), but it is based on the "one young left valve" found at Mayaguez, Puerto Rico, or on larger specimens in the U. S. National Museum. There is also a brief description and figure of a 2.7 mm specimen ascribed to *N. aegeensis* in McLean (1951), and another very brief description and figure in Warmke and Abbott (1961) of a specimen collected in a shallow dredging at Puerto Rico. It is not certain what species these specimens represent. It is interesting to note that Dall first (1886) reported *N. aegeensis* at a depth

range of 175 to 464 fathoms (320 to 849 m). Later, he decided that shallow water material from the shelf off North Carolina also was *N. aegaeensis*. Probably this material should be reexamined.

At least a dozen Recent species of *Nucula* have been described or reported, from the Caribbean region. In the following list, the maximum reported size of the species is given, and also the known depth range in the Caribbean area. No attempt has been made to arrange the species according to the latest classification, or to provide a synonymy.

Recent species of western Atlantic *Nucula* from northern South America to the southeastern United States.

<i>Nucula aegaeensis</i> Jeffreys, 1879	10.7 mm	9-849 m
<i>N. tenuis</i> Montagu, 1808	10 mm	320-823 m
<i>N. crenulata</i> A. Adams, 1856	6 mm	55-805 m
<i>N. proxima</i> Say, 1822	10 mm	2-183 m
<i>N. cymella</i> Dall, 1886	5 mm	375-2013 m
<i>N. verilli</i> Dall, 1886	5 mm	538-3084 m
<i>N. fernandinae</i> Dall, 1927	4 mm	538 m
<i>N. dalmasi</i> Dautzenberg, 1900	6 mm	22-67.5 m
<i>N. surinamensis</i> Altena, 1968	4.5 mm	shallow water
<i>N. venezuelana</i> Weisbord, 1964	2.4 mm	shallow water
<i>N. cancellata</i> Jeffreys, 1881	4 mm	1610 m
<i>N. calliopedemna</i> Dall, 1890	12.5 mm	1610 m
<i>N. calcicola</i> n. sp.	1.9 mm	1-11 m
<i>N. eulebrensis</i> Smith, 1885	6 mm	715 m

There are also more than twenty Cenozoic fossil species described from various formations from Trinidad to the southeastern United States. The list as it stands may not be complete as the paleontological literature is now enormous. Again, no effort was made to revise the classification, but maximum size and presumed age are listed. *N. venezuelana* is listed again since it was originally described from the Pliocene, but the other species are apparently known only from the fossil record.

Cenozoic fossil species of *Nucula* from lands bordering the Caribbean and Gulf of Mexico are:

<i>Nucula venezuelana</i> Weisbord, 1964	2.7 mm	Pliocene
<i>N. marcana</i> Weisbord, 1964	4.4 mm	Pleistocene
<i>N. limonensis</i> Gabb, 1881	3 mm	? Miocene
<i>N. moenensis</i> Gabb, 1881	3.5 mm	? Miocene
<i>N. tuberculata</i> Gabb, 1873	7 mm	Miocene
<i>N. tenuisculpta</i> Gabb, 1873	4 mm	Miocene
<i>N. vieta</i> Guppy, 1867	4.9 mm	Miocene
<i>N. baccata</i> Guppy, 1867	7 mm	Miocene
<i>N. orbicella</i> Olsson, 1922	11 mm	Miocene
<i>N. cahuitensis</i> Olsson, 1922	3.5 mm	Miocene
<i>N. chipolana</i> Dall, 1898	4 mm	Miocene

<i>N. chipolana waltonia</i> Gardner, 1926	4 mm	Miocene
<i>N. sinaria</i> Dall, 1898	4.75 mm	Oligocene & Miocene
<i>N. taphria</i> Dall, 1898	3.8 mm	Miocene (fg sp.)
<i>N. prunicola</i> Dall, 1898	6 mm	Miocene
<i>N. tampae</i> Dall, 1915	7.3 mm	L. Miocene
<i>N. dasa</i> Gardner, 1926	3.5 mm	Miocene
<i>N. defuniak</i> Gardner, 1926	5 mm	Miocene
<i>N. gadsdenensis</i> Mansfield, 1937	3 mm	Miocene
<i>N. moratensis</i> Woodring, 1925	4.8 mm	Miocene
<i>N. hilli</i> Woodring, 1925	8.9 mm	Miocene

All of the 32 other species enumerated in the two lists are distinctly larger than *N. calcicola*. The only Recent species close in size is *N. venezuelana*, but this species is only known from the northern coast of South America, is heavily sculptured, and lives in a muddy environment. However, immature specimens of one or more species could be confused with *N. calcicola*. Material of the unidentified species found with *N. calcicola* at Glovers Reef consists of two right valves, 2.2 and 2.64 mm long. This was the only station where a similar species was found along with *N. calcicola*. However, the Glovers Reef material, a 4.16 mm right valve from Hook Bank (Belize), 13 valves from 19°14' N., 91°20' W (max. size 2.0 mm), and six valves (max size 4.0 mm) from a depth of 113.5 m (east of Port Aransas, Texas), all agree with *N. proxima* in having a narrow elongate resilifer directed anteriorly. The shape and sculpture is similar to that of *N. calcicola*, but the resilifer of *N. calcicola* is quite different from *N. proxima* and its allies. A record of *Nucula proxima* from Panama, based on material collected by Olsson and McGinty, appears to be an undescribed species. A specimen donated to the Academy of Natural Sciences of Philadelphia is a single valve measuring about 2.3 mm in length.

There are many species in the ancient family Nuculidae, and most of these are small simple clams without strong characters setting them off from other species. Perhaps the most divergent of the genera is *Acila* with divaricate external sculpture. *Acila* is not known from the Atlantic. Species in the tropical western Atlantic range from smooth to somewhat sculptured, and have little diversity of form. Thus identification is often difficult, and this is especially true for the smaller species.

The other new species of Nuculidae herein considered are distinctive for several reasons: their extremely small size, few hinge teeth, and comparatively large sculptured and pitted prodissoconchs. They appear to be so different from other nuculids that a new genus is hereby erected to contain them.

Condylonucula newgenus

Extremely small nuculids with a large caplike prodissoconch. The valves are inflated, well-rounded, and have concentric sculpture. The anterior end is longer than the posterior; the prodissoconch is pitted and sculptured and as much as 40% of the length of the dissoconch. Hinge teeth few in number, while the resilifer is small and more or less normal to the hinge line. There is no nacre on the interior of the shell. The adductor muscle scars are paired, roughly equal in size, and the valve margins are smooth.

Type species: Condylonucula cynthiae,
new species

Name: from *condylus*, a knob on the end of a bone, referring to the prodissoconch, and *nucula*, a small nut. *Gender:* feminine.

The genus is erected for a pair of species, both new, from the western Caribbean. They are characterized by the relatively enormous pitted and sculptured prodissoconch, few hinge teeth, concentric sculpture, and smooth ventral margins. They are also smaller than any other species in the family.

Condylonucula cynthiae new species

Description: An extremely small species maturing at a length of about 600 μ (0.6 mm). The shell is compact, a little longer than high, and is rather thick. The prodissoconch is large, about 210 μ long, and has a large knob centrally located adjacent to the hinge line. There are two concentric ridges, an inner one about half way to the edge of the prodissoconch, and an outer ridge forming the projecting outer edge. Both ridges are best developed in the anterior and posterior areas, the inner ridge especially so on the posterior side. The surface of the prodissoconch is pitted. The anterior end of the dissoconch is

well-developed, the posterior end short. The ventral margin is well rounded. About ten to twelve concentric ribs are present on the adult. There are fine concentric striae between the ribs. The interior of the shell is without nacre. Two oval adductor muscle scars are present, the ventral margin is smooth, and the hinge plate is short and broad. There are four anterior, three posterior hinge teeth in the right valve, four anterior, two posterior in the left valve. There is a slight depression or notch on the inside at either end of the hinge. The resilifer is short and almost normal to the hinge.

Name: named for Cynthia Moore, wife of the author.

Material: Holotype. Complete specimen 600 μ long, 480 μ high. USNM No. 758534.

Type locality: About 800 m west of outer reef (lagoon) Courtown Cays (Cayos del E.S.E.) in the western Caribbean off Nicaragua. Depth, 7.5 m.

Paratypes: (specimens are complete unless otherwise noted). Courtown Cays, depth 1.5 m, one 350 μ long, one (bored) 600 μ long, one 460 μ long, one 460 μ long, one 630 μ long, one broken right valve, one fragment, USNM No. 758538. Courtown Cays, depth 1.5 m, one 620 μ long, one right valve 560 μ long, ANSP No. 344388. Courtown Cays, depth 1.5 m one 570 μ long, one left valve 620 μ long DMNH No. 120580. Courtown Cays, north end, about two m, one 465 μ long, one left valve 600 μ long, one left valve 580 μ long, MCZ No. Unknown. Courtown Cays, outer reef, one m, one 630 μ long, one left valve 590 μ long. Serrana Bank, lagoon, one 590 μ long, UMML No. 28-2811.

Two specimens from Serrana Bank, one complete, one a left valve, both 600 μ long, were lost after being photographed with the Scanning Electron Microscope at the University of Illinois. Hence there were originally eighteen good specimens available for this study.

Remarks: The minute size of *C. cynthiae* makes it unlikely that it would be confused with any other species of Nuculidae except another new species (*C. maya*) described in this paper (for comparison of the two species, see remarks after the description of *C. maya*). The young of other species such as *C. calcicola* may look superficially like *C. cynthiae*, but do not have the

strongly sculptured prodissoconch or show signs of maturity.

Maturity is always a problem when studying very small mollusks. There have been many cases of a larval or immature shell being described as an adult. Externally, one should look for a differentiated prodissoconch or protoconch to be certain that the specimen is beyond the larval stage. In bivalves, indications of maturity should be looked for on the inside of the valves. The shell is usually thickened internally after reaching maximum growth, and this is often accompanied by irregularities of the inner surface. Adductor muscle scars become sunken while changes in the hinge line may also occur.

One other species in the family, *Nucula calcicola*, has been found at both Courtown Cays and Serrana Bank. At present, these two atolls (Milliman, 1969), some 250 km apart, are the only known localities for *C. cynthiae*. A number of islands, islets, and shallow banks, however, are located off Nicaragua and Honduras, and probably have other populations of the species. There is also very little information on the vertical range of *C. cynthiae*. All of the specimens were collected in quite shallow water 1 to 7.5 m deep.

Condylonucula maya new species

Description: This is an extremely small species maturing at a length of about 500 μ . The shell is compact, oval in shape when viewed from the side, and moderately thick.

The prodissoconch is large, 220 μ long, and has a small knob centrally located next to the hinge line. The edge of the prodissoconch is somewhat raised above the adult shell, but does not form a distinct ridge. An inner concentric ridge is extremely weak or absent on the anterior and median area of the prodissoconch, but becomes an upright projection on the posterior part. This projecting ridge is about the same height as the central knob. The surface of the prodissoconch is pitted. The dissoconch is oval in side view, and has most of the prodissoconch confined to the posterior half. The anterior end is more elongate than the posterior; both ends are rounded to about the same degree. The ventral margin is moderately well rounded, and there are about 10

to 12 weak concentric ribs.

The shell is transparent when fresh. Two oval adductor muscle scars are present; the ventral margin is smooth; and the hinge plate rather narrow. The hinge teeth number three anterior, two posterior in both valves. The resilifer is a short triangular notch beneath the prodissoconch.

Name: Named for the inhabitants of the Yucatan Peninsula.

Material: Holotype. Complete specimen 500 μ long, 380 μ high. USNM No. 758536.

Type locality: Chancanab Lagoon, Cozumel, Quintana Roo, Mexico.

Paratypes: Chancanab Lagoon, depth 2 m. Seven complete, 365, 270, 430, 530, 480, 500, and 480 μ long; one right valve 500 μ long. USNM No. 758536. One 540 μ , one 520 μ , and a right valve 480 μ long, MCZ No. Unknown. One 460 μ , one 520 μ , one 325 μ , and a left valve 500 μ long. ANSP No. 344389. One 460 μ , one 425 μ , and a left valve 445 μ long, AMNH No. 183858. One 500 μ , one 490 μ , one 380 μ , and 510 μ long. DMNH No. 120579. One 490 μ long. Fm (Field Museum) No. 198080.

Five complete specimens ranging from 470 to 510 μ long, and three separate valves ranging from 370 to 465 μ long have been kept by the author.

Arrowsmith Bank, "Gerda" Sta. 899, September 10, 1967, depth 110 to 220 m, two specimens both 520 μ long. UMML No. 28-2810.

Remarks: *C. maya* is clearly closely related to *C. cynthiae*. The chief differences are: in *C. maya* the prodissoconch is not as strongly sculptured, the central knob is weaker, and the dissoconch is

FIG. 1. Interior view of right valve of holotype of *Nucula calcicola*.

FIG. 2. Exterior view of left valve of holotype of *Nucula calcicola*, length for both is 1.74 mm.

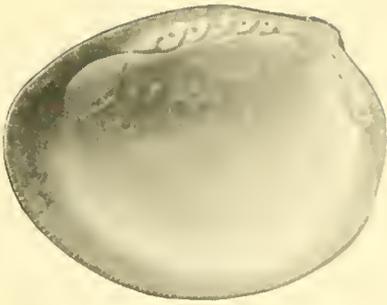
FIG. 3. Interior view of left valve of paratype of *Nucula calcicola*. This was a large specimen, 1.9 mm long, and shows signs of old age, irregular shelly deposits on the interior and strongly developed hinge. This specimen was later lost.

FIG. 4. Exterior view of right valve of holotype of *Condylonucula maya*.

FIG. 5. Interior view of left valve of holotype of *Condylonucula maya*, both 500 μ in length.

FIG. 6. Exterior view of left valve of holotype of *Condylonucula cynthiae*.

FIG. 7. Interior view of right valve of holotype of *Condylonucula cynthiae*, both 600 μ in length.



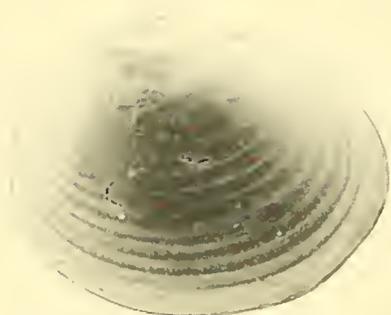
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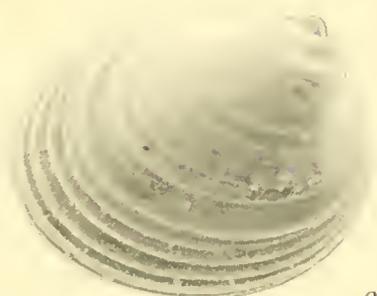
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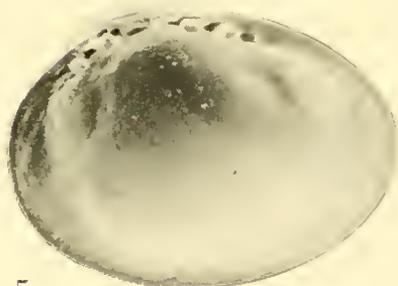
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5



7

New Nuculidae—D. R. Moore (see explanation on opposite page)

more elongate. Two representative adult specimens had the following measurements: (In each case, the percentage refers to the length of the specimen).

	Length	Height	Thickness
<i>C. cynthiar</i>	600 μ 100%	480 μ 80%	380 μ 63%
<i>C. maya</i>	520 μ 100%	390 μ 75%	280 μ 54%

Another comparative feature is the concentric sculpture. It is stronger in *C. cynthiae*, and this species also has fine concentric striae between the ribs.

C. maya is presently known only from Cozumel and Arrowsmith Bank, some 34 km to the NNE of Cozumel. The examples from Cozumel are all from a depth of two m. The Arrowsmith Bank specimens were collected dredging up the steep slope of the side of the bank. They were probably in sediment that poured over the edge of the bank, and, if so, must have been living at a depth of 25 to 35 m.

It is interesting that all known specimens of the two species have been found at atolls or shallow banks, and not on the continental shelf. I have recently examined reef sediment samples from Belize. These samples were taken from continental shelf reefs, and while rich in micro-mollusks, did not contain any *Condylonucula*.

Other species of bivalves slightly less than a millimeter in length have been described. Usually, these descriptions have been based on very scanty material, often dredged, and little has been done since to ascertain whether these are truly mature specimens or only partially grown. The smallest of these appears to be *Cuna gemmula* Turton, 1932, from South Africa described as fully grown at 0.5 mm. There was only one quite transparent valve which was supposed to be quite similar to *C. concentrica* Bartsch, 1915, but not so pointed at the top! It is hardly necessary to point out that the validity of this species is extremely doubtful.

There are signs of maturity to look for in bivalves. These are: thickening of the shell, sunken adductor muscle scars, rugosity of the in-

terior surface, thickening of the hinge line, and, sometimes formation of denticles along the ventral margin. Even with these guides, one must exercise caution, as there is considerable variation in the appearance of the adult from one species to another. It is best to have a series of specimens, preferably from more than one locality, so that morphological changes from sub-adult to adult can be observed. These changes are sometimes dramatic although the maximum dimensions of the shell may be almost unchanged.

SUMMARY

The three species herein described present quite a contrast. *Nucula calcicola* is ubiquitous in the Caribbean and adjacent areas, while the two species of *Condylonucula* appear to be confined to two small areas in the western Caribbean. All three species, however, have only been found in calcareous sediments. Information is usually lacking on ecological requirements of species, but Hampson (1971) has shown that *N. proxima* Say lives in fine to medium quartz sand, and that the similar appearing *N. annulata* Hampson lives in muddy areas.

N. calcicola has been found in back reef to stenohaline inshore areas in quite shallow water. The depth range of the present material is one to 11 m, but live or fresh material has only been found at two meters. *C. cynthiae* has been found only in back reef and lagoonal deposits from one to 7.5 m in fairly coarse sediments. *C. maya* has been found in 2 m in quiet water and at 25 to 35 m (dead material from steep slope). It may well be a deeper water species that shuns the turbulent water of shallow reefs. Chancanab Lagoon, however, provides a quiet environment with oceanic water, and this seems to prove an acceptable niche for *C. maya*. Chancanab sediments are much finer than those in which *C. cynthiae* are found.

The three species have a number of characteristics in common. They are very small (two are the smallest known bivalves), and are rather similar in appearance. They are stenohaline and tropical in distribution. They live in quite shallow water, and in areas with calcareous sediments. Thus their ecological requirements are similar to those of hermatypic reef corals. The

two species of *Condylonucula* especially seem to be confined to a very narrow range of physical conditions. Their very limited geographic range may signify a very brief planktonic larval stage, or none at all.

ACKNOWLEDGMENTS

I would like to thank Gray Multer for the opportunity to collect and study Virgin Island micromollusks. It was because of this material that I started working on the small Nuculidae. I also thank John Milliman for his invitation to take part in the Caribbean Atoll cruise in 1966. Thanks are due to Wayne Bock for sorting part of the Serrana Bank material in which the first two *C. cynthiae* were found. To Jon Staiger, thanks also for the opportunity to participate in the Arrowsmith Bank cruise of September, 1967. To Peter Supko, thanks for two bottom samples from Bermuda. Thanks are also due to Donald Marszalek for bottom material from Belize. I also thank my wife Cynthia for the trip to Cozumel as she discovered the bargain tour that made it possible to visit the island.

Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of this research (PRF No. 5063-AC2). This work was also supported in part by National Science Foundation Grant GB-8684.

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VARICORBULA CHOWANENSIS A NEW SPECIES (BIVALVIA: MYACEA) FROM THE PLIOCENE OF NORTH CAROLINA

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ABSTRACT

Varicorbula chowanensis n. sp. occurs in the late Pliocene deposits along the Chowan River of northeastern North Carolina. This is the first report of the genus in the Neogene Chesapeake Group of Virginia and North Carolina.

Late Pliocene deposits along the Chowan River in northeastern North Carolina contain diverse molluscan assemblages that are indicative of shallow shelf and estuarine environments. Within these assemblages the family Corbulidae is represented by *Caryocorbula inequalis* (Say), *C. cf. conradi* Gardner, and *Varicorbula chowanensis* n. sp. The genus *Varicorbula* has not been reported from well-exposed late Miocene and Pliocene strata of the Chesapeake Group of Virginia and northern North Carolina; however, specimens of *Varicorbula*, labeled *V. caloosae* (Dall), from the Pleistocene Waccamaw Formation of southeastern North Carolina are in the collections of the United States National Museum.

Varicorbula is unique in that it exhibits the inequivalved condition of the Corbulidae to a very high degree. The right valve is extremely convex

and bears coarse concentric rugae. The smaller left valve is flatter and bears concentric growth lines crossed by irregular radial riblets. Yonge (1949) demonstrated that *Varicorbula gibba* (Olivi) lives with the plane of the commissure vertical despite the asymmetry of the valves. He suggests that the large overlap of the valves may allow the animal to compress water in the mantle cavity periodically to expel pseudofeces. The inhalent siphon of *V. gibba* is flush with the sediment surface so that when the clam is actively pumping, large quantities of fine sediment, along with diatoms, bacteria, and organic detritus are carried into the mantle cavity (Yonge, 1949). In order to utilize such a food resource *Varicorbula* needs an effective mechanism to dispose of the sediment accompanying the food. *Varicorbula chowanensis* also lived in bottoms consisting of

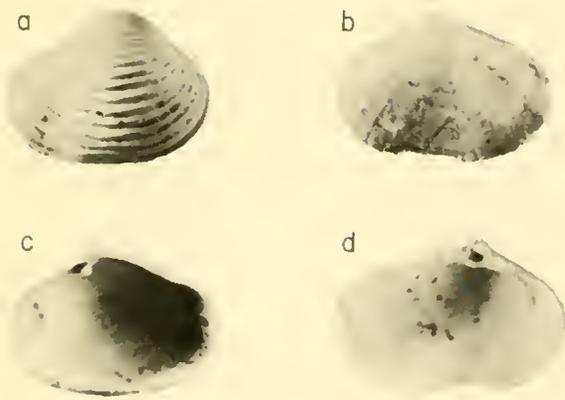


FIG. 1. Exterior of holotype (USNM 241806) of *Varicorbula chowanensis* n. sp., right valve, length 7.2 mm (a); left valve, paratype (USNM 241807), length 6.9 mm (b); interior of right valve (c); interior of left valve (d).

very clayey and silty fine sands. It is likely that the function of the valves hypothesized by Yonge (1949) also operated for the extinct species, *V. chowanensis*.

Family Corbulidae Lamarck, 1818

Genus *Varicorbula* Grant and Gale, 1931

***Varicorbula chowanensis* new species**

(Figs. 1, 2)

Description: Shell small, very strongly inequivalve; right valve convex and inflated with high prosogyrate umbo, rounded anterior, truncate posterior, flat corselet separated from rest of valve by poorly defined posterior diagonal ridge and abrupt anterior turn of concentric ribs; left valve flatter and smaller than right, narrow well defined umbo, rounded low posterior ridge defines irregular corselet, rounded anterior, sub-truncate posterior.

Sculpture of right valve consists of regularly-spaced, rounded concentric ribs, becoming higher and wider near ventral margin; prodissoconch devoid of sculpture. Exterior of left valve with irregular concentric grooves parallel to the growth lines; distinct but frequently irregular growth lines are crossed by faint discontinuous riblets that converge toward the umbo; riblets 3 to 8, with highly variable spacing, and are more distinct on ventral portion of valve.

Interior of right valve with a very faint pallial line and small pallial sinus; with well-developed marginal groove for insertion of left valve; adductor scars small, slightly impressed and closest to dorsal valve margin; single conical cardinal tooth below and slightly anterior of beak; deep subumbonal resilial pit. Interior of left valve shows pallial line; adductor scars poorly-developed; small thick chondrophore immediately beneath and posterior of beak is firmly fused to hinge plate; immediately anterior of chondrophore and beneath beak is a large socket for the cardinal tooth of the right valve.

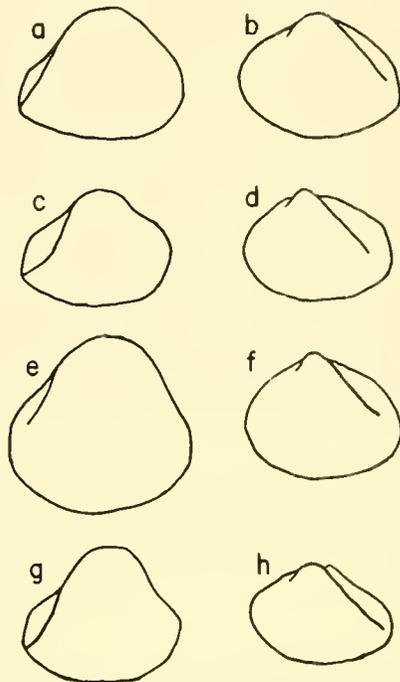


FIG. 2. Valve outlines of Neogene species of *Varicorbula*; *V. caloosae* (Dall), early Pleistocene Caloosahatchee Formation, (a) right valve, length 10.4 mm, (b) left valve, length 8.6 mm, after Olsson and Harbison (1953); *V. chowanensis* n. sp., late Pliocene "Yorktown" Formation, (c) right valve (USNM 241812), length 7.0 mm, (d) left valve (USNM 241815), length 7.0 mm; *V. waltonensis* (Gardner), middle Miocene Shoal River Formation, (e) right valve, length 7.5 mm, (f) left valve, length 6.5 mm, after Gardner (1928); *V. chipolana* (Gardner), lower Miocene Chipola Formation, (g) right valve, length 6.5 mm, (h) left valve, length 5.8 mm, after Gardner (1928).

Measurements

	Valve	H (mm)	L (mm)	No Ribs	No. Ribs ts
Holotype (USNM 241806)	R	5.7	7.2	18	—
Paratypes (USNM 241807)	L	5.0	6.9	—	9
(USNM 241808)	R	6.4	8.4	22	—
(USNM 241809)	R	6.6	8.9	21	—
(USNM 241810)	R	5.1	6.9	21	—
(USNM 241811)	R	5.0	6.6	18	—
(USNM 241812)	R	5.4	7.0	20	—
(USNM 241813)	L	4.4	6.3	—	4
(USNM 241814)	L	5.4	7.8	—	7
(USNM 241815)	L	5.0	7.0	—	6

DISCUSSION

Varicorbula chowanensis is most similar in shape to *V. caloosae* (Dall, 1898). However, it may be distinguished from the latter by its smaller size, more gently sloping anterior and posterior dorsal margins, narrower umbonal region, and its broader, more distinct posterior region (Fig. 2). The *Varicorbula* lineage of the Neogene of the Atlantic and Gulf Coastal Plains is represented by at least four species (Fig. 2). *Varicorbula chipolana* from the lower Miocene Chipola Formation is the earliest reported member of the lineage. The evolutionary relationships of these species remains to be clearly demonstrated.

Type locality: Pliocene deposits along the west bank of the Chowan River, "Yorktown" Forma-

tion, 2.0 kilometers upstream (north) of bridge where U. S. Route 17 crosses Chowan River, Bertie County, North Carolina, locality 27 of Bailey (1973).

Types: Holotype, right valve, USNM 241806, ventral margin partially broken; figured paratype, left valve, USNM 241807, measured and/or figured USNM paratypes, 241808–241815; undesignated paratypes, 3 fragmentary valves. USNM 241816.

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TWO NEW *RABDOTUS* (PULMONATA: BULIMULIDAE) FROM BAJA CALIFORNIA, MEXICO

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ABSTRACT

Two new species of the land snail genus Rabdotus are described from Baja California Sur, Mexico. R. gigantensis is reported from the Sierra de la Giganta and R. laevapex is reported from Isla Cerralvo.

The bulimulid genus *Rabdotus* contains most of the larger land snails of Baja California Sur,

Mexico. Although snails of this genus also inhabit much of mainland Mexico and of the southern

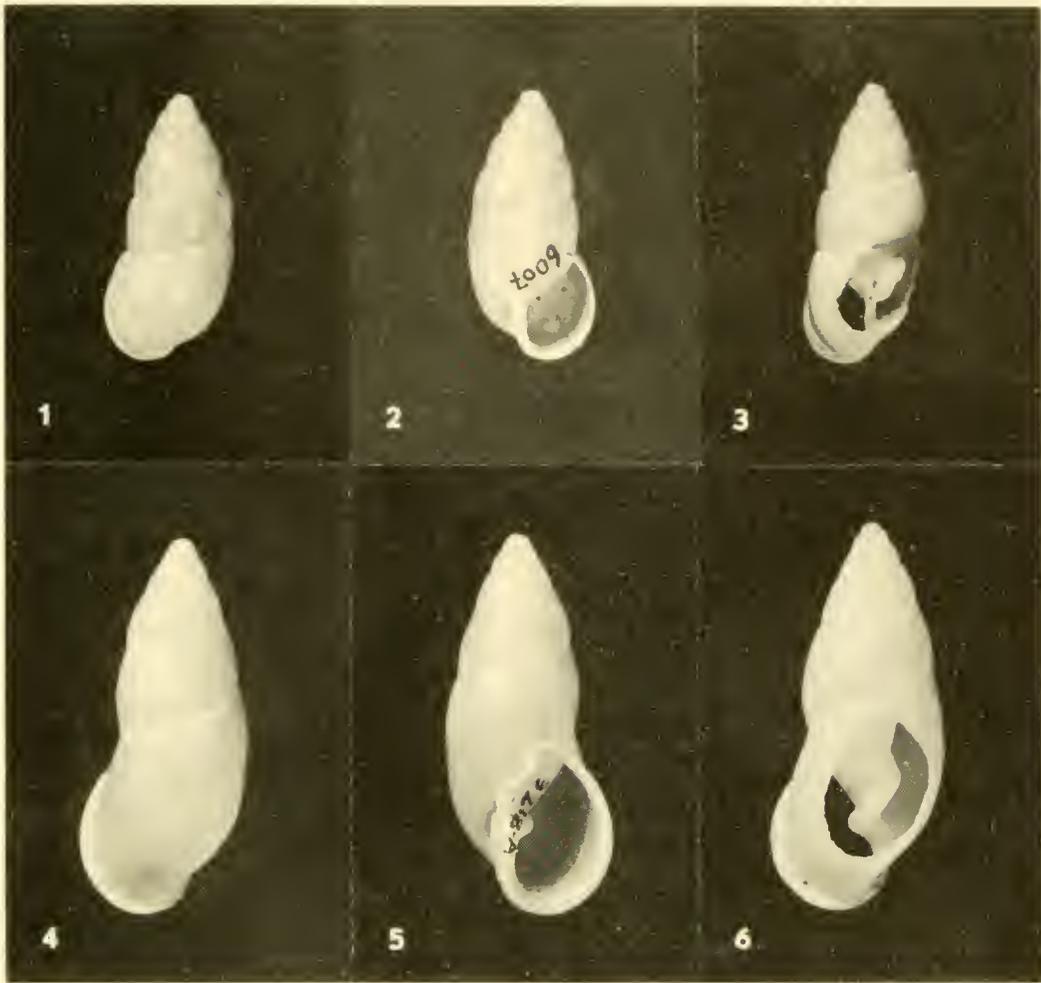


FIG. 1 and 2. *Rabdotus gigantensis* Christensen and Miller, new species. San Javier, Baja California Sur, Mexico. Holotype. CASGTC No. 57937. Shell height 19.7 mm.

FIG. 3. *Rabdotus gigantensis* Christensen and Miller, new species. Shell opened to show columellar lamina. Paratype. CASGTC No. 57944. Shell height 20.5 mm.

FIG. 4 and 5. *Rabdotus laevapex* Christensen and Miller, new species. Isla Cerralvo, Baja California Sur, Mexico. Holotype. CASGTC No. 57942. Shell height 27.8 mm.

FIG. 6. *Rabdotus laevapex* Christensen and Miller, new species. Shell opened to show columellar lamina. Paratype. CASGTC No. 57943. Shell height 28.4 mm.

and southwestern United States, about three quarters of the over thirty known species are confined to the southern half of the Baja California peninsula and nearby islands. This report contains descriptions of two new species from this region, one recorded from several localities in the Sierra de la Giganta, the principal mountain range of the central part of the peninsula, the other known only from Isla Cerralvo, the southernmost island in the Gulf of California.

***Rabdotus gigantensis* Christensen and Miller, n. sp.**

Description. Shell (fig. 1-3) solid, 16.9-21.3 mm in height (mean height of twenty adult shells from type lot 19.2 mm), 7.8-10.2 mm in diameter (mean 8.8 mm), ratio of height to diameter 1.85-2.36 (mean 2.17), ratio of shell height to aperture length 2.18-2.62 (mean 2.44), whorls 5-7/8 to 6-7/8 (mean 6.42); spire convex in outline; embryonic whorls 2 to 2-1/4 in number, rounded,

with strong regular axial riblets the interstices of which are crossed by fine spiral threads; post-nuclear whorls convex, sutures moderately impressed; surface of shell weakly shining, sculpture of early postnuclear whorls of numerous weak growth wrinkles which may bear minute hyphen-like granules arranged in spiral rows, this sculpture becoming obsolete in later whorls; color of shell light brown except peristome and narrow subsutural band sometimes whitish; last whorl slightly inflated, flattened at periphery, often ascending slightly at aperture; columellar margin of peristome reflected, basal and palatal margins weakly reflected, not revolute; terminations of peristome joined by a thin to moderately thick parietal callus; columella with a well-developed sinuous lamina located deep within the aperture; basal region of shell deeply rimate.

Soft parts unknown.

Type Locality. Baja California Sur, Mexico, at San Javier, in a large lava rockslide immediately south of the mission, elevation 350-450 m.

Holotype. California Academy of Sciences Geology Type Collection No. 57937. Height 19.7 mm, diameter 9.3 mm, length of aperture 8.2 mm, whorls 6-5/8. Collected by W. B. Miller, 25 October 1972.

Paratypes. 46 specimens collected by W. B. Miller, 24 October 1971; 53 specimens collected by C. C. Christensen, P. N. D'Eliscu, W. B. Miller, R. L. Reeder, and D. B. Richman, 25 October 1972. Paratypes in the collections of the California Academy of Sciences and Delaware Museum of Natural History (No. 112458) and in the private collections of R. L. Reeder and the authors.

Additional Paratype Material. Specimens have been examined from the following additional localities in Baja California Sur: inland of San Jose de Magdalena on the road to Guadalupe, 43.3 km west of the Transpeninsular Highway, C. Church, 11 December 1970; 11.3 km north of San Jose Comondu, C. Church, November 1969; San Jose Comondu, R. J. Drake, July 1953, and V. Roth, 15 February 1966; 1.0 km east of San Javier, C. Church, 11 December 1970; 15.7 km west of San Javier on the road to Santo Domingo, C. Church, 12 December 1970; 72.4 km south of Loreto and 49.9 km northeast of Villa Insurgentes on Transpeninsular Highway, in lava

rockslides on south side of arroyo, elevation 275 m, W. B. Miller, 23 October 1971; road between El Obispo and Rancho Tinajitas, I. L. Wiggins, 20 November 1959.

Remarks. *Rabdotus gigantensis* is distinguished by its small size, weakly reflected peristome, columellar lamina, and coloration. *R. levis* (Dall) is similar in overall dimensions and form but lacks a columellar lamina; its shell is usually marked with dark axial streaks. *R. dentifer* (Mabille) and *R. chamberlini* (Hanna) are small snails each with a columellar lamina but with the peristome strongly reflected or revolute.

Rabdotus gigantensis is most often found in large talus slides of volcanic rock and is known to occur over nearly the entire length of the Sierra de la Giganta. Although dead shells of this species are common in some localities, no living specimens have yet been collected.

The species is named for the mountains in which it lives.

Rabdotus laevapex Christensen and Miller, *n. sp.*

Description. Shell (fig. 4-6) solid, 24.8-28.6 mm in height (mean height of eight adult shells from type lot 27.7 mm), diameter 11.8-13.4 mm (mean 12.6 mm), ratio of height to diameter 2.10-2.29 (mean 2.19), ratio of shell height to aperture length 2.08-2.25 (mean 2.18), whorls 5-7/8 to 6-3/8 (mean 6.12); spire weakly convex in outline; embryonic whorls not readily distinguishable from postnuclear shell; first two whorls rounded, smooth or with subobsolete axial wrinkles; later whorls convex, sutures weakly impressed, surface of shell shining or dull, sculpture of weak growth wrinkles; color of shell light brown except peristome and narrow subsutural band sometimes whitish, shell sometimes with light axial streaks; last whorl inflated, rounded at periphery, not ascending or descending at aperture; columellar margin of peristome reflected, basal and palatal margins reflected and revolute; terminations of peristome joined by a thin white or clear parietal callus; columella with a strong spiral lamina which is prominently visible within the aperture; basal region of shell deeply rimate.

Pulmonary veins and pallial roof between veins and hindgut light brown; mantle not marked with dark spots.

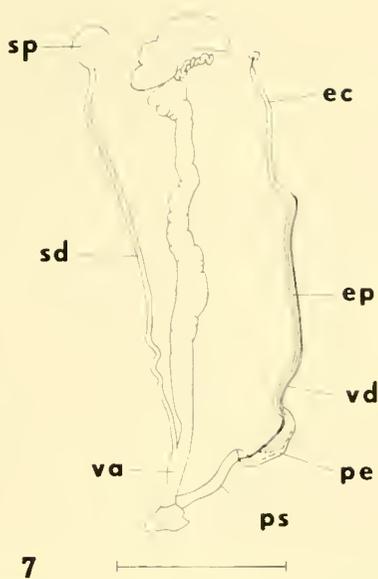


FIG. 7. *Rabdotus laevapex* Christensen and Miller, new species. Genitalia of holotype. Abbreviations: ec epiphallic caecum; ep epiphallus; pe upper portion of penis; ps penial sheath and lower portion of penis; sd spermathecal duct; sp spermatheca; va vagina; vd vas deferens. Scale line 10 mm.

Genitalia (fig. 7) typical of the genus in general structure, epiphallus usually greater in length than penis or epiphallic caecum, comprising over 40% (average of 6 specimens) of the combined length of these three structures; penis and epiphallic caecum approximately equal in length, vagina much shorter than penis; dimensions of genitalia of holotype (figured): penis 9 mm in length, epiphallus 16 mm, epiphallic caecum 9 mm, vagina 3 mm, spermathecal duct 26 mm.

Type Locality. Baja California Sur, Mexico, on west side of Isla Cerralvo, approximately 0.5 km inland of the beach at El Limofia anchorage, in a small rockslide on the south slope of a narrow arroyo, elevation 50-100 m. Living snails were found sealed to small rocks.

Holotype. California Academy of Sciences Geology Type Collection No. 57942. Height 27.8

mm, diameter 12.2 mm, length of aperture 12.8 mm, whorls 6. Collected by C. C. Christensen, 8 August 1974.

Paratypes. 7 adult and 5 immature specimens collected with the holotype. Paratypes in the collections of the California Academy of Sciences and Delaware Museum of Natural History (No. 112457) and in the private collections of the authors.

Remarks. The sculpture of the embryonic whorls is the outstanding character of *Rabdotus laevapex* and distinguishes it from all other members of the genus. In other *Rabdotus* these whorls bear regular axial riblets; in *R. laevapex* these are smooth or bear only weak wrinkles which do not resemble the riblets of other species. This condition is not the result of wear, as it is found in the shells of live-collected immature specimens of 2-1/2 whorls. The name assigned to this species refers to its smooth apex.

Although the shells of *Rabdotus lamellifer* (Pilsbry), *R. rimatus* (Pfeiffer), and *R. spirifer* (Gabb) resemble that of *R. laevapex* in size and general form, these species differ from the new species anatomically; in each of them the penis is greater in length than either the epiphallus or epiphallic caecum, and the length of the vagina is more nearly equal to that of the penis than is the case with *R. laevapex*.

ACKNOWLEDGMENTS

We wish to thank the individuals named above who collected specimens used in this study and Mr. Barry Roth of the California Academy of Sciences for the loan of material, as well as Dr. D. A. Thomson of the University of Arizona and Sr. Felipe Maldonado, captain of the yacht *La Sirena*, who provided transportation to Isla Cerralvo. We also wish to thank Judith A. Christensen for assistance with the preparation of the figures which accompany this report.

STUDIES ON FOULING INVERTEBRATES IN THE INDIAN RIVER, FLORIDA 2: EFFECT OF *MODULUS MODULUS* (PROSOBRANCHIA: MODULIDAE)

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ABSTRACT

*The buildup of fouling invertebrates on tiles placed among seagrass blades is considerably less than on tiles placed in adjacent areas devoid of seagrass. Snail counts and the results of caging experiments suggest that the grazing action of *Modulus modulus* may retard the buildup of fouling organisms on surfaces within the grass beds.*

Observations on fouling patterns on the Indian River lagoon of eastern Florida indicate that the accumulation of fouling invertebrates on tiles placed among seagrass blades is considerably less than on tiles placed in adjacent areas devoid of seagrass. The processes responsible for this are not known but the following mechanisms were suspected: (1) large predators may graze more actively among the grass blades (a large predator is operationally defined here as one which cannot go through a 12 mm mesh); (2) rubbing of grass blades on the tiles due to wave action may mechanically remove newly settled organisms; and (3) survival of newly settled fouling organisms may be affected by small animals such as *Modulus modulus* Linné, 1758, a snail that often is found locally on grass blades.

The research presented in this paper was designed to experimentally test whether any of these mechanisms are responsible for the retardation of fouling in the grass beds.

MATERIALS AND METHODS

The study area was located in a seagrass bed north of Link Port on the west bank of the Indian River lagoon near Fort Pierce, Florida (31.1°27' N; 20.9°80' W) (Young *et al.*, 1976). The site consisted of subtidal dense stands of *Halodule wrightii* Ascherson, 1868, interspersed with large sandy patches devoid of grass. Small stands of *Thalassia testudinum* Konig, 1805, were occasionally present.

The experimental fouling substrata were 15 cm by 15 cm Italian quarry tiles bolted to 50 cm lengths of 2.4 cm (½ inch) PVC (polyvinylchloride) pipe pushed into the sediment. The bottom edge of each tile was about 1 cm above the sediment surface. Treatments are listed in Table 1. Each treatment consisted of five replicate tiles. Treatment results were compared using Student's-t test. To determine the effect of large predators, some tiles were set in cages constructed of 12 mm mesh (½ inch hardware cloth), measuring 2 m on a side. In order to test abrasion effects of grass on fouling accumulation, some tiles were set in 2 m by 2 m caged and uncaged areas from which grass blades were cut at the level of the sediment surface.

Specimens of *Modulus modulus* were counted four times (Table 1) in October and November 1976 from the smooth side of each tile. Three counts were made during the day and one count was made at night. The amount of fouling was determined by scraping all accumulated growth

TALBE 1. Comparison of average dry weights of accumulation of fouling organisms and average numbers of *Modulus modulus* on tiles subjected to various treatments.

Treatment	Average dry wt (grams)	Average number <i>Modulus modulus</i>
uncaged, in grass	0.84	3.20
caged, in grass	1.08	2.70
uncaged, sand patch	11.42	0.15
caged, sand patch	40.80	0.15
caged, in clipped grass	2.30	4.40



FIG. 1. Rack used to hold Italian quarry tiles. The screen has been removed to show more clearly the rack's structure. Ruler is 33 cm in length.

from the smooth side of each tile, drying the scrapings at 80° C for 72 hours and weighing them.

The effect of *Modulus modulus* on fouling was tested by placing five tiles in each of two fouling racks (Figure 1). Both these racks were covered with nylon window screening (1 mm mesh). One hundred specimens of *M. modulus* were placed in one rack and the other was kept free of this species for a control. The racks were suspended at a depth of 0.5 m from a float at the Harbor Branch Foundation laboratory for about six weeks (7 March 1977 – 22 April 1977). Screens were scrubbed with a brush every two days to prevent fouling organisms from clogging the screens. Coverage by fouling organisms was measured by recording all fouling organisms that occurred at each of 80 random points (Greig-Smith, 1964) on the smooth side of the tile. Points that contained no fouling were also enumerated in order to quantify uncolonized space on the plates.

RESULTS

The dominant fouling animals in the grassbeds consisted of *Balanus eburneus* Gould, 1841, *Balanus amphitrite* Darwin, 1854 and *Spirorbis* sp. These are common fouling species in the In-

dian River (Mook, 1976). Accumulation of fouling organisms was significantly ($p < .01$) higher ($t = 6.2610$) on tiles set within the sand area than on tiles set in the grass area (Table 1). In the sand patch, the tiles within the cage had significantly ($p < .01$) more fouling ($t = 4.85$) than tiles outside the cage, whereas no significant differences were found between caged and uncaged tiles within the grass bed in either clipped ($t = 1.6485$) or unclipped ($t = 0.4878$) areas. These differences suggest that large predators are probably important grazers of fouling organisms outside the grass but their role may be limited within the confines of the grass bed itself, at least when the fouling communities are relatively young. The identity of the predators was not determined; however, the sheephead, *Archosargus probatocephalus* Walbaum 1792, an abundant fish in the Indian River (Gilmore, 1977), is known to prey on some fouling organisms (Mook, 1977).

No significant difference in fouling accumulation was recorded between tiles in clipped and unclipped areas ($t = 1.849$) (Table 1), indicating that the mechanical abrasion of grass blades rub-

TALBE 2. Comparison of average number of points out of 80 occupied by various fouling animals on tiles placed in racks with and without *Modulus modulus*. "No organisms" indicates average number of points without any fouling animals present. Average number of species is also compared. Each rack contained five tiles.

Organism	With <i>Modulus</i>	Without <i>Modulus</i>	t
<i>Diplosoma macdonaldi</i> Macdonald, 1859 (T)**	24.6	47.2	7.59*
<i>Perophora viridis</i> Verrill, 1871 (T)	1.0	7.2	2.58*
<i>Bugula neritina</i> Linne', 1758 (E)	3.6	10.2	1.80(ns)
<i>Coropecum tenuissimum</i> Cann, 1908 (E)	2.6	10.4	4.71*
<i>Spirorbis</i> sp (P)	.06	0.4	0.30(ns)
<i>Conophium tubes</i> (A)	0.0	11.4	10.16*
<i>Balanus</i> sp (B)	0.0	1.0	2.24(ns)
"No organisms"	49.2	15.2	9.69*
Average species number	3.6	5.8	3.77*

* Significant to 0.05 level

** T = tunicate, P = polychaete, E = ectoprocta, A = amphipod, B = barnacle.

bing across tile surface has no discernable effect on settlement of fouling organisms.

There were significantly ($p < .01$) greater numbers of *M. modiolus* on tiles within the grass bed than on those outside the grass bed ($t = 4.5905$) (Table 1). A negative correlation exists between the number of snails found on the tiles and the amount of fouling ($r = 0.71$). These observations suggest that grazing by *M. modiolus* may retard the accumulation of fouling. When specimens of *M. modiolus* were placed in screened fouling racks, the amount of fouling buildup by most species was reduced (Table 2).

Dissections of a few *Modiolus* stomachs revealed a small crystalline style and diatom tests, an indication the *Modiolus modiolus* probably is a herbivore, feeding on the epiphytic algae and detritus which accumulates on surfaces within the grass beds (Houbrick, personal communication). The grazing action of *Modiolus modiolus* probably also dislodges newly settled larvae of fouling organisms, thus retarding the development of fouling. These mechanisms may also aid in keeping the surfaces of seagrass blades clear of fouling.

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SEASONAL CHANGES IN REPRODUCTIVE ACTIVITY AND BIOCHEMICAL COMPOSITION OF THE FINGERNAIL CLAM, *SPHAERIUM TRANSVERSUM*

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ABSTRACT

The life span of Sphaerium transversum in Louisiana is about one year. Mature adults are reproductively most active during winter (30-40 young/adult) and least active during the summer (0-12 young/adult). During the height of reproductive activity 60-70% of the adult dry tissue mass is developing juveniles retained in the branchial chamber. There is a seasonal cycle of tissue protein and carbohydrate content, which correlates directly with reproductive activity.

The fingernail clams of the family Sphaeriidae have been studied extensively in terms of life

histories, reproduction and growth (Foster, 1932; Van Cleave et al., 1947; Thomas, 1959; Heard,

TABLE 1. Seasonal variation in size and reproductive activity in *Sphaerium transversum*.

Month	Sample Size	Adult Weight mg	Juveniles	
			Number	C I ^a
April 1974	10	300.4 ± 20.1 ^b	16 ± 3	2.6 ± 0.3
May	10	354.4 ± 14.3	23 ± 1	3.1 ± 0.4
June	10	232.8 ± 16.5	12 ± 1	1.8 ± 0.3
July	10	198.8 ± 9.6	7 ± 2	1.2 ± 0.3
August	10	106.9 ± 12.2	9 ± 2	1.2 ± 0.3
September	8	58.5 ± 3.0	5 ± 1	0.5 ± 0.1
October	9	147.6 ± 11.9	13 ± 2	1.5 ± 0.4
November	-	-	-	-
December	10	330.0 ± 29.9	27 ± 2	2.4 ± 0.3
January	10	327.8 ± 31.9	29 ± 4	1.9 ± 0.3
February	10	410.6 ± 46.5	38 ± 5	2.1 ± 0.2
March	10	352.9 ± 32.6	30 ± 2	2.8 ± 0.2
April 1975	10	339.9 ± 47.4	26 ± 3	2.0 ± 0.3

a Component index = mg dry/100 mg entire animal wet weight

b Mean ± standard error of mean

1964, 1965). Many sphaeriids have been noted to have a life span of one year (Foster, 1932; Heard, 1965). However, there have been no attempts to determine the biochemical changes associated with the growth, maturation and reproductive activities of fingernail clams. The small size of many of these species is probably an important factor in the relative absence of physiological information. *Sphaerium transversum* (Say), however, attains a size of 16 mm in length and up to 500 mg in total wet weight. The local abundance of this species and its rapid growth and maturation make it a good experimental animal and offer some insight into the seasonal changes of its reproductive activity and biochemical composition.

MATERIALS AND METHODS

Sphaerium transversum were collected from Bayou Manchac at its intersection with U. S.

Highway 61 south of Baton Rouge from April 1974 to April 1975. The animals were collected by dip net and the largest members selected and transported to the laboratory out of water in order to prevent release of juveniles from the branchial chamber. Data were obtained from the animals within several hours after collection. Each animal was blotted dry and its entire weight recorded. Ten animals were opened and developing juveniles having shells were separated, counted and then dried at 85° C to obtain dry juvenile weights. Ten additional animals were opened and the soft tissue transferred to a test tube. Soft tissue and shells were dried overnight at 85° C. The dry tissue was digested with 0.5 ml 20% KOH at 100° C for 30 min. The digest was diluted with distilled water and total carbohydrate was determined colorimetrically by a phenol-sulfuric acid method (Montgomery, 1957). The alcoholic precipitation of glycogen was

eliminated since the direct analysis agreed ($\pm 4\%$) with the recovered precipitate. Total tissue protein was determined by the method of Lowry et al. (1951). Component indices were determined by dividing the dry weight of the component by the entire wet weight of the animal and multiplying by 100 (Stickle, 1975). All data are expressed as the mean \pm one standard error of the mean with the number given in parentheses. Voucher specimens are deposited in the Delaware Museum of Natural History (No. 102016).

RESULTS AND DISCUSSION

The life span of *S. transversum* in Bayou Manchac is about one year. The adults die off during the spring and summer leaving a population of new young by late summer (Table 1). In September 1974 the larger animals averaged 50-60 mg total weight and a maximum length of 8.4 ± 0.2 (N=10) mm. All of these animals were reproductively active. The smallest size range of adults that contained embryos with shells was 5.5-6.5 mm in length. Almost all adult *S.*

transversum have developing embryos of from 0.1-0.2 mm in length which are enclosed in a membranous sac or brood pouch in the branchial chamber (Thomas, 1959). The number of embryos within a brood pouch is variable, ranging from 20 to 30. These early-stage embryos were not among those counted unless a fully developed shell was evident. Adult *S. transversum* are apparently reproducing continuously. As the adults grow during the fall and winter the number of developing young, retained in the branchial chamber, increases to a maximum of about 60. Each mature adult was observed to have three arbitrary categories of young within the branchial chamber. 1) Young juveniles with shells which were contained in a brood pouch. These small juveniles were less than 0.5 mm in length with an average dry weight (at the limit of measurement) of 0.05 ± 0.01 (N=8) mg. 2) Juveniles of larger size (0.5-1.5 mm) which were free in the branchial chamber. 3) Those juveniles just prior to release (2-3.5 mm) that obtained a maximum total dry weight of 1 mg. Although the largest

TABLE 2. Seasonal variation in size and component index in *Sphaerium transversum*.

Month	Adult Weight mg	Component Index (mg dry/100mg entire animal)				
		Shell	Tissue	Water	Protein	Carbohydrate
April 1974	308.4 \pm 17.3 ^a	16.9 \pm 0.4	4.4 \pm 0.2	78.7 \pm 0.4	1.1 \pm 0.0	0.9 \pm 0.1
May	348.4 \pm 15.9	15.9 \pm 0.2	5.1 \pm 0.3	79.0 \pm 0.3	1.3 \pm 0.1	0.8 \pm 0.1
June	321.5 \pm 17.0	15.5 \pm 0.6	3.4 \pm 0.3	81.1 \pm 0.7	1.0 \pm 0.1	0.4 \pm 0.1
July	215.5 \pm 7.0	15.5 \pm 0.3	3.9 \pm 0.2	80.6 \pm 0.4	1.2 \pm 0.1	0.4 \pm 0.1
August	64.2 \pm 5.3	13.3 \pm 0.7	5.0 \pm 0.4	81.7 \pm 0.6	1.0 \pm 0.2	0.4 \pm 0.1
September	51.6 \pm 3.1	18.3 \pm 0.7	3.8 \pm 0.5	77.8 \pm 0.6	0.8 \pm 0.2	0.3 \pm 0.1
October	121.5 \pm 9.4	18.0 \pm 0.5	8.8 \pm 0.4	73.2 \pm 0.6	1.4 \pm 0.1	0.5 \pm 0.0
November	236.7 \pm 16.2	16.9 \pm 0.9	4.3 \pm 0.2	78.8 \pm 0.9	1.6 \pm 0.1	1.0 \pm 0.0
December	256.4 \pm 16.4	20.0 \pm 0.9	5.6 \pm 0.3	74.4 \pm 0.8	1.6 \pm 0.1	0.6 \pm 0.1
January	250.6 \pm 11.5	18.1 \pm 0.5	4.9 \pm 0.4	77.0 \pm 0.6	1.3 \pm 0.1	0.6 \pm 0.0
February	427.3 \pm 14.0	19.1 \pm 0.8	3.7 \pm 0.2	77.4 \pm 0.9	1.1 \pm 0.0	0.7 \pm 0.0
March	281.8 \pm 16.9	19.0 \pm 0.2	4.1 \pm 0.4	76.9 \pm 0.4	1.1 \pm 0.1	0.6 \pm 0.1
April 1975	444.0 \pm 33.0	17.5 \pm 0.6	2.3 \pm 0.2	80.2 \pm 0.5	0.5 \pm 0.0	0.2 \pm 0.0

a Mean \pm standard error of mean, sample size was 10 animals.

juveniles probably had fully developed gonads, they did not have embryos (Gilmore, 1917).

The juvenile component index (CI) is an estimate of the magnitude of reproductive activity in the adults (Table 1). During the height of reproductive activity the juvenile CI is about 3 mg dry weight/100 mg total animal weight. More revealing, however, is a comparison between juvenile CI and adult tissue CI. Of the adult dry tissue, during the winter months, 60-70% is due to the combined weights of the developing juveniles (see Tables 1 and 2). In April 1975 the juveniles accounted for 87% of the total adult dry tissue. This suggests that the majority of the adult activities are devoted to reproduction, ultimately leading to the death of the adult (Heard, 1965).

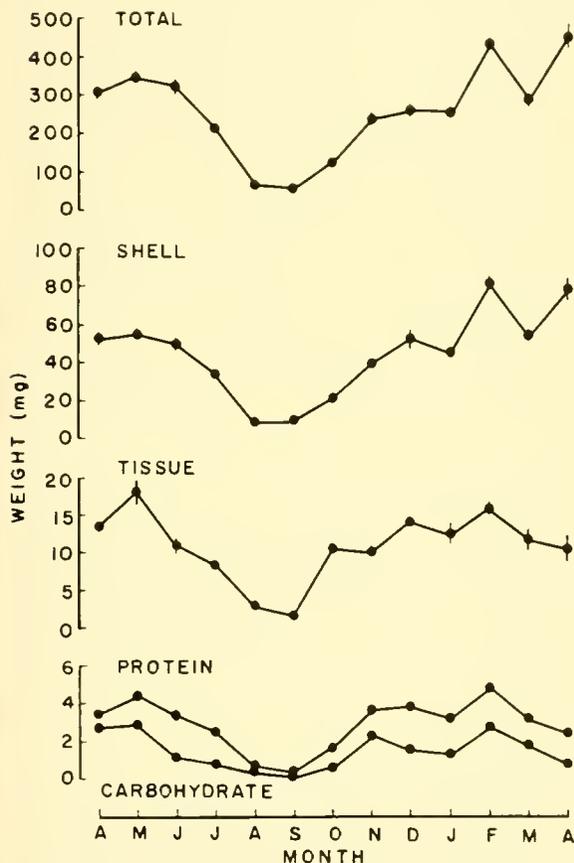


FIG. 1. Seasonal changes in weight of *Sphaerium transversum*. Each vertical line represents one standard error of the mean.

Physical factors also may be contributing to the adult die-off during the summer months. The average dissolved oxygen measured by Winkler titration during July - September 1974 was low (0.6 ppm O₂). In addition the surface water temperature during the summer averaged 28° C.

Table 2 shows the seasonal changes in entire weights and component indices of the reproductively active animals. The decline in weight in the summer of 1974 is probably due to the increasing death rate of the adult population. Although we cannot rule out adult emigration to deeper water or burrowing, it is unlikely (Horst and Costa, 1975; Gale, 1976). Free-living young sphaeriids display a rapid weight gain during the first months after release (Mackie *et al.*, 1976). This period of growth is evident in *S. transversum* during the fall months (Fig. 1). The average shell length in February 1975 was 13.5 ± 0.5 (N=10) mm with a maximum length of 16.4 mm. Tissue weight increased most rapidly during October. Part of the increase was due to protein and carbohydrate synthesis. Most of the increase was due to unmeasured variables: lipid deposition, associated with gonad development, and/or an inorganic component.

Although the animals vary in weight during the year, the shell and water component indices are relatively uniform. There is a significant ($P < 0.05$) decrease in shell CI in August; however, the meaning is obscure. It is possible that there is allometric shell deposition in *S. transversum* as noted in other bivalves (Joy and McCoy, 1975). Total protein and carbohydrate CI show a positive correlation with reproductive activity during the fall and winter. Carbohydrate and protein CI also show a decline towards the end of the reproductive season. The decrease in protein and carbohydrate content may reflect the deteriorated condition of the adults which can be more readily observed only when large numbers of juveniles have been released. Protein and carbohydrate were not expressed as a function of dry tissue weight in Table 2 because a significant and seasonally variable amount of "adult tissue" was actually developing juvenile tissue and shell. The juveniles could not be separated from the adult tissue without loss of adult tissue. The quantity of tissue carbohydrate (6-23% of dry tissue) is

similar to those reported for other molluscs (Calvin, 1931; Webber, 1970; DeZwann and Zandee, 1972; Badman and Chin, 1973; Dietz, 1974). Protein content in the dry tissue ranged from 16 to 37%. The protein to carbohydrate ratio of about 2 also is similar to other bivalves (Ansell *et al.*, 1964; Ansell and Trevallion, 1967; Dietz, unpublished observation).

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INTRODUCED LAND SNAILS OF TRAVIS COUNTY, TEXAS

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Currently a survey of the land snails of Travis County, Texas, has turned up ten non-native land snails. Only one of these, *Rumina decollata*, has been previously reported in this county. Report of

the other nine species has only been in a simple preliminary checklist (Neck, 1976b). Previous records exist for all these species in other parts of Texas (see Dundee, 1974).

Helicidae

Helix aspersa Müller. Native of western and southern Europe. This species has been found in several home gardens in the Austin residential areas. This species is known as the European Brown Snail or European Spotted Snail. Occurrence is spotty; populations are characteristically of low density and restricted to urban areas. *H. aspersa* is widespread in California but invasion of natural areas is quite restricted due to the annual summer drought (Potts, 1975). Frequently hot, dry summer months in central Texas are a severe obstacle to the establishment of thriving populations of this species in other than artificial garden habitats.

Otala lactea (Müller). Native of southern Spain and northern Africa. Individuals of this species are known from home gardens as well as self-sustaining feral colony which contained both banded and unbanded snails. Banded snails have very dark brown, distinctive bands. Individuals of this feral colony were commonly seen estivating on the trunks of mesquite, in the same manner as *Rabdotus alternatus* Say (as illustrated by Pilsbry, 1946:2(1): p. 5, fig. 2). Individual snails in gardens are relatively common but probably represent short-lived occurrences. Self-sustaining colonies may exist in small (one-fourth acre) plots in urban areas. This species is known as the Milk Snail or Spanish Snail (Dundee, 1970).

Otala vermiculata (Müller). Native of the Mediterranean area. In Travis County this species is known only from a single urban residential locality. Feral colonies undoubtedly could survive as one such colony is known in Bastrop. Bastrop County, Texas, approximately thirty miles south-southeast of Austin. All shells seen have been banded; bands vary in their distinctness from light background color.

Limacidae

Lehmannia poirieri (Mabille). Native of western and southern Europe. Extremely dense populations of this slug occur in urban garden areas which receive supplemental watering. With one exception, it is unknown in rural areas. This population occurs on a seepage slope in the flood-

plain of Onion Creek. Urban natural areas appear able to support only smaller population levels.

Limax flavus Linnaeus. Native of temperate Europe. This slug is much less commonly encountered than the preceding species. Although Pilsbry (1948: 529) described this species as a "slug of cultivated places," most Austin localities of *L. flavus* are semi-natural islands in urban areas. In fact, *L. flavus* is more likely to be found in semi-natural urban islands than *L. poirieri* although this latter species is much more common on an overall scale.

Milax gagates (Draparnaud). Native of western Europe including Britain and Ireland. This slug is rarely encountered and has been found only along the banks of watercourses and urban garden situations. Only a single collection (and that one an urban garden) is known since before the short but severe drought of 1970-71. Feral populations of this species should be considered perilous although areas of previous collection do not receive supplemental water. Even in the moist Pacific Northwest of North America, e.g. British Columbia, *M. gagates* is generally associated with greenhouses (see references in Rollo and Wellington, 1975).

Polygyridae

Polygyra septemvolva volvoxis Pfeiffer. Native to southeastern and coastal Texas and other coastal plains areas outside the state. In Travis County, this species has not been found under natural conditions; two localities are known—a greenhouse and a residential backyard which contained potted plants from this greenhouse. The nearest natural occurrence reported is Burleson County (Pilsbry 1940: 1(2):591. The Travis County population originated from Cameron County. This species is most common in warm, humid coastal areas. No successful reproduction was observed in the residential locale. Travis County may be too cold and/or dry for this species to survive under natural conditions.

Achatinidae

Rumina decollata Linnaeus. Native of southern Europe and northern Africa. This is by far the

most abundant non-native snail in Travis County as well as much of the southern United States (Dundee, 1970). This species is probably the most familiar snail for most of the general public, because it is the most abundant urban snail in Austin. *R. decollata*, however, is also able to colonize rural areas via downstream transport. It is the only non-native snail species commonly found in rural areas.

The first literature report of this species in Travis County was by Strecker (1935:23). Suhm (1957) reported that this species had burrowed into sediment at the Smith Rockshelter, a famous archeological site in southeastern Travis County. Branson (1959) later reported it from Zilker Park, an Austin municipal park. It has also been reported from Austin Caverns (cave now used as a storm sewer) and the Barton Springs archeological site (in Zilker Park) by Reddell (1965).

Approximate time of introduction of *R. decollata* in this area can be determined. The publication by Strecker (1935) appeared posthumously following Strecker's death in January 1933; therefore, initial Travis County collections were made no later than 1932. The time of initial introduction into Travis County is unknown, but it is probably no earlier than the late 1880's as Singley (1893) did not record this species from the state. Introduction probably came later, as Pilsbry (1905) reviewed the world range of this snail but did not list any collections from Texas. The first Texas report of this species was by Camp (in Ferriss 1914) from Brownsville. No other Texas localities were mentioned although Ferriss compared the Brownsville specimens to those in his collection from Louisiana and South Carolina. At this point, arrival in Travis County would most likely have been between 1915 and 1932.

Archeological investigations of historic sites of the last and early twentieth centuries are potentially important sources to pinpoint when *R. decollata* became established in various areas. However, there is an inherent problem. Even if the layer from which the deepest shells are found could be dated accurately, the burrowing habit of this snail would complicate the situation. In Travis County alone, this species has been found in several archeological excavations of pre-

European sites (see references in first paragraph). Estimates of time of arrival of this snail would most likely be on the early side.

Opeas pyrgula Schmacker & Boettger. Native of Japan and China. This small snail has been found living in two residential localities. Some individual dead shells have been found in urban natural areas which are downstream from residential areas. These shells indicate further urban colonies. No feral colonies have been established by such downstream dispersal of living snails, however. Colonies observed occur in areas protected from cold winter winds and dry, hot summer weather conditions.

Ceciloides acicula (Müller). Native of central and western Europe. This minute species is known from the banks of a creek running through a residential area. Only a single living specimen was found, but this blind species is generally subterranean in habit (Pilsbry, 1909) which would reduce collecting chances. This species has been reported feeding on grass roots to a depth of 40 cm while preferring "soils rich in lime" (Likharev and Rammalmeier, 1952). Report of this snail in Travis County at this locality has been previously mentioned (Neck 1976a). No subsequent collections have been made, even at the original collection site.

CONCLUSIONS

Introduced snails may occur in rural, urban natural or residential areas. A species occurring in a residential area may be totally dependent upon human activities for maintenance of a viable population. Occurrence in urban natural islands indicates an ability of the species to survive under natural conditions. Occurrence in rural natural areas would indicate an ability to colonize new habitats on their own.

Significantly, the most successful non-native snail of Travis County, Texas, *R. decollata*, is from the Mediterranean area. Central Texas does not have a Mediterranean-type climate, but the summers are often very dry. *R. decollata* is well-adapted to survive arid periods. The ability to produce offspring parthenogenetically (Selander, et al., 1974) is also very important in its ability to rapidly populate newly colonized areas.

Non-native snails are introduced by a variety of means, either accidentally on ornamental plants or deliberately as fish bait. Almost all of the introduction to Travis County were probably accidental. The feral colony of *Otala lactea* could have been a deliberate introduction.

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THREE NEW PULMONATE GASTROPODS FROM THE LATE TERTIARY OF NEW MEXICO

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In the course of geological and paleontological studies of late Cenozoic deposits in northeastern New Mexico, with a colleague, Dr. John C. Frye, and under the auspices of the New Mexico Bureau of Mines and Mineral Resources, a molluscan fauna comprising some 27 species was discovered in the Kimball seed zone (Ogallala Formation, late Pliocene) sediments. Molluscan fossils in the Ogallala Formation are rare, and well-preserved shells even more so. The shells occur in caliche-cemented, fine sand, however, and shells suffered some damage in the recovery process. Among the shells discovered in the deposit

are three kinds judged to undescribed taxa. Their descriptions follow.

Type Locality: Late Pliocene deposits exposed in a small draw, tributary to Sand Draw, about 100 yards east of N. M. State Highway No. 18, and about 8 miles south of the junction of N. M. 18 and U. S. Highway 65 in Clayton, Union County, New Mexico, and situated in the SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 2, Twp. 24 N, R 35 E, Union County, N. M., Lat. 36° 20' 14" N., Long. 103°, 09' 31" W. in an exposure known as the Clayton South Section. The types are deposited in the New Mexico Bureau of Mines and Mineral Resources, Socomo, N. M.



FIGS. 1-3. *Holotypes*, Fig. 1, *Lymnaea claytonensis*, *n. sp.*, $\times 5$. Fig. 2, *Gastrocopta debilis*, *n. sp.*, $\times 10$. Fig. 3, *Gastrocopta arena*, *n. sp.*, $\times 10$. *Magnifications approximate.*

Lymnaea claytonensis, *n. sp.*

Fig. 1

Diagnosis: A slender lymnaeid shell, having 5 to 6 rounded whorls, shouldered above, and having a laterally compressed, elliptical aperture, occupying about one-half the total length of the shell.

Description of holotype: Shell of slender lymnaeid form; whorls a little more than 5 in number, rounded and somewhat shouldered; suture well-impressed, slanting obliquely forward; aperture elliptical, outer peristome simple and thin, parietal wall adnate upon body whorl, and twisted upon the umbilicus reducing that opening to a narrow chink; nuclear $1\frac{1}{2}$ whorls having granular surface, remaining whorls with distinct, slightly oblique, vertical ridges, crossed by fine spiral lines, producing a satinlike surface texture; total length, 7.0 mm, diameter, 2.80 mm, aperture length, 3.64 mm, aperture width, 2.10 mm.

The specific name, *claytonensis*, derives from the name of the section, in turn derived from the nearby town of Clayton, Union County, New Mexico. Holotype in NM 52-75-1; paratypes in NM 52-75-12.

Comparisons: Some paratypes are larger than the type (but damaged), reaching an estimated length of nearly 11 mm. The ultimate whorl on these older shells is often characterized by revolving ridges, about 5 in number; or the last whorl may be irregularly malleated. None of these features is judged to have taxonomic significance. *Lymnaea claytonensis*, although differing from

them in its more slender shape, and compressed, elliptical aperture, seems to relate best to the *Lymnaea humilis-truncatula-cubensis* complex, because of the general proportions and size of the shell, and the fine spiral sculpture. Its closeness to the circumcaribbean *cubensis* may indicate a southern element in the lymnaeid fauna at this site.

Gastrocopta debilis, *n. sp.*

Fig. 2

Diagnosis: Shell small, bearing the characters of the genus, about 2.5 mm in length; whorls five, rounded; aperture irregularly rounded, peristome reflected, lip thin, having well-developed crest behind, separated from the lip by a well-developed trough; denticles 4, the two palatals weakly developed to almost absent.

Description of holotype: Shell minute, subcylindric, tapering slightly toward blunt apex; whorls five, rounded, bearing surface sculpture of fine, irregularly disposed diagonal striations, except for finely granular apical $1\frac{1}{2}$ whorls; suture impressed; aperture about as high as wide, peristome reflected, thin, but bearing a callus within; margins of peristome approaching, but connected by no more than a thin wash across parietal wall; a strong crest parallels outer peristome separated from it by a trough; no impressions behind palatal folds; denticles 4: angulo-parietal simple in all views, inclined slightly toward the right; columella lamella simple horizontal, neither entering nor ascending; two palatal folds, both weakly developed, the lower more elongate and more deeply entering than the upper; basal fold absent.

The name *debilis* refers to the weakly developed palatal folds. Holotype deposited in NM 52-76-1; paratypes in NM 52-76-5.

Comparisons: There is a minimum of variation among the numerous paratypes, but what occurs is related to the strength of the two palatal folds. Among a hundred shells, four of them have palatal folds more than weakly developed, and in another four of them, the two palatal folds are essentially absent. *G. debilis* superficially resembles *G. pellucida parvidens* of Sterki but differs from that species in the simple angulo-parietal fold, and the prominent crest behind the

peristome. *G. debilis* differs from *G. corticaria* in that the latter lacks the crest behind the peristome, the angulo-parietal is not simple, and the two palatals in *corticaria* are strongly developed.

***Gastrocopta arean*, n. sp.**

Fig. 3

Diagnosis: A small ovoid gastrocoptid, little more than 2.0 mm in length, having five rounded whorls, flared aperture with crest behind the peristome, and four denticles: angulo-parietal, columellar and 2 palatals.

Description of holotype: Shell elongate, ovoid, imperforate; 5 convex whorls, smooth nuclear whorl forming bluntly conic apex the granular surface texture extending to last half of ultimate whorl but beyond first 1½ nuclear whorls, overlain by fine diagonal striations, aperture having flared, simple peristome, with crest behind, the right margin extending toward, but not reaching opposite margin, to which it is connected only by thin callus; denticles 4: angular limb of angulo-parietal extending from parietal limb and joining with margin of peristome, parietal limb elevated, elongate, extending deeply within aperture; columellar lamella nearly vertical; basal lamella absent; upper palatal lamella conic and rising from a thick callus, the tip closely approaching parietal lamella; lower palatal nodular, very deeply inserted in aperture and smaller than upper palatal lamella; the palatal lamellae producing an elongate impression behind the peristome. Total length, 2.38 mm; diameter, 1.2 mm, aperture length, 0.77 mm, aperture width, 0.84 mm. *Gastrocopta arean* is known only from the holotype (NM 52-76-21) and three paratypes (NM 52-76-5) the shells of the paratypes are variously damaged.

The name *arean* refers to the fine sandy matrix from which this and other taxa of mollusca were recovered.

Comparisons: Similar in form and in the general configuration of the denticles to *G. armifera*, from which it differs by its small size, about half that of *armifera*, by the simple, untwisted columella lamella, and by the deeply immersed, nodular lower palatal lamella. The surface texture is also unique, as the granular almost waxy surface sculpture extends to the last half of the ultimate whorl, where diagonal striations suddenly begin. *G. arean* bears no resemblance to any of the small gastrocoptids known to me.

The three taxa of gastropods described above are known only from the type locality, given earlier.

The total molluscan fauna recovered from the Clayton South locality includes 25 taxa, listed as follows in generic alphabetical order:

AQUATIC	TERRESTRIAL
<i>Ferrissia parallela</i> (Halderman)	<i>Euconulus fulvus</i> (Müller)
<i>Ferrissia shimaki</i> (Pilsbry)	<i>Gastrocopta arean</i> n. sp.
<i>Ferrissia tarda</i> (Say)	<i>G. cristata</i> (Pilsbry & Vanatta)
<i>Gyraulus circumstriatus</i> (Tyron)	<i>G. debilis</i> , n. sp.
<i>G. parvus</i> F. C. Baker	<i>G. pilsbryana</i> (Sterki)
<i>Lymnaca bulimoides</i> Lea	<i>Hawaiiia minuscula</i> (Binney)
<i>L. claytonensis</i> , n. sp.	<i>Pupilla blandi</i> Morse
<i>L. dalli</i> F. C. Baker	<i>Pupoides albilabris</i> (C. B. Adams)
<i>L. parva</i> F. C. Baker	<i>P. hordaceus</i> (Gabb)
<i>Physa anatina</i> Lea	<i>P. inornatus</i> Vanatta
<i>Psidium casertanum</i> (Poli)	<i>P. modicus</i> (Gould)
	<i>Succinea grosvenori</i> Lea
	<i>Succinea gelida</i> F. C. Baker
	<i>Vallonia perspectiva</i> Sterki
	<i>Vertigo milum</i> (Gould)

RADIODISCUS HUBRICHTI BRANSON, 1975, A SYNONYM OF *STRIATURA*
(*S.*) *PUGETENSIS* (DALL, 1895) (PULMONATA: ZONITIDAE)

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ABSTRACT

A paratype of Radiodiscus hubrichti Branson, 1975, compares exactly with material of Striatura (S.) pugetensis (Dall, 1895). The two taxa are considered to be synonyms. Scanning electron microscope photographs of shell sculpture in the two distinct species, S. (S.) pugetensis and S. (S.) milium (Morse, 1859), show that they have basically identical sculpture.

The minute (1-3 mm) shells of such genera as *Striatura*, *Punctum*, *Radiodiscus*, and *Planogyra* are easily confused. They have a common pattern of decoiling and spire protrusion, all have radial ribbing interspaced with microribs, and in each group the apical and post-apical sculpture are markedly different. Even the best illustrations published previously (Pilsbry, 1946, 1948) suggest that there are more similarities than differences. Use of the scanning electron microscope permits showing that the shell sculpture in these genera, although very similar in gross appearance, is formed quite differently. This paper reports on the basic sculpture of *Striatura*, s. s., while a subsequent contribution (Solem, in this issue of *The Nautilus*) will illustrate the same features as found in *Striatura (Pseudohyalina)*, *Punctum*, *Radiodiscus* and *Planogyra*. Comparative remarks are included in the second paper.

SHELL SCULPTURE

Although much of the surface in the paratype of *Radiodiscus hubrichti* (FMNH 175456) is coated with debris (figs. 4, 5), sufficient clean areas remain so that details of the microsculpture could be studied (figs. 6, 7). The apical sculpture for the first 1-3/8ths whorl consists of crowded spiral ridges (fig. 5). There is an intrusion of weak radials on the remaining slightly more than one-eighth apical whorl. A constriction at the suture marks the end of this region. The post-nuclear sculpture consists of prominent radial ribs and weak spiral elements. This

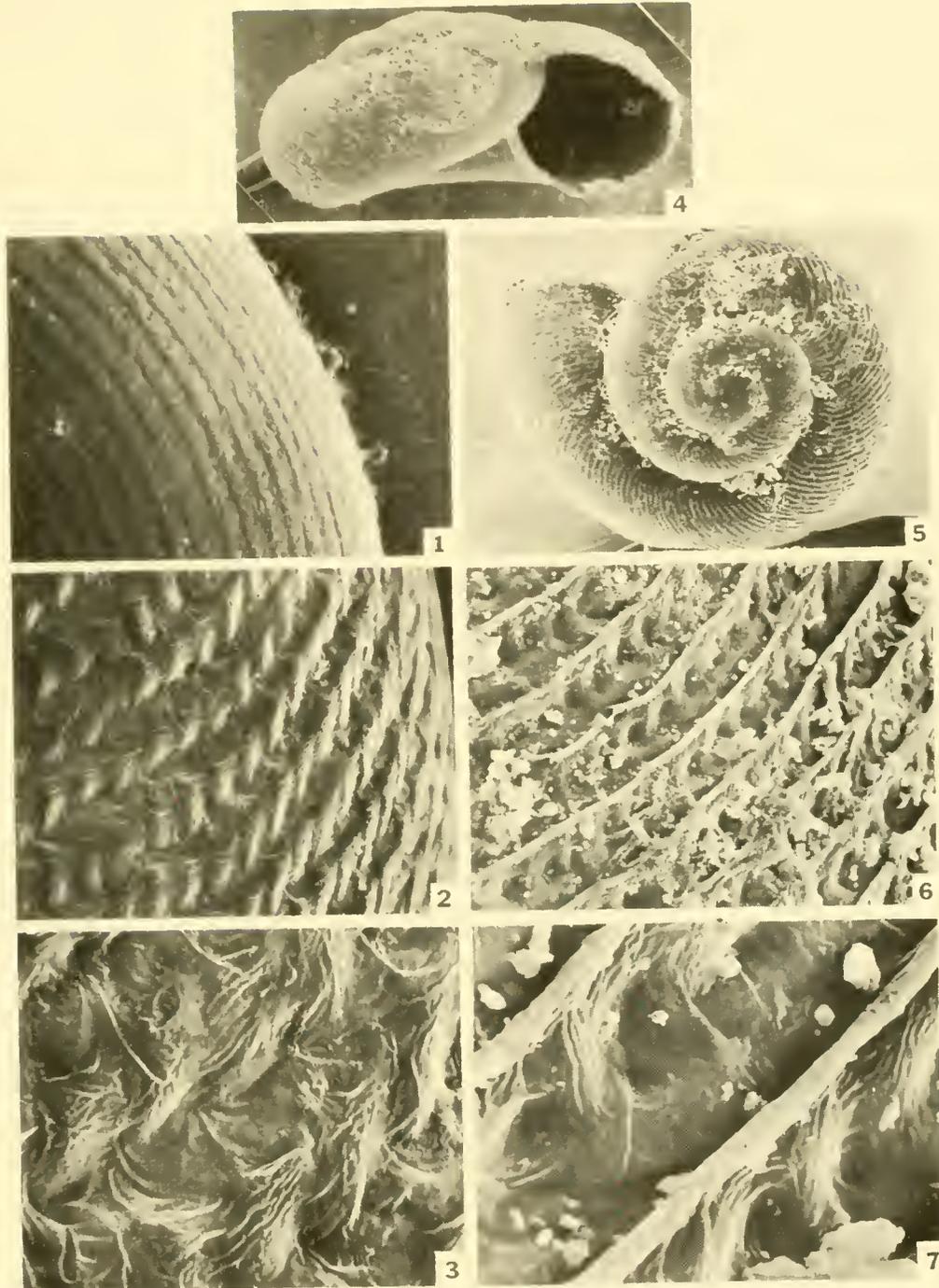
continues to the lip edge. Viewed at intermediate magnification (fig. 6), the radials are seen to be narrow thread-like elevations on top of weakly raised ridges. At high magnification (fig. 7), the inter-rib area shows "pits and swirls". There are distinctive micro-folds on the pit edges as well as the surface of the radial ribs (upper left).

The apical sculpture of *Striatura milium* (fig. 1) is the same as that found in *S. pugetensis*. The post-nuclear sculpture (figs. 2, 3) of *S. milium* appears different at first glance, since the raised radial threads of *S. pugetensis* (fig. 6) are absent. When viewed at comparable high magnification (fig. 3), the "pits and swirls" found in inter-rib areas of *S. pugetensis* (fig. 7) are seen to be intensified in *S. milium* and represent the only post-nuclear sculptural element.

At the highest magnification (figs. 3, 7), both species show a very peculiar pattern of micro-folding. This folding is very similar to stress marks seen in dried paint or plastic films. It is interpreted as the result of periostracal shrinkage drying. This "folding" also is characteristic of many zonitoid (Solem, unpublished) and pupillid taxa (see also Gittenberger, 1975, pl. I, fig. 4 and Solem, in this issue of *The Nautilus*).

SYNONYMY AND DISTRIBUTION

Striatura (S.) pugetensis (Dall, 1895) has a sporadic distribution from Vancouver Island south to Guadeloupe Island, Baja California, and the Palomar Mountains near San Diego (Pilsbry, 1946: 492). It is quite common near Seattle and



FIGS. 1-3. *Striatura (S.) milium* (Morse, 1859). FMNH 90769. Near Minden, Halliburton Co., Ontario, Canada. P. M. Oughton! FIG. 1. Nuclear sculpture. 560X. FIG. 2. Sculpture on body whorl near aperture. 565X. FIG. 3. Detail of two "ribs" on body whorl. 1,670X. FIGS. 4-7. *Striatura (S.) pugetensis* (Dull, 1895). FMNH 175456. Paratype of

Radiodiscus hubrichti Branson, 1975. Mt. Storm King, Olympic Peninsula, Washington. FIG. 4. Side view of shell. 36X. FIG. 5. Top view of shell. 36X. FIG. 6. Sculpture on body whorl showing the raised "ribs" on top of the same pattern seen in Fig. 2. 370X. FIG. 7. Detail of two radial ribs showing shrinkage pattern and inter-rib pits and swirls. 1,510X.

on the Olympic Peninsula, from which *Radiodiscus hubrichti* was described. The dimensions cited by Branson (1975), his description, and his figures, all agree with the information concerning *S. pugetensis* given by Pilsbry (1946). Direct comparison of a paratype of *Radiodiscus hubrichti* (FMNH 175456) with the more than 25 sets of *S. pugetensis* in the collection of Field Museum of Natural History leaves no doubt that the two taxa are identical.

The following localities for *S. pugetensis* have not been published previously. They somewhat extend the distributional limits cited by Pilsbry (1946: 492), and are grouped by state for convenient reference.

Washington: Kittitas Co., 10 miles west of Easton (FMNH 63076, H. S. Dybas! June 20, 1957; Jefferson Co., Olympic Hot Springs (FMNH 63074, H. S. Dybas! June 19, 1957).

Idaho: Kootenai Co., Medimont (FMNH 63075, FMNH 63078, H. S. Dybas! June 23, 1957).

Montana: Flathead Co., T32N, R18W, S6 Glacier Park (FMNH 110716, Marie Moor! July 7, 1960).

Oregon: Curry Co., ravine of Pistol River (FMNH 117741, H. S. Dybas! May 23, 1957); Hood River Co., Cascade Locks (FMNH 54322, H. W. Harry! November 1945).

California: San Francisco, Marina Hospital (FMNH 97655, W. H. Dall! ex Fred Button); Alameda Co., Hayward (FMNH 97708, ex Fred Button); Sacramento Co., northeast of Folsom (FMNH 97956, A. Solem & A. Smith! April 9,

1960); San Diego Co., San Diego (FMNH 63077, ex Walter F. Webb).

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SHELL MICROSCULPTURE IN *STRIATURA*, *PUNCTUM*, *RADIODISCUS*,
AND *PLANOGYRA* (PULMONATA)

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ABSTRACT

Previous anatomical studies have placed Striatura (Zonitidae), Punctum (Punctidae), Radiodiscus (Charopidae), and Planogyra (Valloniidae) in unrelated families. Their minute size, similar shell shapes, and the sharp differentiation between spiral sculpture on the nuclear whorls and the post-nuclear sculpture of major and minor radial elements, have led to confusion between these genera. Scanning electron microscope photographs of shell microsculpture show that the apparent sculptural similarities are convergent. The same gross result is achieved in quite different ways.

In many parts of the world, land snails that are 1 to 2 mm in diameter have a complex microsculpture on the shell. When this sculpture is viewed under high optical magnifications, 50 to 100X, a distinction can be made between "major radial ribs" that number 15 to 250 on the last whorl of the shell, and "micro-ribbing" that lies between the "major ribs". Traditionally such species were described as, or subsequently associated with, "endodontid" land snails but anatomical investigations of the past six decades have split many taxa off into a wide variety of families. The many differences in pallial structure, genitalia, radulae, free muscle and nervous systems revealed by the anatomical studies strongly suggest that the similarities in shell form and sculpture are the result of convergent evolution.

Unfortunately, adequate studies of the sculptural elements and their method of formation have not been possible until very recently because of inherent limitations in magnifications, resolution, and depth of field with optical equipment. The scanning electron microscope (hereafter SEM) overcomes these problems and permits investigations of sculpture components and method of formation. As a byproduct of investigations on the Pacific Basin endodontoid land snails, data on shell sculpture in several Nearctic taxa have been accumulated. They illustrate basic

differences in mode of sculpture formation and suggest possible major differences between higher groupings in terms of shell structure.

The genera illustrated here, and the anatomical studies that enabled definitely assigning them to family units, are *Striatura* (*Pseudohyalina*) (Zonitidae, H. B. Baker, 1928a), *Punctum* (Punctidae, H. B. Baker, 1927), *Radiodiscus* (Charopidae, H. B. Baker, 1927), and *Planogyra* (Valloniidae, H. B. Baker, 1928b, 1935). Illustrations of two species belonging to *Striatura*, s. s. were presented in the preceding paper, Solem (1977) and are referred to below. The Valloniidae belongs to the Order Orthurethra and the other three families to the Order Sigmurethra. Both the Punctidae and the Charopidae currently (Solem, In Press) are placed in the Superfamily Arionacea of the Suborder Aulacopoda, while the Zonitidae belongs to the Superfamily Limacacea of the same Suborder. None of these families appear to be related in a direct descendant-ancestor manner.

The families also differ greatly in their basic distribution patterns. The Charopidae (Solem, unpublished) is a "Gondwanaland" taxon with high diversity in South Africa, Australia, New Zealand, New Caledonia, some parts of Polynesia, Juan Fernandez and southern South America. A few taxa reach Indonesia, New Guinea, Central America, and the Western United States. The

Punctidae are primarily Australia and New Zealand in distribution, with scattered occurrences in Africa, South America, Tahiti, Hawaii, and the Holarctic region. The Zonitidae is most diverse in the Holarctic, but has extensive Central American, Polynesian, and some South American taxa. The Valloniidae is strictly a Holarctic family with a fossil record extending back to the Paleocene of Europe. North America is thus on the fringe of the charopid radiation, but central to the zonitid and valloniid distribution patterns. The punctids have their center of diversity elsewhere, but North America is the main secondary center of diversity.

SHELL SCULPTURE AND FORMATION

Although Baker (1928a: 33) pointed out that the three dissected species he grouped as *Striatura* could perhaps be placed better as monotypic genera, subsequent workers such as Pilsbry (1946) preferred to use a more broadly defined genus. Certainly the shell sculpture in *S. pugetensis* (Dall, 1895) (see Solem, 1977: figs. 1-3), *S. milium* (Morse, 1859) (see Solem, 1977: figs. 4-7), and *S. (Pseudohyalina) exigua* (Stimpson, 1850) (figs. 1-3) is consistent with a monophyletic derivation. The species differ obviously in their major ribbing. *S. exigua* has widely spaced, narrow, high major ribs (figs. 2, 3) that terminate short of the suture (fig. 1). *S. pugetensis* (Solem, 1977: figs. 5, 6) has much lower, more crowded, narrow ribs. These ribs clearly are periostracal in origin, since (*loc. cit.*, left center of fig. 6) broken rib edges show no underlying calcareous support. *S. milium* (Solem, 1977: figs. 2, 3) gives the appearance of having radial ribs under optical examination, but the SEM shows that a series of short diagonal ridges are lined up in a radially transverse row and hence there are no continuous radial ribs. *S. exigua* (figs. 2, 3) has a clear micro-spiral sculptural element that could be derived from the diagonal ridges of *S. millium* (Solem, 1977: fig. 2).

The apical sculpture of *S. milium* (Solem, 1977: fig. 1) consists of broad, flat ridges separated by narrower grooves, with faint traces of a radial element. In both *S. pugetensis* (Solem, 1977: fig. 5) and *S. exigua* (fig. 1) the apex has very narrow

spiral ridges, with their interstices wider than the ribs.

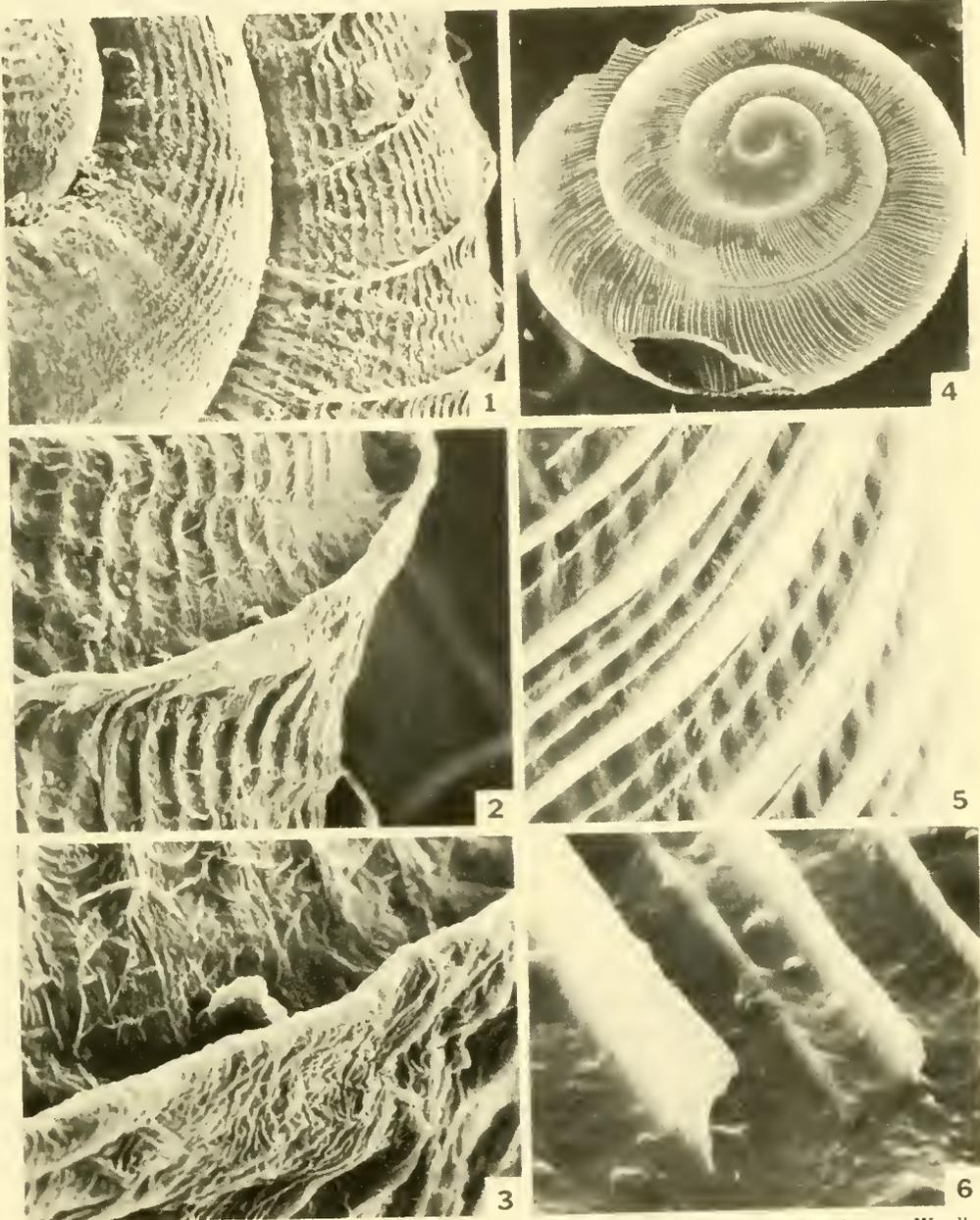
The most characteristic feature of *Striatura* is the very peculiar micro-folding pattern (Solem, 1977: figs. 3, 7). This is particularly clear on the major rib surface in *S. exigua* (fig. 3). Similar stress marks in dried films of paint or plastic are familiar to physical chemists. I interpret this folding pattern as the result of shrinkage drying by an outer periostracal layer.

Punctum (figs. 4-6, 11, 12) superficially looks very similar to *Striatura* in sculpture, having spiral apicals (Giusti, 1973: pl. 5, fig. 1) and narrow, crowded radial ribs when viewed at optical range magnification (fig. 4). At higher magnification (figs. 5, 6), the presence of two or three micro-riblets between each pair of major ribs is obvious. By inspecting an area where the ribs are broken (fig. 6), the very thin, lamellar nature of the ribs, the occasional sudden termination of a micro-riblet, and the fact that the major ribs surmount a low radial swelling on the shell surface can be detected. When the sculpture is viewed from a very low angle (figs. 11, 12), the presence of spiral swellings, with the radial sculpture essentially unaffected by these elements, is evident. In addition, there is a vague pattern of corrugations on the surface of the spiral ridges.

Previous reports on the shell sculpture of *Radiodiscus* (summarized by Pilsbry, 1948: 654-655) characterize the apex as "minutely engraved spirally" and the "rest of the shell densely radially costate". While the apex does start out (fig. 7) with continuous spiral cords, very shortly these become interrupted by narrow radial lines. At very high magnification (fig. 8), the apical sculpture can be seen to consist of short, slightly sinuated segments that line up spirally. The post-nuclear sculpture (figs. 9, 10) is complex, and compares in all essentials with that found in such Pacific charopids as the New Zealand *Ptychodon microundulata* (Suter, 1890) (see Solem, 1970: pl. 59) and a still undescribed Tongan species (Solem, 1974: 199, figs. 8a, b). The major radial ribs in all these taxa are periostracal extensions above a calcareous swelling (Solem, 1974: 199, fig. 8b). There are a few to many micro-riblets, again formed by the periostracum, between the major ribs (fig. 9; Solem,

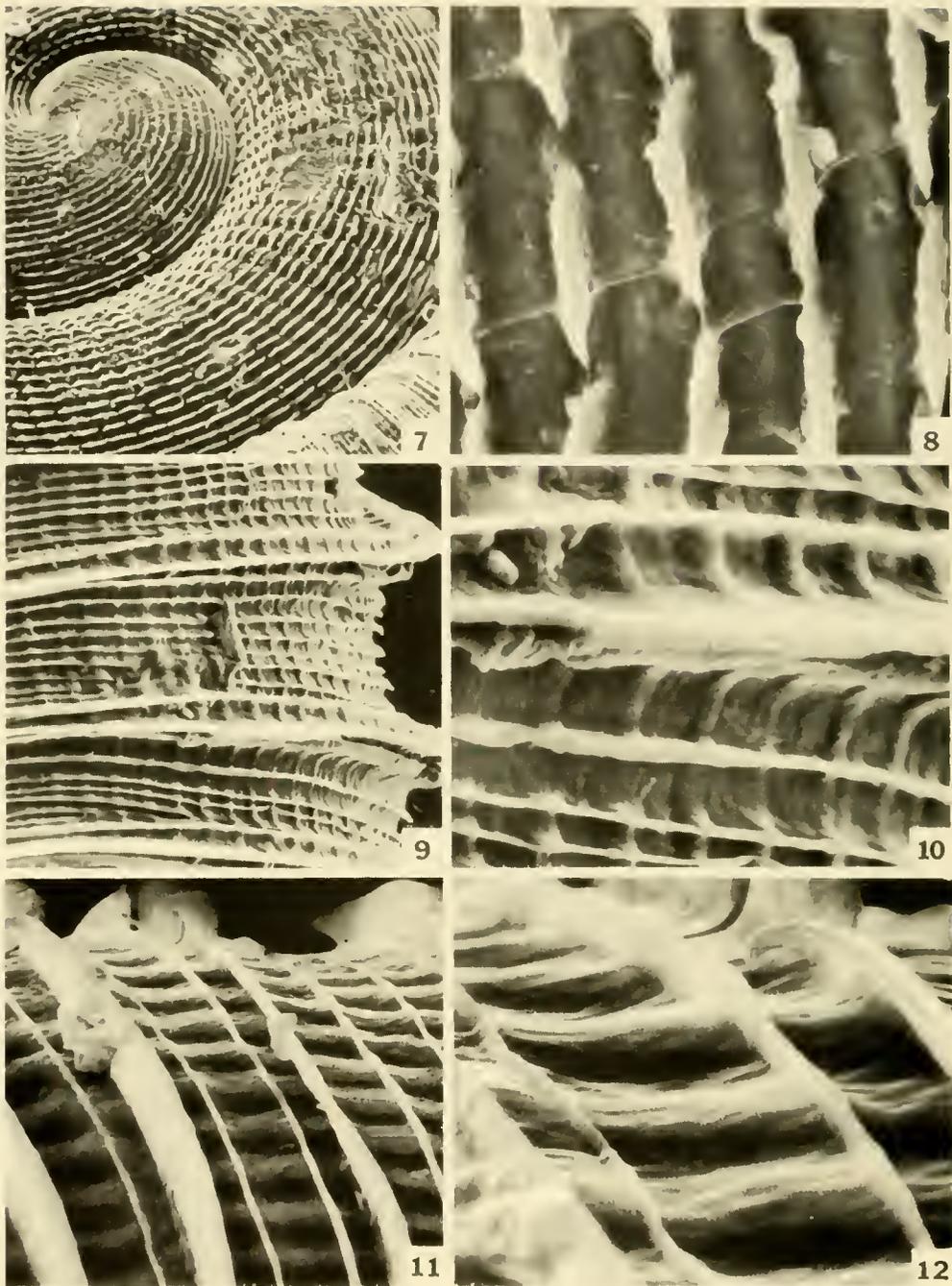
1970: pl. 59, figs. 8, 9; Solem, 1974: 199, figs. 8a, b). In addition, there is a complex spiral microsculpture (fig. 10). Larger spiral elements (also visible in fig. 9) connect two microradials, tend-

ing to buttress the apical side of the microradial. This is particularly evident in *Ptychodon micro-undulata* (Solem, 1970: pl. 59, fig. 10), but is much less developed in *Radiodiscus* (figs. 9, 10). Be-



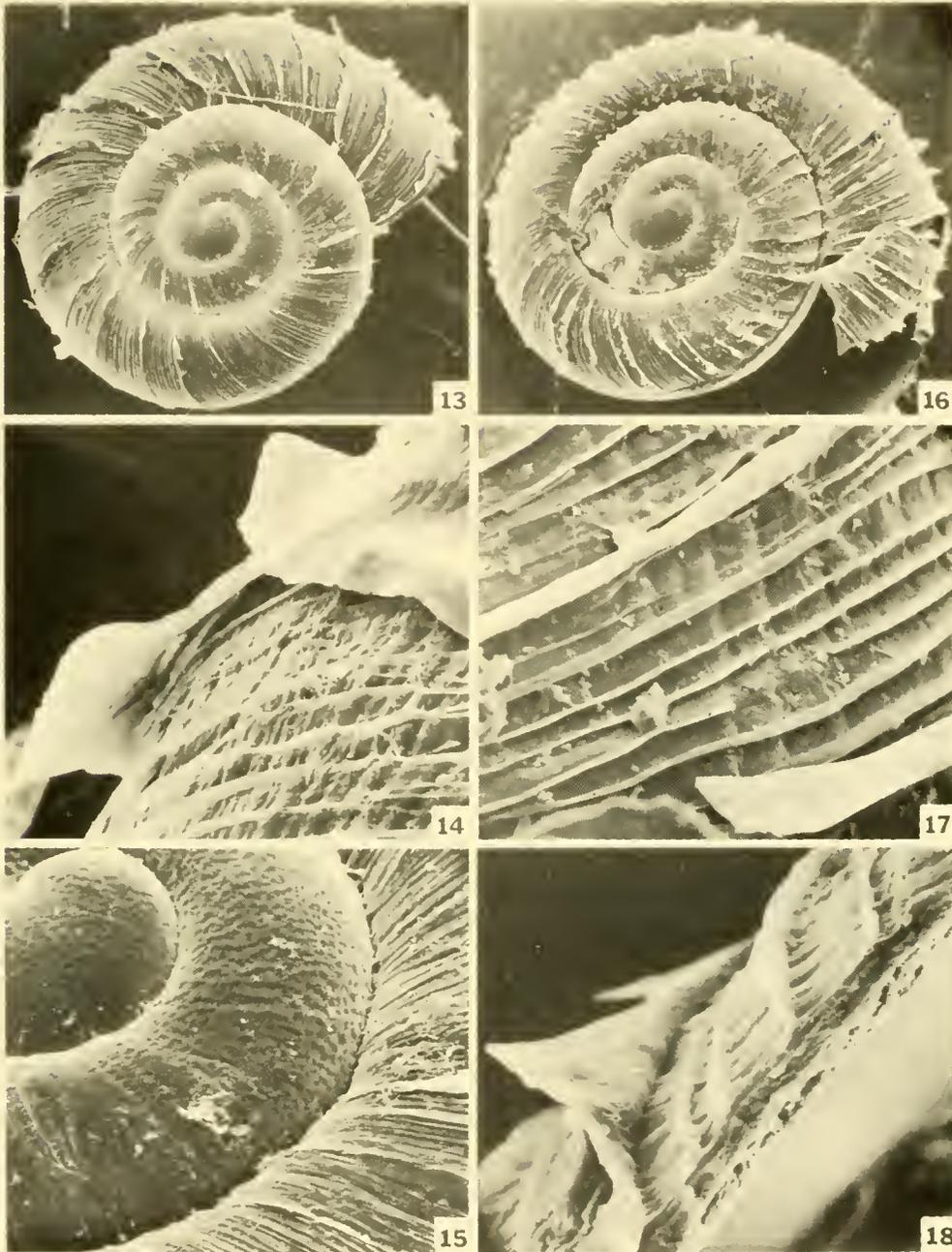
FIGS. 1-3. *Striatura* (*Pseudohyalina*) *exigua* (Stimpson, 1850). Ohio. FMNH 11020. FIG. 1. Apical (left) and post-nuclear (right) sculpture. 185X. FIG. 2. Sculpture on body whorl showing one major radial rib. 620X. FIG. 3. Detail of periostracal surface on major rib. 1,850X. FIGS. 4-6. *Punctum*

minutissimum (Lea, 1841). Cedar bog on Woodburn Road, 4 miles southwest of Urbana, Champaign Co., Ohio. October 20, 1969. E. Kefer! FMNH 151102. FIG. 4. Entire shell (lip broken). 63X. FIG. 5. Sculpture on body whorl. 1,560X. Broken ends of major radial (left) and two microradials (center and right). 5,400X.



FIGS. 7-10. *Radiodiscus (R.) millocostatus* Pilsbry & Ferriss, 1906. Wickersham Gulch, Huachuca Mts., Cochise Co., Arizona. James Ferriss! FMNH 146619. FIG. 7. Apical sculpture. 195X. FIG. 8. Detail of late apical sculpture. 1,900X.

FIG. 9. Two major ribs on body whorl. 630X. FIG. 10. Detail of a major rib and microriblets on body whorl. 2,000X. FIGS. 11-12. *Punctum minutissimum* (Lea, 1841). FMNH 151102. FIG. 11. Sculpture on body whorl. 2,000X. FIG. 12. Detail of microsculpture on body whorl. 6,700X.



FIGS. 13-15. *Planogyra asteriscus* (Morse, 1857). Fraserdale, Cochrane Dist., Ontario, Canada. S. D. Downing! June 1938. FMNH 46783. FIG. 13. Apical view of subadult specimen. 36X. FIG. 14. Major rib and microsculpture on body whorl. 355X. FIG. 15. Apical sculpture and early post-nuclear sculpture.

285X. FIGS. 16-18. *Planogyra clappi* (Pilsbry, 1898). Quamicham, Vancouver Id., British Columbia. FMNH 140588 ex W. J. Eyerdam. FIG. 16. Apical view of subadult specimen. 37.3X. FIG. 17. Sculpture on body whorl. 373X. FIG. 18. Broken edge of body whorl showing major rib and details of microsculpture. 792X.

tween these "major" spiral elements are vague spirial corrugations (fig. 10; Solem, 1970, pl. 59, figs. 10, 11) that resemble those found on the spiral ridges in *Punctum* (fig. 12).

Planogyra asteriscus (Morse, 1857) (figs. 13-15) from the boreal areas of Eastern North America and *P. clappi* (Pilsbry, 1898) (figs. 16-18) from Oregon to British Columbia differ from each other in major rib spacing (compare figs. 13 and 16) and umbilical width. They both have very high, lamellar periostracal ribs that stand erect when the live animal is in the moist litter, but warp and twist (fig. 14) in the dry museum cabinets (H. B. Baker, 1928a: 122). Seen at a broken edge (fig. 18), the periostracal nature and thinness of the ribs is obvious. Similarly, the microradial riblets are formed by the periostracum (fig. 17) and are fewer in number in *P. clappi* (fig. 17) than in *P. asteriscus* (fig. 14). Both species have a weak microspirial sculpture that shows most clearly in figs. 14 and 18 because of the oblique angle of view. The microspirals blend into the raised radial ribs, but do not buttress them as in many Charopids. The apical sculpture in *Planogyra* usually is eroded, but in unworn examples (fig. 15) it can be seen to form a series of corrugated wrinkles and pits with a vague diagonally radial pattern. At the highest magnification (fig. 18) there are evident irregularities on the periostracal surface. These appear homologous to the structures on the spiral microribs of *Radiodiscus* (fig. 10) and *Punctum* (fig. 12), and quite different from the stress drying marks in *Striatura* (fig. 3; Solem, 1977: figs. 3, 7).

COMPARATIVE REMARKS

Under optical examination, the spiral apical sculpture and post-nuclear sculpture with both major radials and usually microradials found in the four genera appear quite similar, but at the higher magnifications of the SEM, major differences appear. In both *Striatura* and *Planogyra*, the shell sculpture appears to be totally periostracal in nature. The raised major ribs are simple lamellar protrusions from the surface. They are scarcely wider at their base than at their midsection (figs. 2, 18). In *Punctum* and *Radiodiscus*, the microradial riblets are purely periostracal, but the major radial ribs are

underlaid and partly formed by a swelling in the calcium layer. *Punctum* (fig. 6) differs in that the periostracal ribs are simple lamellae, while in the Charopidae (Solem, 1974: 199, fig. 8b) the basal portions of the periostracal ribs are distinctly wider than the middle sections, with tapering continuing to the top of the ribs.

Microspirial sculpture is present, but differs greatly. In *Striatura* (fig. 2; Solem, 1977: figs. 2, 3, 6, 7) the spiral elements initially are short diagonals, becoming coalesced into wavy spiral cords only in *S. exigua* (fig. 2). In both *Planogyra* (fig. 18) and *Punctum* (figs. 11, 12) the microspirals are basically independent of the radial ribs and riblets, but in *Radiodiscus* (figs. 9, 10) they serve to buttress the apical edge of each riblet. In *Punctum* and *Radiodiscus*, weak spiral corrugations are associated with the spirial ridges.

All four genera have spiral sculpture on the nuclear whorls. In *Radiodiscus* (figs. 7, 8) this consists of short interrupted threads arranged serially in spiral rows, although other charopids (Solem, 1970: pl. 58, fig. 1) normally have prominent, narrow spiral cords, such as are seen in both *Punctum* (Giusti, 1973: pl. 5, fig. 1) and *Striatura* (fig. 1). *Planogyra* (fig. 15), in contrast, has a less well defined, almost punctate sculpture.

The most striking difference is the peculiar micro-folding pattern found in *Striatura* (fig. 3; Solem, 1977: figs. 3, 7). This effect is lacking from the other taxa, although having analogous structures in some other Orthurethra (see Solem, 1977).

The sculpture of these four taxa, although "macroscopically" very similar and functionally probably serving an identical purpose, is composed of quite different elements. On the basis of this and other data available now, primarily a review of Pacific Basin endodontoid taxa, it seems possible that certain of these differences are consistent for at least family units. The total periostracal nature of the shell sculpture in *Striatura* and *Planogyra* contrasts with the combination of calcareous and periostracal sculpture in *Punctum* and *Radiodiscus*. At the other extreme the Endodontidae, as restricted by Solem, has a uniformly thin periostracum, with even

the microsculpture on the apical whorls formed mainly by the calcareous layers. Except where the sculpture is secondarily reduced in the Charopidae, the combination of periostracal and calcareous elements is consistent, as is the use of microspiral ridges to buttress the riblets. In the valloniids, species of *Vallonia* with regularly spaced ribs do have calcareous extensions into the ribs, and some of the punctids from Australia and New Zealand lack the calcareous swellings underneath the main ribs.

The tapered and buttressed ribs in the Charopidae are quite unlike the simple lamellar ribs of the other taxa, while the stress folds and "pit and swirl" microsculpture of the zonitid *Striatura* separate it from the other three. A study of the physical chemistry of the periostracum in *Striatura* as compared to the other taxa might yield highly significant information.

In conclusion the grossly similar shell sculpture of these four taxa show several significant differences in mode of formation and composition. Extended studies on the ribbed pupillids, small polygyrids, streptaxids, and helicids might yield equally interesting results.

ACKNOWLEDGMENTS

Figures 1 through 12 were taken during a factory demonstration of a JEOLCO SEM, and figures 13 through 18 were taken on a Cambridge S4-10 provided Field Museum of Natural History by NSF grant BMS72-02149. I am grateful to Mr.

Fred Huysmans for the excellent photographic prints, to Dorothy Karall for mounting them into prints, and to Sharon Bacoyanis for help with manuscript preparation.

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We deeply regret to announce the temporary suspension of the Department of Mollusks at the Delaware Museum of Natural History effective November 15, 1977. Public exhibits at the museum will remain open. However, the Curator and Assistant Director of the Museum, R. Tucker Abbott, and the Assistant Curator of Mollusks, Russell H. Jensen, as a consequence, will be leaving their positions. Professional malacologists are invited by the

Director to continue to use the facilities of the museum. Those wishing malacological information may address Dr. Abbott at P.O. Box 4208, Greenville, Delaware, 19807 and Mr. Jensen at R.D. 1, Box 55, Chadds Ford, Pennsylvania, 19317.

These events will not adversely affect the publication of *The Nautilus*, *Indo-Pacific Mollusca*, *The Standard Catalog of Shells* or publications of American Malacologists, Inc.

DEATHS

We regret to announce the sudden death of **George E. Radwin**, Curator of Mollusks at the San Diego Museum of Natural History. George was born August 20, 1940, at Far Rockaway, N.Y., and died of a heart attack at the age of 37, on September 30, 1977, in San Diego. Most of his research was on the taxonomy of the Muricidae and Columbellidae. He was senior author of the recent book, *Murex Shells of the World*. He received his Ph.D. in 1968 from The George Washington University, and went to San Diego in 1970. He is survived by his wife, Rodda, to whom all malacologists send their sincere condolences.

Henning M. Lemche, former head of the Department of Mollusks, of the Zoological Museum, University of Copenhagen, Denmark, died August 4, 1977, after a brief illness. Dr. Lemche was an outstanding malacologist, well-known for his works on nudibranchs and *Neopilina*.

Isabelle E. Welch of Falls Church, Virginia, an ardent shell collector and partner in *The Shell Cabinet*, died on August 15, 1977. She was a former employee of the U.S. Navy, a member of the A.M.U. and several shell clubs. Miss Welch produced several taped travelogs of her shelling experiences in the Bahamas and the Galapagos.

NEWS

Stanford University Collections Transferred to the California Academy of Sciences

The molluscan shell collection, the type specimen collection, and a major part of the invertebrate fossil collection of the Department of

Geology, Stanford University, have been transferred on indefinite loan to the Department of Geology, California Academy of Sciences. All enquiries regarding these Stanford collections should be directed to the Academy. The combined Academy and Stanford collections are now available for study. The shell and fossil collections are housed separately, and both collections have work space and other facilities for visitors.

The combined Academy—Stanford shell collection, containing an estimated one million specimens, is of world-wide scope, but is especially rich in marine species from the Eastern Pacific and land snails from Western North America. The fossils transferred from Stanford to the Academy include the Cenozoic stratigraphic collection and the systematic collection of fossil cephalopods and echinoids. The combined Academy—Stanford fossil collection contains about one million specimens (mostly mollusks), principally from Cenozoic and Late Mesozoic rocks of the Pacific Coast of North America (Alaska to Mexico). The combined Academy—Stanford type collection, housed in a separate room, contains several thousand specimens including primary and secondary types of living mollusks, and fossil invertebrates (mostly mollusks), vertebrates and plants.

Peter U. Rodda
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San Francisco, California 94118

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