



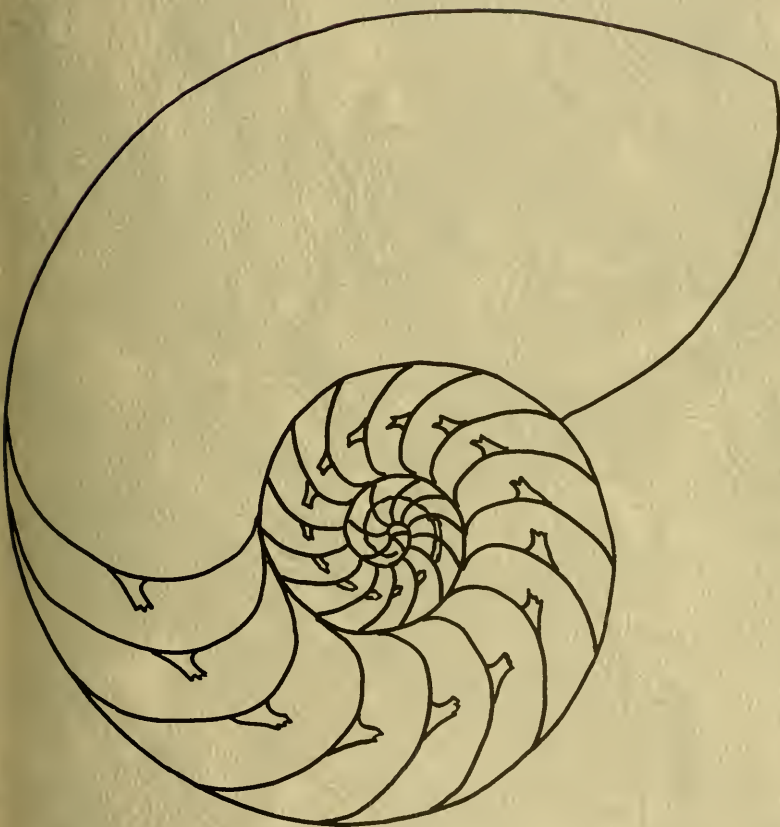
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(signed) R. Tucker Abbott, Editor

PUBLICATIONS RECEIVED

- Porter, Hugh J. 1974. *The North Carolina Marine and Estuarine Mollusca - An Atlas of Occurrence*. Univ. of North Carolina, Institute of Marine Sciences, Morehead City. 351 pp., paperback. A checklist with many new records for the mollusks of 176 families. Useful bibliography.
- Coomans, H. E. 1974. *Life and Malacological Works of Hendrick Elingsz van Rijgersma (1835-1877)*. Bijdragen tot de Dierkunde, vol. 44, no. 2, pp. 116-214. Worked on Dutch West Indies mollusks.
- Abbott, R. Tucker, Oct. 1974. *American Seashells*, second edition. The Marine Mollusks of the Atlantic and Pacific Coasts of North America. Van Nostrand Reinhold Co., N.Y. 663 pp., 24 new colored plates, about 3000 text illus. Includes about 6500 species and subspecies. \$49.50.
- Salvini-Plawen, L. V. and R. Tucker Abbott, Nov. 1974. *Phylum Mollusca*. Vol. 3 of Grzimek's Animal Life Encyclopedia. Van Nostrand Reinhold, N.Y. 225 pp., 47 colored plates, numerous text figures. A survey of the structure, biology and systematics of the 390 families of land, freshwater and marine mollusks. Remainder of this volume, pp. 226-540, deals with Bryozoa, Brachiopoda, echinoderms and tunicates.
- Ross, Arnold and William K. Emerson, Nov. 1974. *Wonders of Barnacles*. Dodd, Mead and Co., N.Y. 78 pp., text illus. a well-done introduction to the barnacles for the general public. \$4.95.
- Saul, Mary. Oct. 1974. *Shells*. Country Life, London. 192 pp., 32 colored pls., numerous text illus. An excellent ethnological account of man's use of shells. About \$9.00.

FOUR NEW SPECIES OF LAND SNAILS FROM THE EASTERN UNITED STATES

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ABSTRACT

Mesodon orestes Hubricht (*Polygyridae*) from Waterrock Knob, Haywood Co., North Carolina; *Paravitrea mira* Hubricht (*Zonitidae*) from near Council, Buchanan Co., Virginia; *Paravitrea toma* Hubricht (*Zonitidae*) from near Maysville, Madison Co., Alabama; and *Helicodiscus lirellus* Hubricht (*Endodontidae*) from near Lexington, Rockbridge Co., Virginia are described as new. The taxonomic value of the teeth in *Helicodiscus* is discussed.

Mesodon orestes new species

Figs. 1-3

Description: Shell imperforate, depressed, conoid-globose, thin, dull, pale olive-brown; sutures deeply impressed; whorls 5, rather convex, the last rounded but with the periphery above the middle; base convex, excavated in the umbilical region, constricted behind the lip; aperture oblique, lunate, lip broadly reflected, thickened, white, appressed over the umbilicus; a small perietal tooth sometimes present; nuclear whorl with fine radial striae, becoming gradually stronger, body whorl with distinct but low rib striae; second to fourth whorls with fine irregularly placed pits; body whorl with numerous distinct spiral engraved lines; epidermis distinctly wrinkled radially between the striae.

Height 10.5 mm., diameter 17.7 mm., whorls 5.0 Holotype.

Height 11.4 mm., diameter 18.3 mm., whorls 5.3 Paratype.

Height 9.4 mm., diameter 14.7 mm., whorls 5.0 Paratype.

Distribution: North Carolina: (type locality) Haywood Co.: 6200 ft., Waterrock Knob, Blue Ridge Parkway, holotype 232583, and paratype 232582 Univ. of Michigan Mus. Zool.; other paratypes 40465, collection of the author.

Remarks: *Mesodon orestes* resembles *M. wheatleyi* (Bland) most closely, but differs in having distinct spiral engraved lines, rather than short hairs. From *M. ferrissi* (Pilsbry) it differs in being smaller, in having more spirally engraved lines, in having pits rather than papillae, and in having the epidermis distinctly wrinkled between the striae.

Paravitrea mira new species

Figs. 4-6

Description: Shell large for the genus, subhyaline, glossy, pale amber colored, 8.5 whorls; umbilicate, the umbilicus funnel-shaped, contained about 6 to 6.5 times in the diameter of the shell; spire low dome shaped, sutures moderately impressed, whorls somewhat flattened, base somewhat flattened, excavated around the umbilicus; last whorl slowly expanding behind the lip; lip thin, aperture oblique, lunate; in the last whorl there are usually two rows of rather large teeth, in immature shells there are 3 teeth in each row, in adults the inner tooth is intermittently absent; sculpture of irregularly spaced radial grooves above, becoming obsolete below.

Height 3.9 mm., diameter 6.3 mm., umbilicus diameter 1.0 mm., umbilicus diameter one whorl in 0.5 mm., 8.5 whorls. Holotype.

Distribution: Virginia: (type locality) Buchanan Co.: ravine, 2.5 miles west-southwest of Council, holotype 232584, and paratypes 232585 UMMZ., other paratypes 42109, collection of the author; low ground near creek, 2.2 miles southwest of Vansant. Dickenson Co.: ravine, 2 miles southeast of Birchleaf. Kentucky: Pike Co.: wooded hillside, 1.7 miles west of Meta.

Remarks: *Paravitrea mira* is related to *P. reecei* Morrison and *P. tridens* Pilsbry. It differs from both in its larger size, *P. tridens* is toothless in the adult. Immature shells might be mistaken for *P. reecei* but the teeth are smaller in that species.

Paravitrea toma new species

Figs. 7-9

Description: Shell small, pale amber, subhyaline, glossy; spire low dome-shaped, sutures shallow, sculpture of numerous irregularly spaced radial grooves, distinct above but becoming weaker below; periphery somewhat flattened in immature shells, becoming more rounded at maturity; umbilicus deep and well-like, exhibiting all the whorls, contained over 5 times in the diameter of the shell; base flattened and excavated around the umbilicus; whorls slowly expanding, last whorl expanding more rapidly; aperture lunate, oblique; lip thin, simple; teeth absent at all stages of growth.

Penis very large, top-shaped, lower $\frac{3}{4}$ ths rather thin walled, upper part thick walled; epiphals joining at base of upper chamber, about as long as the penis, enlarging slowly distally to an abruptly rounded end; duct attached to epiphals a little before the end; penial retractor muscle attached below the summit.

Height 2.6 mm., diameter 4.8 mm., umbilicus diameter 0.9 mm., 6.5 whorls. Holotype.

Distribution: *Alabama:* (type locality) Madison Co.: burrowing in shale rubble at base of hill, opposite Denmark Store, 10 miles northwest of Lexington, holotype 232588, and paratype 232587 UMMZ., other paratypes 29664, collection of the author; near Aladdin Cave, 7 miles northeast of Maysville. Jackson Co.: limestone hillside, 1.7 miles northeast of Princeton.

Remarks: *Paravitrea toma* is most closely related to *P. seradens* Hubricht, differing in the complete absence of teeth at all stages of growth. It also resembles *P. conecuhensis* (Clapp) in size and shape but that species has pairs of teeth in its immature stages.

Helicodiscus lirellus new species

Figs. 10-12

Description: shell discoidal or nearly so; whorls 4.5 to 5, pale greenish yellow, dull, subtranslucent; umbilicus wide and shallow, showing all of the whorls, occupying about 45% of the diameter of the shell; whorls somewhat flattened, slowly increasing, sutures deep, impressed; sculptured with coarse growth wrinkles and very fine,

spiral threads, 15 to 18 on the body whorl; aperture lunate, the peristome thin; within the aperture there are 2 pairs of teeth on the outer and basal walls, these teeth radially elongate, and distinctly separated; alternating with these are 2 teeth on the parietal wall, the parietal teeth in front of the teeth on the outer and basal walls; these teeth are present at all stages of growth, the back set being absorbed as a new set is added near the aperture.

Height 1.8 mm., diameter 4.4 mm., umbilicus diameter 1.9 mm., aperture height 1.4 mm., aperture width 1.3 mm., 5 whorls. Holotype.

Distribution: *Virginia:* (type locality) Rockbridge Co.: burrowing in shale rubble at base of hill, opposite Denmark Store, 10 miles northwest of Lexington, holotype 232588, and paratypes 232589 UMMZ., other paratypes 42020, collection of the author.

Remarks: *Helicodiscus lirellus* is closely related to *H. multidentis* Hubricht and *H. diadema* Grimm. From the former it differs in having fewer and finer lirae and in having somewhat smaller teeth. From *H. diadema* it differs in not having hairs on the lirae and in the smaller teeth.

In a recent book by Bequaert & Miller (1973, p. 86.) *Helicodiscus triodus* Hubricht, *H. multidentis* Hubricht, *H. diadema* Grimm, and *H. saludensis* (Morrison) were placed in the synonymy of *H. parallelus* (Say), apparently without examining specimens or carefully reading the descriptions, as these four species are probably the most distinctive in the genus. Over the years I have collected over 700 lots of *H. parallelus* and I have found it to be a very uniform species which does not intergrade with any of the recently described species. I have never seen the slightest trace of parietal teeth in it, which is a characteristic of all four of the species listed above. They also place *Helicodiscus singleyanus inermis* H. B. Baker in the synonymy of *H. singleyanus* (Pilsbry). The difference in shell sculpture by which these two forms were originally differentiated is a poor character, but differences in size and shape are sufficient to warrant their recognition as distinct species. *H. inermis* is distinctly smaller than *H. singleyanus* and the sutures are not as deeply impressed. *H. jacksoni* is smaller than *H.*



FIGS. 1-3. *Mesodon orestes* Hubricht, holotype. holotype.
 FIGS. 4-6. *Paravitrea mira* Hubricht, holotype. Photographs provided through the courtesy of
 FIGS. 7-9. *Paravitrea toma* Hubricht, holotype. Dr. John B. Burch, Museum of Zoology,
 FIGS. 10-12. *Helicodiscus lirellus* Hubricht, University of Michigan.

inermis and the umbilicus is larger. These three species are easily separated when their differences are understood, but these differences are hard to describe.

They also recommend that the subgenus *Hebetodiscus* H. B. Baker be raised to the status of a genus. In my opinion it may not be able to survive as a subgenus. There are intermediate species: *H. apex* (C. B. Adams), *H. roundyi* (Morrison), *H. aldrichianus* (Clapp), and *H. tridens* (Morrison). But more important is the probability that it is polyphyletic, that its species are the culmination of different lines of shell degeneration.

On page 85 they make the following statement concerning *H. parallelus* (Say), *H. fimbriatus* Wetherby, *H. salmonaceus* W. G. Binney, and *H. eigenmanni* Pilsbry: "These four species share a disk-like shell, with flattened

upper surface, a sculpture of spaced spiral threads, a broad umbilicus, and occasional small internal teeth in the last whorl. The presence and number of these teeth vary, however, sometimes within one population; as the teeth are often resorbed by the snail and their material redeposited later, they provide no reliable specific characters." While in immature shells the set of teeth nearest the aperture may be incompletely developed, in mature shells teeth-transfers cease and the teeth become stable. With mature specimens the teeth are very good characters for the recognition of species.

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THE ASIAN CLAM *CORBICULA* IN THE UPPER MISSISSIPPI RIVER

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Since its introduction to North America in 1938 the Asian clam, *Corbicula manilensis*, has expanded its range from the Columbia River, south to Baja California, and east to Florida. In the Mississippi River system it has spread from Louisiana and Mississippi north to the upper Ohio River (Stein, 1962; Burch, 1972). In a recent review of this clams' distribution and ecology (Sinclair, 1971) it was thought that its range still excluded the upper Mississippi River, i.e. above Cairo, Illinois.

Studies during the summer of 1974 revealed the presence of *Corbicula manilensis* in an effluent channel of a power generating plant at Lansing, Allamakee Co., northeast Iowa. The heated water of the effluent channel runs for about half a mile before emptying into the Mississippi River about 660 river miles above Cairo, Illinois. A few shells have also been collected along the Iowa side of the Mississippi River just downstream from the entrance of the effluent channel.

There appeared to be a very aggregated distribution of this clam along the bottom of the effluent channel. In some places they were not present, while at other sites their population densities were over 200 per square meter. From preliminary studies on the size-frequency distribution of this clam it appears that there were some clams at least two-years old. During June of 1974 it was noted that clams had a wet weight of either from two to five grams (presumably last years veliger larvae) or from 11 to 22 grams (presumably at least two-years old). Studies are currently being conducted on the growth and survival of different size clams living within enclosures in the effluent channel and in the main channel of the Mississippi River.

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- Stein, Carol B. 1962. An extension of the known range of the Asiatic Clam, *Corbicula fluminea* (Muller) in the Ohio and Mississippi Rivers. *Ohio Journ. Sci.*, 62(6): 326-327, 2 figs.

POPULATION STUDIES ON *HELISOMA ANCEPS* (MENKE)
(GASTROPODA: PLANORBIDAE)

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ABSTRACT

A population of *Helisoma anceps* (Menke) (Gastropoda: Planorbidae) was studied for 17 months near Cooperstown, Otsego Co., New York, in a small lake (Moe Pond) on the lands of the SUNY Oneonta Biological Field Station. Height-width and height-weight regression lines are illustrated. A size-frequency histogram represents the weekly data collected on reproduction, growth and mortality of the population. *Helisoma anceps* began ovipositing in late May and ceased late July. The species exhibited one cohort, hatching during June and July. Biomass and density data are given. Growth rate data show slower increases in weight with maturity and slower growth when temperatures were lower in the fall. There was an inverse relationship between total egg production and eggs oviposited per egg mass with population density. High mortality in these populations was attributed in part to physical stresses such as desiccation of immatures, and freezing of the habitat during the winter months, and, in part, to predation.

INTRODUCTION

In 1971 studies on the characteristics of a population of *Helisoma anceps* (Menke) (Gastropoda: Pulmonata: Planorbidae) were undertaken in Moe Pond. This small eutrophic lake drains into Otsego Lake, Otsego Co., New York, the headwaters of the Susquehanna River, and is a part of the properties of the New York State University College at Oneonta Biological Field Station at Cooperstown. Moe Pond has an effective width of 330 m, and an effective length of 750 m. Its greatest depth is 3.7 m. Most aquatic macrophytes grow from the littoral areas to water only 12 cm in depth.

The sample area, located on the southwest side of the lake, includes water 0-10 cm deep in a 60 m long strip adjacent to the shore. Substrate in the area is mostly channery, silt and sand derived from Devonian shales and glacial deposits. A 1-4 mm thick layer of silt and aufwuchs covers the rocks. Submergent *Eleocharis* (needlerush) and *Chara* (stonewort) grow in pat-

ches on the silt, and *Carex* (sedge) is emergent at the shoreline. The terrestrial area adjacent to the collection site is an old field. *Onoclea* (sensitive fern) rhizomes and roots form a low bank which projects into the water along one half of the area. The remainder of the bank supports grasses and common weeds.

Important invertebrate associates include the pulmonate limpet *Ferrissia parrallela* Haldeman and several common orders of aquatic insects. Also present is the scud, *Hyallela azteca* and the leeches, *Helobdella stagnalis* (L.) and *Placobdella* sp.

The water level is highest in the spring, but recedes quite rapidly after May exposing 0.1-0.4 m of inorganic and organic substrate. Due to its small size and protection from the wind, waves rarely attain a height greater than 5 cm. Ice covered the water from late December 1970 to late April 1971.

METHODS

For designation of sample sites, uniform intervals were marked along a one-meter-wide area that was parallel to the shoreline. This

transect was 60 m long and divided into 20 three meter sample plots.

Numbers generated from a computer random number program (APL) determined which plots were to be sampled at the various collection dates.

Five 462 cm² locations along the transect were sampled once a week. It was impossible to take valid samples after ice formed because the water was frozen very close to, or against, the substrate in the collection area.

To facilitate collecting, a square metal frame, 21.5 cm on one side and 11 cm high, was placed in the water at depths from 0.10 cm. Also used for sampling were four 21.5 cm rods placed 21.5 cm apart to form a square. This method proved more satisfactory because the sample area was not shaded by the high sides of the metal frame. All stones inside the frame, or rods, were picked up and inspected visually for snails and their eggs. The total number of snails and eggs for each sample was noted. When there were high densities of immature snails present in populations found on silt and fine gravel substrates, those materials were scooped up and placed in a beaker filled with water so that they could be inspected with a 2.5X hand lens. When vegetation was dense enough to obscure inorganic substrates, 115 cm² out of the plot was removed and returned to the laboratory. Snails were collected from the vegetation using a dissecting microscope. Each sample contained 0 to 27 snails which is similar to the 3 to 20 individuals per sample that satisfactorily represents the density of snail populations as stated by Hairston *et al.*, (1958).

Height-diameter data were collected and analyzed using the methods of Sokal and Rohlf (1969) to show annual changes in the shell morphology. The resulting regression lines are illustrated in figure 1 and expressed as the H:D ratio for the species (Clampitt, 1970; Wurtz, 1949).

A vernier caliper was used to measure the snails to the nearest 0.1 mm. The diameter of *H. anceps* is the length of a straight line from the outermost part of the outer lip, to the opposite extreme edge; the height is that of the largest whorl (Harman and Berg, 1971). Snails found inside the transect were returned to the

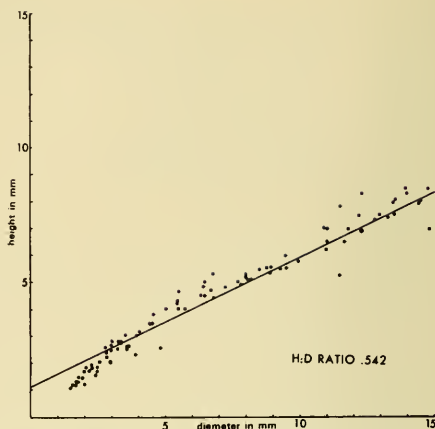


Fig. 1 Height-diameter regression. *Helisoma anceps* Mae Pond 1971.

water as soon as they were measured to assure minimal disturbance of the populations.

To represent weekly changes in numbers and growth of the populations during the sample period, a size-frequency histogram was used (fig. 2) (Hunter, 1961a, b; Duncan, 1959). All of the snails were classed in the following size ranges by diameter measurements: 0.5-1.4 mm = 1 mm, 1.5-2.4 mm = 2 mm, etc. up to 14.5-15.4 mm = 15 mm. The diameters are shown on the ordinate and the number of snails in each size class is represented by the width of the vertical line. The data from each collection date represent the average of five samples that is specified by a vertical line from the abscissa. Row E above the histogram indicates the number of snails in all the size classes at the respective sample date.

Because the numbers of eggs and numbers of eggs per mass oviposited is important in ascertaining mortality and natality rates for each population, and in determining if the populations react in a density-dependent fashion, these data are given in conjunction with the histogram (fig. 2). Each egg mass was counted, as were the numbers of eggs in each mass. The state of development; prelarval (0.2 mm), larval (0.4-0.5 mm) and possession of a protoconch (0.8 mm) were noted. Since prelarval (newly laid) eggs observed at week X would

also be present at week X+1 (because development took 2-3 weeks), those eggs which included young with protoconchs (before hatching) at week X+1 were not included in the total count of eggs for that week. The numbers in row A, above the histogram, represent the relative number of eggs collected on each sample date. The percentages were found by using 100% to represent the maximum number of eggs ever collected during any one sampling period during the year. Row B includes a series of circles with the darkened areas illustrating the data in row A. Row C shows the average number of eggs for each sample date and Row D the average number of eggs per mass. The percentage of survival of eggs was computed from data representing the differences in averages of eggs per mass between prelarval and protoconch stages of development.

Size-weight regressions (Sokol and Rohlf, 1969) were used to obtain biomass and growth rate statistics because during routine sampling only the dimensions of the organisms were recorded. It was necessary to use this technique

to keep disturbances in the sample area at a minimum (Eckblad, 1971a). Sixty *H. anceps* were collected for size-weight (wet weight of shell and soft parts) measurements from areas adjacent to the transect. Analysis of each regression line indicated three slopes that were evident at various periods during development. Therefore three equations were computed for the best fit (fig. 3). A semi-log graph was used with weight in grams as the ordinate on the log scale and snail diameter in mm as the abscissa.

In calculating biomass, the total weight was determined by adding the weight of each class obtained from the diameter-weight regression line (fig. 3). Density was determined by counting the total number of snails per sample. In figure 4 the left vertical scale illustrates the total number of snails per 1m² and the right vertical scale represents the total biomass in grams for that area.

The growth rate (r) reflects changes in weight (w) of a cohort as it develops over a time interval (t). The equation used to calculate these growth rates is $r = (\log W_1 - \log W_0) / t$

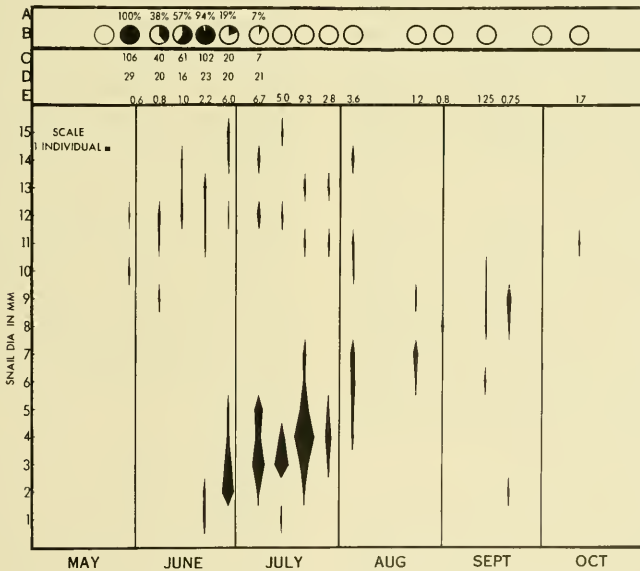


Fig.2 Size-frequency histogram *Helisoma anceps* Moe Pond 1971.

(Eckblad, 1971b). From the size-frequency histogram two cohorts were chosen and traced from 0.5 mm to 12 mm. The size class of each cohort on each sample date was determined and then its weight ascertained from the size-weight regression line.

Water samples were analyzed for pH using a Beckman pH meter (Model no. 1009). The Alsterberg modification of the Winkler method was followed for determining values of dissolved oxygen in ppm. Total alkalinity in ppm as CaCO_3 was ascertained by titration with 0.02N H_2SO_4 using methyl orange as the indicator. A nomograph was used to calculate CO_2 ppm (Moore, 1939).

Air and water temperatures were recorded on each sample date. Maximum-minimum thermometers left in the water for 24 hr. periods were used to determine diurnal temperature fluctuations.

RESULTS

Temperature measurements for Moe Pond, taken between 9 and 11 a.m., fluctuated greatly. The pond warmed from 5 to 21°C in less than one month. Oxygen values fluctuated between 3.8 and 8.2 ppm. The pH values were highest in June and September, (8.2-8.7). The lowest readings (7.3) were in August, 1971. Alkalinity followed pH in its basic changes; the highest values (38-40 ppm) being present in June, and lowest (19 ppm) recorded at the same times as the low pH values.

The life cycle of *Helisoma anceps* is illustrated graphically in figure 2. Eggs between 1 and 3 days old were found June 1, 1971. Oviposition by snails 8.5-12.4 mm in diameter continued until the first of July, but the rate steadily decreased after June first. *Helisoma anceps* oviposited the largest number ($\bar{x} = 73$ per sample) of eggs in June when snail density was low (less than 1 per meter at each sample date) and declined to zero in two weeks as snail numbers increased (0.6-6.7 per m^2). No eggs were produced after July.

During the reproductive periods the population exhibited a weekly variation in the average number of eggs per mass. Maximum numbers of eggs per mass occurred ($\bar{x} = 29$) the first week of the reproductive period (fig.

2). After this the number of eggs per mass averaged slightly less ($\bar{x} = 23-16$) until the end of the reproductive season. When egg laying ceased (July 14) the population decreased, but some adults persisted until May 1972. In May and June 1971 the ovipositing adults grew 1 to 4 mm in diameter. They reached about 11 mm in diameter in July at which time growth slowed appreciably.

One cohort (distinct groups hatching at different times the same summer) was present from the end of June, 1971 to the end of September when its members attained sizes ranging from 9.5 to 10.4 mm in diameter. There was no late summer cohort to supplement the June cohort so its individuals must have survived the winter in order to maintain the population. Two adults were found on June 21, 1971 that exhibited three varices, indicating a life span extending over three winters. Survival rates in 1971 were 0.1% from egg to adult and 10% from newly hatched young to adult.

Regression lines computed from the Height:Diameter data in figure 1 illustrate morphological differences in the shells during growth. The shells of young specimens exhibit H:D ratios somewhat greater than 1:1. Older shells appear more flattened with H:D ratios of about 1:2. Diameter-weight coordinates and regression lines (fig. 3) of *H. anceps* have a steep slope initially which levels off slowly when intermediate sizes are reached. The larger sizes result in the gentlest slope. This indicates that the larger snails gain less weight per unit diameter increase than the smaller gastropods.

Biomass and population density for *H. anceps* are shown in fig. 4. The biomass was large ($\bar{x} = 9.0 \text{ g/m}^2$) in June, July, and August. The population density was greatest ($\bar{x} = 180/\text{m}^2$) in July when the greatest number of immature snails was present. Biomass averaged 6.9 g/m^2 and density = $70/\text{m}^2$ between April and October, 1971.

Figure 5 indicates the changes in growth rate which occurred during five months in 1971. The growth rates are highest in June and July and gradually decline to near zero in October and November. Weekly fluctuations are evident, but it is evident that as the snails grow larger they increase in size at a slower rate.

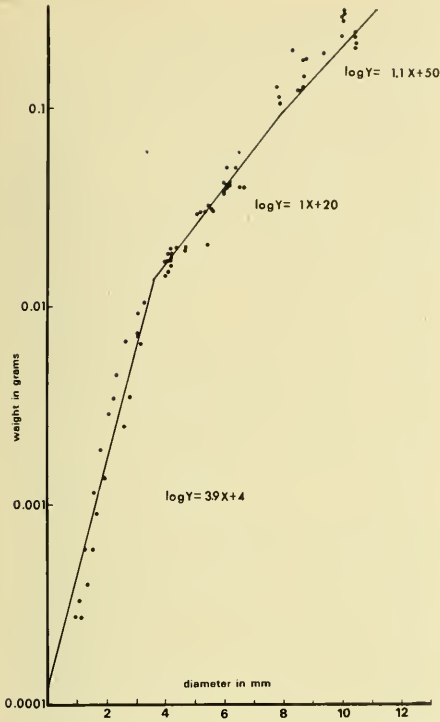


Fig.3 Diameter-weight regression. *Helisoma anceps*.

DISCUSSION

Freshwater pulmonate life cycles vary greatly but in the temperate zone annual life cycles are most common (Hunter 1961a, b, Boycott 1936).

Within this type of life cycle several patterns have been observed (Dewitt, 1955; Hunter, 1961a, b; Duncan, 1959; McGraw, 1959; Geldiay, 1956; Burkey, 1971; Gillespie, 1969). The mature members of the population may produce one, two or three cohorts or continuously produce throughout their reproductive period (Burkey, 1971; Walton and Jones, 1926). If there is more than one cohort, the first may be replaced or supplemented by the succeeding cohorts (Hunter, 1961a). Some individuals produced in one summer may grow and mature before overwintering; others may attain near maximum

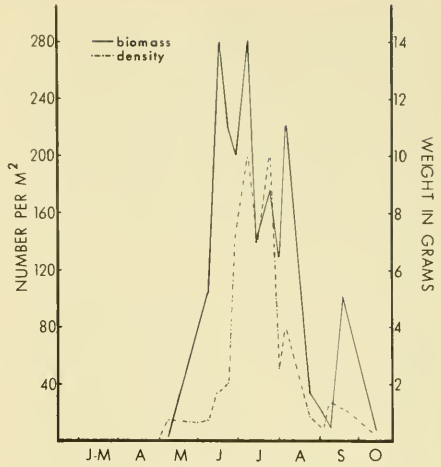


Fig 4 Biomass density *Helisoma anceps* Moe Pond 1971

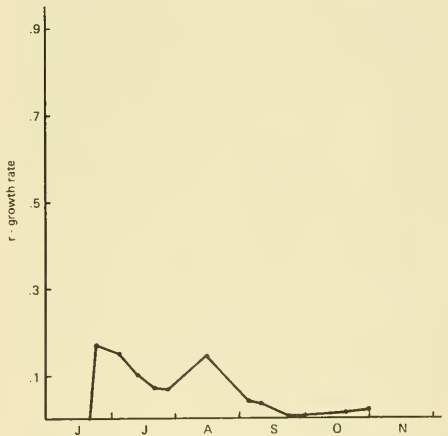


Fig. 5 Growth rate. *Helisoma anceps* Moe Pond 1971

sizes and mature after overwintering; or spend the winter as small immature individuals which grow the following spring before reaching maturity. Many species of larger pulmonates have biennial life cycles (Berrie, 1965). A true biennial lives for two years, reproducing the

second. The *H. anceps* population at Moe Pond was of this type.

There was one cohort which hatched in June 1970, maturing in May 1971. The adults which produced this cohort survived until late summer. Some individuals survive the second winter and reproduce again the following year. Evidence of this was the presence of varices, lines on the shell that reflect several months of slow winter growth. Two individuals were observed in June, 1971 which had survived a third winter.

Variation in initiation of oviposition, development of eggs, and fecundity of adults are related to physical and biotic factors. Other authors (Dewitt, 1954; Eisenberg, 1970) have observed differences in reproductive responses of gastropods due to these following environmental stimuli; temperature, population density, and nutrient availability. At Moe Pond the water temperature was 14-15°C (10:00 a.m.) when *H. anceps* egg masses were first observed (May 22, 1971). If a specific increase in temperature was necessary to stimulate oviposition, then an increase of less than 14-15°C was adequate. The total number of eggs produced by a snail during its reproductive period in this study appeared to be correlated more closely with population density than any other factor. This agrees with Eisenberg's (1970) conclusions on *Lymnaea elodes*. Egg production was highest when population densities were low. The fewest eggs were laid when the snails were very abundant or when they had reached the end of their reproductive period. The numbers of eggs per mass also directly correlated with population density. As shown in figure 2, eggs per mass were greatest when population density was lowest, and eggs per mass fewest when population density was at its greatest.

Frank (1968) suggested that there is a selection for early maturing snails in populations when individuals reach adult stages long before they die. Populations reproduce faster, therefore generation time decreases the earlier maturity occurs. In the populations studied, the observation that the most productive adults were not the oldest and largest snails, but the snails which had been mature for approximately a month, supports his hypothesis.

Two causes of mortality were apparent, physical stresses and predation. A small percentage (less than 1%) of overwintering adults, which did not succumb to these factors probably died of old age.

The organisms observed in this study were not obviously influenced by the chemical parameters measured. The data collected were within the ranges given by Harman and Berg (1971) for central New York where these chemical parameters were considered to be unlimiting.

The presence of ice effects the distribution of snails. In Moe Pond the transect area was frozen solid, including several cm of substrate, most of the winter and therefore uninhabitable. Cheatum (1934) noted that some snails migrate to deeper water during periods of ice cover, some species of *Helisoma* burrow in the substrate (Clampitt, 1972), while others have been seen crawling on the underside of the ice (Harman, unpublished).

The population considered in this study had a density (less than 1/m²) during the winter period. Despite this, the population density increased considerably in the spring because of the high fecundity of adult snails. Therefore, the high percentage of winter mortality is compensated for, and does not influence the population density the following year (Eisenberg, 1966, 1970).

Fluctuating water levels in June and July often exposed a strip of substrate 5 to 10 cm wide along the shore within short period. Since egg masses required 1 to 2.5 weeks to develop, those oviposited in the shallowest areas were often exposed to the air. After hatching, the young snails migrated to eulittoral areas. They often crawled completely from the water, were stranded and died.

The littoral substrates at Moe Pond are heterogeneous, supplying food to snails and providing cover from predators. The leech, *Helobdella stagnalis* was abundant in the study area. The number of leeches fluctuated directly with the snail population or lagged behind by one or two weeks. *Helobdella stagnalis* extracts the fluids from snails, eventually sucking in all the soft parts (Mann, 1955). Murdoch (1971) concluded that the more prey there are, the more predators, so a constant percentage of animals is usually

removed from the population. However, if a particular size class is decimated, predators may play a role in population density regulation (Brockelman, 1969). Predators observed in this study appeared to contribute substantially to snail mortality when population densities were high.

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OBITUARY

JOHN QUINCY BURCH (1894-1974)

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The name of Burch is a hallmark in the twentieth century history of Pacific Coast malacology. Patriarch of this clan was the world-known shell and book dealer, mollusk researcher, and editor, John Q. Burch. "John Q.", as he was familiarly called by thousands of his friends around the world, was born on June 20, 1894, in Chillicothe, Livingston County, Missouri, and died on August 7, 1974, at the age of 80, at Seal Beach, California.

His family moved to El Paso, Texas, in the 1900's, where he met and later married Rose

Adams. John Q. was the youngest in his El Paso High School class, and excelled in football and won the gold medal for debating. He received his law degree in 1915 at the University of California, after attending Texas University at Austin for three years. After serving as an aviator in World War I, he was a salesman for a law book firm in California from 1918 to 1944, and was also briefly associated with Rose in the Nogales Seed Merchant Co. in Arizona in 1922.

John Q.'s first interest in shells was obtained from his son, Thomas Adams Burch, who in 1940-41 was President of the Conchological Club of Southern California. John Q. became the next president, and one of the originators and the editor of the monumental Minutes of the Conchological Club of Southern California. The entire family soon became very active in collecting and dredging for shells, including his daughter-in-law Beatrice Burch. In 1944 he



FIG. 1. John Q. Burch in a formal portrait taken in 1942.



FIG. 2. John Q. Burch on Christmas Day, 1966, on his son's boat, Janthina V, at Cholla Bay, California.

began a long and successful career as a dealer in shell books and specimen shells. He became a life member of the American Malacological Union in 1959, and belonged to many other conchological and scientific societies.

One of his greatest contributions was the voluminous "Minutes" that he composed, typed and mimeographed. They not only included valuable contributions by people such as A. G. Smith, Myra Keen, A. M. Strong, and George Willett, but during the war years, especially, kept everyone informed of conchological happenings around the world. He contributed several hundred articles himself. These are listed in the Index to the Minutes prepared by A. G. Smith (Minutes 169, 199, 200). The 200th

and last number was issued in June 1960.

John Q. was an affable and always helpful gentleman. Few shell dealers ever attained his reputation for honesty and constant attempt to give the best locality data possible. Museum and private collections throughout the world are the richer for the many splendid samples of mollusk material dredged off Redondo Beach, California, and elsewhere. This is a lasting monument to a beloved conchologist who will be remembered for centuries to come.

A longer biography, including a list of his 37 articles on mollusks, was published by his daughter-in-law, Beatrice, in *The Tabulata*, Vol. 4, no. 1, pp. 7-12, in January 1971.

USE OF DISPOSABLE BEVERAGE CONTAINERS BY THE FRESHWATER CLAM,
CORBICULA

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Utilization of disposable beverage containers by fishes has been reported by Kottcamp and Moyle (1972), but to the author's knowledge their use by invertebrate animals has not been reported.

Living specimens of the introduced Asiatic freshwater clam, *Corbicula manilensis* (Philippi, 1844) were found in surprising abundance in discarded disposable beverage containers, during the 1972-1973 dewatering of the Delta-Mendota Canal in central California. The beverage containers were examined by biologists from the Department of Ichthyology, California Academy of Sciences, while conducting a survey of the fish in the canal. Examination of beverage containers was conducted with the hope of gathering data to compare to the Kottcamp and Moyle (1972) paper which reported the use of cans by fishes in neighboring waters.

Of the more than 50 cans and bottles examined, all contained clams with approximately 80% totally full. The absence of available space is most likely the reason that no fish were found occupying the containers.

In approximately 20% of the containers that were opened for closer examination, some of the clams were seen to be as much as twice the size of the original opening of the container, indicating substantial growth during occupancy of the container. None of the clams seemed to be in any way affected by their occupancy in the containers.

In the Delta-Mendota Canal huge beds of *Corbicula* were built up on the inside radius of the turns and behind obstructions such as check structures and sunken automobiles. The means by which the containers became filled with clams is probably hydrolics and voluntary movement. Sedimentation and clam transport in the canal were seen to be quite dramatic as abandoned cars hauled out of the canal were found to be filled to the windows with mud and clams. Upon opening a locked fishing tackle box recovered at the bottom of the canal, live clams were found inside.

Other invertebrate species found to be living in the containers were the brackish water crab, *Rhithropanopeus harrisi*, tubificid worm, *Branichyura sowderii*, and isopod, *Gnorimosphaeroma lutea*.

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AN ANOMOLOUS SEX-RATIO IN THE SUBLITTORAL MARINE SNAIL,
LACUNA VINCTA TURTON, FROM NEAR WOODS HOLE¹

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ABSTRACT

Sampling of a natural population of Lacuna vineta Turton near Woods Hole, Massachusetts, over the summers of 1968-1973 showed significant differences between the sexes in mortality. By early July, after the principal reproductive period, all the larger snails in the population are male. This anomalous dimorphism is discussed in relation to the more usual pattern of large females surviving longer, and to alternative hypotheses regarding the bioenergetics of reproduction.

Among the most common small snails living in the lower intertidal and shallow sublittoral of the temperate Atlantic and Pacific coasts is the mesogastropod prosobranch, *Lacuna vineta* Turton. Generally placed in the Stirps or Superfamily Littorinacea, the genus *Lacuna* shares many features of reproductive and somatic physiology with the more aquatic littorinids such as *Littorina obtusata* L. Like most mesogastropods *Lacuna vineta* has separate sexes. During several summers (1968-1973) we have been collecting *Lacuna vineta* around Woods Hole, Massachusetts, for use in respiratory studies (McMahon and Russell-Hunter, 1973), and in comparative studies of egg-production bioenergetics (see Russell-Hunter, 1970, pages 179-181). The majority of our collections have been made on a boulder-beach below the lighthouse at Nobska Point (41° 30'54"N; 70° 39'20"W). It has become obvious to us that, as regards the survivorship of larger (overwintered) snails, each year in late spring and early summer, there is a great disparity between the sexes. Proportionately more females die, so that by early July all the larger snails in the population are male. Our most detailed sampling was done in 1969 and 1973, and Figure 1 presents a summary of the data for

these years as the successive stages of a single generation. It can be seen that the sex ratio of males: females changes from about 50:50 (from November through March) to about 60:40 in May and to about 70:30 by the end of June. By mid-July, the only survivors of the generation (now 11-14 months old) are male. This has been true for all six summers observed. Egg-laying has been observed in the field population from March through early June. Comparison of size distributions for the earlier samples (Figure 1) shows the females as having grown somewhat more rapidly than the males. Further, if we allow for appropriate adult growth rates through the spring and summer months, it is clear that the mortality rates in June and July are higher for larger snails than they are for smaller, in addition to being higher for females than for males.

All of our sex determinations were made on freshly-collected living samples before shell-measurement and fixation, and we used the presence or absence of the penis (which in *Lacuna* is relatively large and prominent) in our determinations. We are very unlikely to have overestimated the number of males. In such gonochoristic prosobranchs, underestimation of the number of males in a population is much more likely due to regressive changes in penial structures which can occur either naturally in some sexual cycles

¹ Supported by a research grant from the National Science Foundation, grant #GB-36757, to Dr. W. D. Russell-Hunter.

(Jenner and Chamberlain, 1955; Jenner, 1956), or in certain abnormalities of host reproductive physiology induced by parasitic infections (Rothschild, 1936). It is also worth noting that the greater survivorship of males in the field is not paralleled in the laboratory. Paired snails used in our laboratory assessments of fecundity showed no differential survival between the sexes after reproduction ended. Lastly, extensive collecting of other species in and around the population site for *Lacuna* enables us to say with some degree of certainty that the changing sex ratios in the natural population are the result not of any differential migration to an-

other habitat but of real differential mortality.

In almost all other cases where differences in mortality between the sexes have been reported in snails, these differences operate in favor of females: in other words, as each cohort ages, the proportion of larger female snails increases. Pelseener (1926) noted such female proportions in populations could rise to 63% in *Rissoa parva*, 80% in *Bithynia leachi*, and 60% in *Nassarius reticulatus*. In his classic study of life-cycle in *Littorina littorea*, Moore (1937) found the percentage of females to rise to 76.9% in a population at Trevol, near Plymouth, England, U. K.

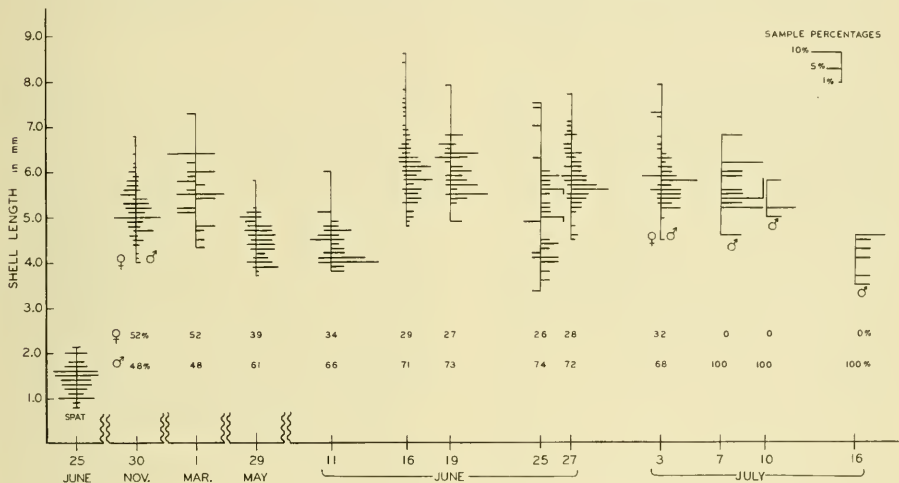


FIG. 1: Changes in size and sex distribution in relation to survivorship in a natural population of *Lacuna vineta* Turton. Sets of histograms show size distributions in samples of *Lacuna* from Nobska Point, near Woods Hole, Massachusetts, presented as the successive stages of a single generation (although the data are derived from two summers, 1969 and 1973); note that the horizontal axis is only a continuous scale of time after (i.e., to the right of) June 11. Except for one histogram of spat on the extreme left, each histogram shows the shell sizes and relative numbers for females on the left and those for males on the right. To facilitate comparisons, the first eleven of the histograms indicate the percentage of the total sample (both sexes) in each class interval of shell size. The actual sample numbers fell from 126 (Nov. 11) to 14 (July 7); difficulty of collection reflecting mortality. The last two histograms (for July 10 and July 16) are arbitrarily not plotted as percentages since they represent the very small samples, 4 and 7 respectively, of the longest-lived male members of the generation. The two lines of numbers below the histograms of adult snail samples represent the relative percentages of females and males: the changing sex ratios of the generation.

The pattern of differential survivorship which we have found in *Lacuna vineta*, with a generation (or combined cohorts) coming to consist entirely of large males, is unusual and biologically anomalous. In general, the usual patterns with disproportionately more large females surviving are clearly of adaptive value in any situation of competition for food or other limiting resource. This is so largely because (in most snails which have been investigated) a *single* successful copulation can provide for a long subsequent period of fertile egg-production. In the opinion of one of us (W.D.R.H.), these patterns, and the two more widely distributed phenomena of protandry in hermaphrodites and of sexual dimorphism with large females, are inextricably linked to the greater bioenergetic cost of "femaleness" (especially in egg-production) implicit in much of our earlier work on molluscs (Apley, Russell-Hunter and Avolizi, 1967; McMahon, 1974; Russell-Hunter, 1970; Russell-Hunter, Apley and Banner, 1971; Russell-Hunter, Apley and Hunter, 1972). On the other hand, some other theoretical biologists concerned with the evolution and genetics of sexual dimorphism (such as Scudo, 1973) emphasize the advantages of having larger numbers of smaller, more mobile, males. These two adaptive hypotheses are not necessarily mutually exclusive, and some combination of them could account for the evolution of the more common patterns of differential mortality of the sexes (with females surviving). The opposite disparity, with large males surviving preferentially which we have found in *Lacuna*, is anomalous and remains enigmatic.

ACKNOWLEDGMENTS

We are grateful to several colleagues for help in collecting — John L. Banner III, Martyn L. Apley and Jay Shiro Tashiro — and to Sandra E. Belanger and Perry Russell-Hunter for help in preparing this manuscript.

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BIOMPHALARIA HAVANENSIS (PFEIFFER) FROM GRENADA, WEST INDIES¹

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ABSTRACT

The freshwater planorbid snail, Biomphalaria havanensis (Pfeiffer), is recorded from three localities on Grenada Island, Lesser Antilles. The shell and genitalia are described and illustrated. Live snails were exposed to both the *St. Lucian* and *Puerto Rican* strains of *Schistosoma mansoni* but none became infected, although control infections of *B. glabrata* were 85% successful. Grenada snails identified by E. A. Smith in 1895 as *Planorbis terverianus* Orbigny and by C. S. Richards in 1973 as *B. straminea* (Dunker) are *havanensis*.

Not much has been written on the molluscan fauna of the West Indies island of Grenada. The only record I could find is a report by E. A. Smith (1895), on a very few land and freshwater shells. One of these was identified by Smith as *Planorbis terverianus* (Orbigny). There has been interest in the last decade in the freshwater planorbid species of the West Indies because of the medical importance of some of them. Many of these species have in the past been placed under the genera *Planorbis*, *Tropicorbis* and *Australorbis*. I am abiding with the decision of the International Commission on Zoological Nomenclature (Opinion 735, 1965) in giving precedence to *Biomphalaria*.

In 1965, I made a survey of some Caribbean islands including Grenada to determine the actual and potential hosts of *Schistosoma mansoni*, and the endemicity or non-endemicity of the disease schistosomiasis on these islands. The biomphalarid material I collected on Grenada were *Biomphalaria havanensis* (Pfeiffer, 1839) as indicated in this present paper. The field-collected adult snails were found to be non-susceptible to *S. mansoni*. In view of a recent finding (Richards, 1973) that juvenile biomphalarids, identified by him as *Biomphalaria straminea* from one of my collection sites on

Grenada, are susceptible to infection with *S. mansoni*, a clarification of the identity and morphology of these snails is of significance. A report on some other freshwater and land snails

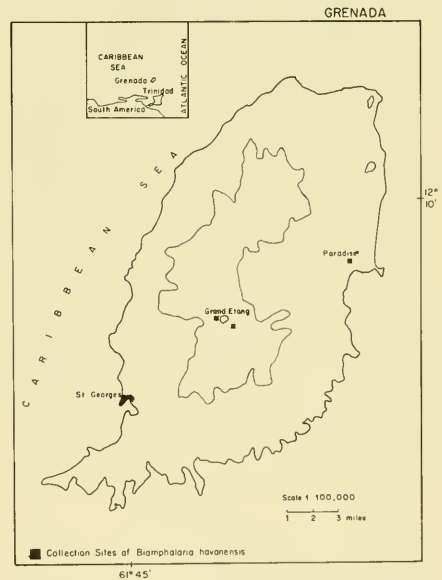


FIG. 1. Map of Grenada showing collection sites of *Biomphalaria havanensis*. Shaded area indicates the central highlands.

¹ This investigation was supported by a Research Career Award number K6-AI-18, 424, and by research grant number 1 R22, AI-11645, from the U.S. Public Health Service national Institute of Allergy and Infectious Diseases.

from Grenada will appear in a forthcoming paper.

Grenada of the Lesser Antilles, lies about 90 miles north of Trinidad and the South American coast in the Caribbean Sea (Fig. 1). The terrain is mountainous, but gentler slopes occur on the eastern and southwestern coasts. The high mountains extend almost longitudinally in the center, and from these mountains arise streams in all directions towards the sea. Rainfall varies considerably and is as low as 40 inches per annum on the dry southwest coast, and exceeds 150 inches in the central highlands. The dry season occurs from January to May and the wet season from June to December with November as the wettest month. Temperatures are relatively constant, fluctuating between 78 and 90° F during the day, and between 65 and 75° F at night.

HABITATS

During this partial survey *Biomphalaria havanensis* was located in three sites:

1. Grand Etang Lake: This lake is perched 1740 feet above sea level in a volcanic crater, and is over two miles in circumference. It is larger than two other lakes, Antoine and Levera in the north of the island. Red soil is characteristic of the area of Grand Etang Lake; there is not much in the way of aquatic vegetation, but sedges and bank vegetation are common. The snails were found in shallow, quiet waters along the bank.

2. Stream arising from Grand Etang Lake: The snails were located at about one to one and a half miles from the lake. The stream is narrow, about six feet in width, but is deep.

3. Creek in the vicinity of Paradise, in the east central part of the island: A large number of snails were collected from this site. The creek is about four feet in width and only about one to two feet in depth. The snails were found on many decaying leaves on the mud bottom.

DESCRIPTION

The descriptions below are of Grenada specimens of *B. havanensis*.

Shell (Fig. 2): The diameter of the shell in my material does not exceed 8 mm, nor the height 2 mm. In these specimens the shell has

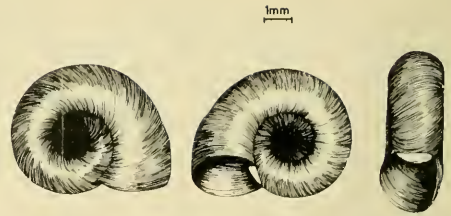


FIG. 2. *Shell* of *B. havanensis* from Grenada, in right (upper, umbilical), left (lower, spire) and apertural view. The right and left sides of the shell, as indicated here, are in relation to the living animal.

up to 45 whorls increasing moderately in diameter; they are rounded and are separated by moderate sutures. In some specimens the whorls look bluntly subangular. The right (upper or umbilical) side is shallow with a central notch which may be deep in some specimens especially the large ones. The left (lower or spire) side is broadly and shallowly concave. The aperture is heart-shaped and is deflected to the left, especially in adult specimens. The peristome is thin and continuous. The shell is encrusted with black deposits in the population from the creek near Paradise, while these deposits are reddish to pink in the populations from the other two sites.

Animal: Twenty snails were dissected for morphological details of the animal. The exterior of the animal is pale gray. The mantle is studded with distinct rounded or elongated black or gray spots, more numerous in the population from creek near Paradise than in the other two populations. In the pallial cavity, there is no renal ridge on the ventral surface of the kidney. However, the dorsal mantle ridge and rectal ridge are both present and are quite distinct. The teeth of a radular half row on either side of the central tooth are: 7 or 8 laterals, 1-2 intermediates, and, from the 10th tooth on, 9-11 marginals. The mesocone on the lateral teeth is dagger-like, triangular and is sharp and pointed. In the genitalia (Fig. 3) the ovotestis has several diverticula, arranged in transverse rows of two or three, predominantly unbranched and are club-shaped. The seminal

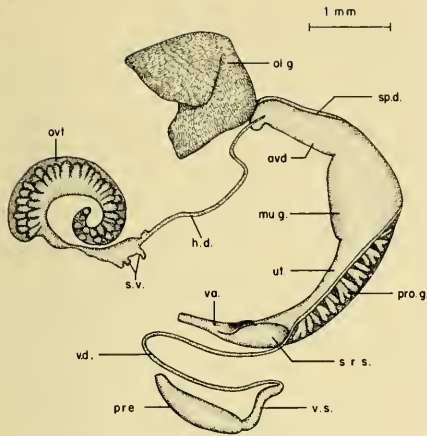


FIG. 3. Dissected genitalia of *B. havanensis* from Grenada. **al.g.**, albumen gland; **h.d.**, hermaphroditic duct; **mu.g.**, muciparous gland; **ovd.**, oviduct; **ovt.**, ovotestis; **pre.**, preputium; **pro.g.**, prostate gland; **sp.d.**, sperm duct; **s.r.s.**, seminal receptacle sac; **s.v.**, seminal vesicle; **ut.**, uterus; **va.**, vagina; **v.d.**, vas deferens; **v.s.**, vergie sac.

vesicles are finger-like. The prostate has an average 16 short and branched tubules. The spermathecal sac is club-shaped, and its duct is short, about half the length of the sac. The vagina to the right of the spermathecal duct has a poorly developed vaginal pouch when compared to that in certain other species.

In specimens measuring 5 to 7.5 mm in shell diameter and 1.8 to 2 mm in height, the female genital tract averaged 6.4 mm. The length ratio (calculated from average measurements of 20 genitalia) of female tract (=1), that is, from the point of bifurcation of hermaphroditic duct to female genital opening, to: oviduct, 0.40; penial complex, 0.38; hermaphroditic duct, 0.40; prostate, 0.38; spermathecal duct and sac, 0.15. The preputium, 1.45 mm, is longer than the vergie sac which is 1.0 mm.

SUSCEPTIBILITY TO *SCHISTOSOMA MANSONI*

Experiments were carried out to test the susceptibility of *B. havanensis* from Grenada to

infection with two strains of *S. mansoni*, one from Puerto Rico and the other from St. Lucia. The snails were exposed individually to about 10 miracidia of the schistosome. The exposure temperature and the maintenance temperature after the exposure was 24 to 25 C. For the Puerto Rican strain of *S. mansoni* the following snails were exposed: 65 snails measuring 5.5 to 7.5 mm in diameter from Grand Etang Lake, and 79 snails measuring 5 to 8 mm in diameter from creek near Paradise. For the St. Lucian strain 182 snails measuring 6 to 7.5 mm in diameter from creek near Paradise were exposed to the miracidia. No *B. havanensis* became infected when observed starting a month after exposure, while up to 85% of *B. glabrata* from Puerto Rico exposed in each case as controls became infected and released cercariae.

DISCUSSION

My survey did not cover the entire island, but *Biomphalaria havanensis* is apparently widely distributed judging by finding it in three localities during this partial survey. Moreover, Smith (1895) reported his *Planorbis terverianus* from a small ditch near St. George's, in the southwestern part.

In the morphological part of this investigation criteria established by the author (1969) for the differentiation of biomphalarid species of the neotropics are followed in this present paper for the identification of the biomphalarid material from Grenada. These criteria are shell characteristics, shape of mesocone on the radular lateral teeth and, more importantly, characteristics of the genitalia, in particular characteristics of the prostate gland and vagina, the length ratio of preputium to vergie sac, and the length ratio of the female genital tract to oviduct, to penial complex, to hermaphroditic duct, to spermathecal duct and sac and to prostate. On the basis of these characteristics and ratios as described above in this paper the Grenada biomphalarid is *B. havanensis* (Pfeiffer). The hermaphroditic duct in the Grenada material is, however, slightly shorter than that in the typical *B. havanensis*. I regard Smith's (1895) *Planorbis terverianus* Orbigny a synonym. The type locality of *havanensis* Pfeiffer, 1839, and *terverianus* Orbigny 1841, is

Havana, Cuba. The snails from the volcanic lake (Grand Etang Lake), those from the stream arising from the lake, and those from the creek near Paradise agree anatomically and in shell characteristics. However, those from the first two habitats have a lightly pigmented mantle. This is only an ecological difference and does not warrant their separation taxonomically.

In his recent short research note on the susceptibility of the Grenada specimens to infection with *S. mansoni* Richards (1973) identified his specimens as *Biomphalaria straminea* (Dunker). They were collected for him by Dr. F. F. Ferguson of Puerto Rico. On the basis of my study the snails from Grenada are definitely not *B. straminea* because of the following reasons: 1. The vagina does not have transverse folds on the right of the spermatheca which give it a corrugate appearance, something which is characteristic of *B. straminea*. Moreover, a vaginal pouch is present, although small, while it is absent in *B. straminea*. 2. The length ratio of preputium to vergic sac is different. The vergic sac is either equal to, or longer than preputium in *B. straminea*, whereas it is shorter than preputium in the Grenada material, that is, *B. havanensis*. 3. The length ratios of female genital tract to other parts of the genitalia are different. For example, in my Venezuelan material of *B. straminea* (Malek, 1969) the ratios are: female tract (=1) to penial complex, 0.50; to hermaphroditic duct, 0.52; to spermathecal duct and sac, 0.25; to prostate, 0.40. In the Grenada *B. havanensis* the same ratios are as follows: 0.38; 0.40; 0.15 and 0.38.

Baker (1945), page 500, lists *Tropicorbis gundlachi* (Dunker) from the nearby island of Trinidad. Apparently on the basis of the shell Baker synonymized *T. gundlachi* with *T. stramineus*. His figures 33-35 show that his snail, that is, *T. gundlachi* from Trinidad, is

probably also *B. havanensis*, but this conclusion should await anatomical studies.

As to the host capacity of the Grenada biomphalarids my results agree with those of Richards (1973), that adult snails are not susceptible to infection with *Schistosoma mansoni*. It is of interest, though, that Richards found that juvenile snails are susceptible to infection with the same blood fluke. It should be noted that schistosomiasis is not endemic on this West Indies island. During my stay on the island I checked with public health officials, and examined some hospital records and confirmed the truth of this contention. With human population movements, however, there is the possibility of introduction of the disease from some neighboring islands where the disease is endemic because of the existence on Grenada of susceptible snail intermediate hosts.

ACKNOWLEDGMENTS

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POPULATION CHANGES OF THE APPLE SNAIL, *POMACEA PALUDOSA*,
IN THE SOUTHERN EVERGLADES

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ABSTRACT

A six-year program of monthly sampling of aquatic animals in the southern Everglades, Florida, provided information on population changes of *Pomacea paludosa* in relation to two water regimes — fluctuating water levels with seasonal drought and continuously high water levels. Higher population levels were attained under more permanent water conditions. However the average size of snails was smaller indicating increased juvenile recruitment. Larger snails apparently survived drought better than did smaller snails.

The apple snail, *Pomacea paludosa* (Say), occurs in the extreme southeastern United States in southern Alabama, southern Georgia and throughout the Florida peninsula. It is especially common in the freshwater wetlands of southern Florida where it forms an important intermediate link in the aquatic food chain. The endangered Everglade kite (*Rostrhamus sociabilis*) is almost completely dependent on the snail for food (Strieglitz and Thomson 1967). The limpkin (*Aramus guarana*) feeds heavily on *Pomacea* (Harper 1936, 1941; Cottam 1941), and the snail forms an important part of the diet of more euryphagous avian predators such as the boat-tailed grackle (*Cassidix mexicanus*) (Snyder and Snyder 1969) and the white ibis (*Eudocimus albus*) (Kushlan in prep.). Young alligators (*Alligator mississippiensis*), snapping turtles (*Chelydra serpentina*) and other aquatic predators also consume this snail.

Despite its ecological importance and recent reduction in numbers due to habitat alteration (Heard 1970, U.S. Department Interior 1973:120), little is known about the ecology of this species. It is most active at night and is capable of aestivation by burrowing in the mud when marshes begin to dry. Survival during such periods is evidenced by the appearance of egg clusters soon after water levels rise. Survival through drought is of critical importance in the marshes of the southern Everglades which typically experience a seasonal fluctuation

of water level and are usually without surface water during the latter part of the dry season. In some years which do not follow the typical pattern, water remains above ground level throughout the year.

A program of quantitative sampling of aquatic organisms from 1966 through 1972 provided information on the abundance and size distribution of *Pomacea* in the southern Everglades of Everglades National Park. The purpose of this paper is to describe changes in the population of *Pomacea paludosa* over the 6-year study period especially in relation to population differences between years of typically fluctuating water conditions and years of extended high water levels. In as far as seasonal fluctuation or stable high water conditions are representative of snail habitats in other areas of southern Florida, implications can be drawn concerning the role of water levels in other parts of the snail's range.

METHODS

Data discussed in this paper were collected as part of a more extensive program to monitor populations of aquatic organisms in the southern Everglades conducted by the U.S. Geological Survey for the U.S. National Park Service. Samples were taken with ten 4.5 m² pull-up traps described by Higer and Kolipinski (1967). Traps were located in sawgrass marsh (*Cladium jamaicense*) and mixed-marsh prairie composed of several species of herbaceous plants (*Eleocharis cellulosa*, *Rynchospora tracyi*). Traps

were generally used on two consecutive nights each month. These samples generated monthly averages for the number of snails per square meter, the wet weight biomass (including shell) of snails per square meter, and the average weight per snail. In order to take into consideration any seasonal changes in snail population, an average value of each parameter was calculated for each hydrologic year which runs from the beginning of the rainy season in June to the end of the dry season the following May.

RESULTS AND DISCUSSION

Fig. 1 shows how water level fluctuated in the southern Everglades from 1966 through 1972. The typical water level pattern characterized by low water levels during the dry season, occurred in the hydrologic years of 1966-67, 1967-68, 1970-71 and 1971-72. From 1968 to 1970 water levels were continuously high. Fig. 1 also shows the average abundance, biomass and size of snails each year. The data from the hydrologic years of 1968-69, 1969-70 and 1970-71 reflect changes in the snail population coincident with prolonged high water. It is apparent that both abundance and biomass increased during the high water and then declined when the typical pattern was re-established after 1971. The average size of snail decreased during the high water period probably due to higher production and survival of young snails. Average size increased during 1971-72 suggesting that larger snails survived the dry period of 1970-71 better than did smaller snails and perhaps that juvenile recruitment declined.

In general, the results suggest that higher population levels are attained under more permanent water conditions in contrast to conditions in which surface water reaches low levels in the dry season. Apparently there is a differential survival of large snails through dry periods, and greater juvenile recruitment in constantly high water. As a result, the average size of snails is greater under conditions of fluctuating water levels.

It is not unlikely that these general relations hold in ecologically similar areas elsewhere in southern Florida. For example canal-edge marsh-

es, water impoundment marshes, and lake-edge marshes may have higher populations than the Everglades. It is not surprising therefore that these are preferred foraging habitats of the Everglade kite, limpkin and grackle. Limpkins and white ibis also feed on snails throughout the Everglades especially when water levels are low. However canal-edge habitats, such as those observed by Snyder and Snyder (1969), probably

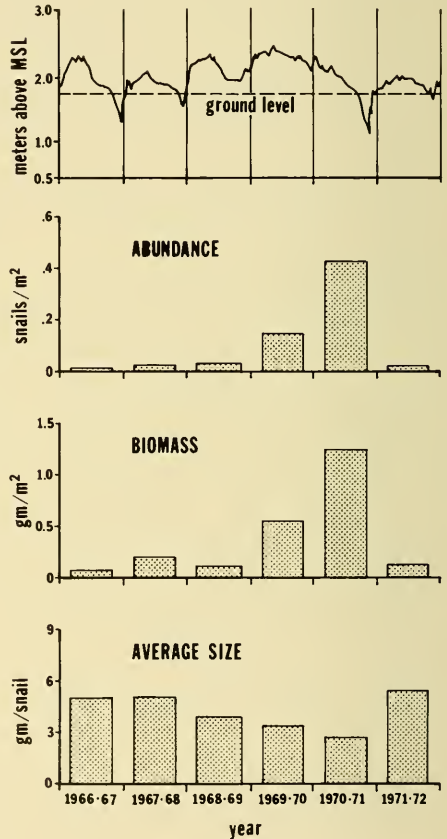


FIG. 1. Changes in water level and in the abundance, biomass and average size of snails in the southern Everglades from 1966 to 1972.

combine high snail densities with ready availability to avian predators.

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POSITION OF EPIPHRAGMS IN THE LAND SNAIL *OTALA LACTEA* (MÜLLER)

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ABSTRACT

Dormant land snails (Otala lactea Müller) were X-rayed to determine the position of the membranes (epiphragms) secreted across the shell aperture. Measurements of the distance between the mantle and the aperture rim (peristome) were made. Spacing between multiple epiphragms was determined. Data on epiphragm spacing and arrangement suggested that the extent of retraction of the snail body into the shell is not related to the total number of epiphragms secreted by a snail. As the number of epiphragms increases, the distance between the mantle and the epiphragm closest to it decreases. Similarly, the mean distance between successive epiphragms decreases as the total number of epiphragms increases.

INTRODUCTION

The formation of multiple epiphragms by land snails is generally interpreted as a response to conditions which threaten dormant snails. Grassé (1968) views the production of more than one epiphragm as a reaction to the persistence of drought. Cooke *et al* (1895) report that multiple epiphragms are laid down as the length of hibernation increases. Cadart (1955)

proposes that with each retraction of the snail body into its shell, a new "veil" is produced.

A number of recent studies have been made to assess the functional role of the epiphragm as a barrier to water loss (Machin, 1967, 1968; Schmidt-Nielsen, 1971). The studies described here represent an attempt to identify the manner in which epiphragms are laid down, i.e., their position relative to the snail body and



FIG. 1. Typical contact print from a radiograph of a dormant snail. The four small arrows indicate the position of four calcified epiphragms; the larger arrow points to the mantle.

aperture. It is hoped that this information can be used to design a compartmentalized model of the snail shell, body and epiphragms. The model would enable one to account for water exchange between the snail and its environment.

MATERIALS AND METHODS

Adult *Otala lactea* (Müller) were imported from Morocco. The dormant snails were placed on sheets of Kodak No-Screen Medical X-ray film at a target-to-sample distance of 85-90 cm. They were oriented so that the outermost epiphragm was approximately perpendicular to the plane of the film. A Universal X-ray Products dental unit with no added filtration operating at 60 kV was set to provide 12 mAs-exposures. This particular setting provided an image of the shell, mantle and epiphragms; the number of epiphragms for each dormant snail was "read" from the X-ray images (Fig. 1).

Estimates of maximum spacing between successive epiphragms were obtained by placing a fine wire (Marked off at 1 mm intervals) along the upper curvature of the X-ray image of the

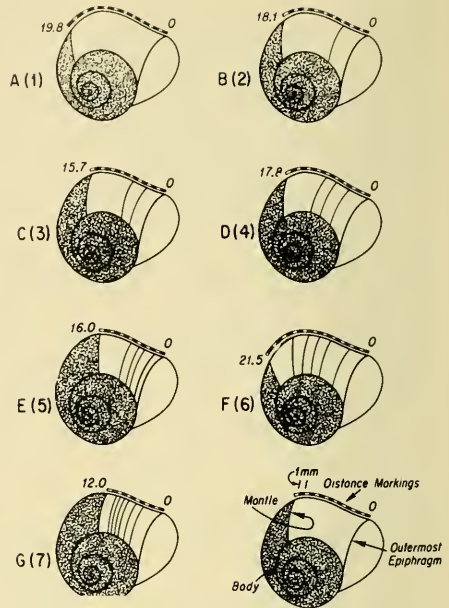


FIG. 2. Schematic representation of epiphragm spacing as a function of the total number of epiphragms. The seven views (coded A-G) correspond to "model" snails with 1-7 epiphragms. The numbers in parentheses indicate the total number of epiphragms in a given view.

shells. Distances were measured to the nearest 0.5 mm. Films were viewed under a dissecting microscope ($\times 7$).







RESULTS

The analysis of X-ray images of 112 dormant snails showed that as the number of epiphragms per snail increases, the distance between the mantle and the epiphragm closest to it decreases (Table 1, Fig. 2). The table also indicates that the distance between the mantle and the outermost epiphragm (the one closest to the aperture) remains virtually unchanged as the number of epiphragms per snail increases. Calculation of the mean distance between successive epiphragms revealed a general decrease

TABLE 1. *Measurement of Epiphragm-Mantle Distances.*

Total number of epiphragms	N	Mean distance between mantle and closest epiphragm (mm)*	Mean distance between mantle and epiphragm nearest aperture (mm)*
1	36	19.8 ± 1.5	19.8 ± 1.5
2	27	13.1 ± 1.4	18.1 ± 1.8
3	25	8.9 ± 0.9	15.7 ± 1.3
4	17	8.4 ± 1.4	17.8 ± 1.7
5	4	7.2 ± 3.4	14.0 ± 3.6
6	2	5.5 ± 1.2	21.5 ± 1.5
7	1	2.0 ± 0.0	12.0 ± 0.0

* $\bar{X} \pm SE$ TABLE 2 — *Mean Distances between Successive Epiphragms (mm)**

	EPIPHRAGM INTERVAL	TOTAL NUMBER OF EPIPHRAGMS					
		2	3	4	5	6	7
	1-2 (nearest the mantle)	5.1 ± 0.6	3.1 ± 0.3	2.4 ± 0.2	1.8 ± 0.4	3.5 ± 1.5	1.0
	2-3	—	3.7 ± 0.3	2.9 ± 0.4	1.1 ± 0.1	2.0 ± 1.0	1.0
	3-4	—	—	4.1 ± 0.7	2.1 ± 0.4	2.5 ± 0.5	1.0
	4-5	—	—	—	1.8 ± 0.2	4.5 ± 0.5	1.5
	5-6	—	—	—	—	3.5 ± 0.5	1.5
	6-7 (farthest from the mantle)	—	—	—	—	—	4.0
MEAN DISTANCE BETWEEN ALL EPIPHRAGMS †		5.1	3.4	3.1	1.7	3.2	1.7

* $\bar{X} \pm SE$

† Calculated as the distance between the first and last epiphragms divided by the number of intervening spaces.

in the length of the space between epiphragms as the total number of epiphragms increases (Table 2, Fig. 2). This tendency can be expected solely on the basis of the limited space made available by the confines of the rigid shell.

DISCUSSION

There are no documented reports of the analysis of spacing and/or arrangement of multiple epiphragms within the shells of land snails. This study raises the possibility that a

number of variables, either environmental or physiological or both, may influence the number and positioning of epiphragms.

An earlier investigation (Rokitka and Herreid, in preparation) showed that *O. lactea* form calcified epiphragms that vary in extent of calcification and in thickness. Furthermore, as the length of dormancy increases, epiphragm formation continues so that the epiphragms closest to the body may be formed days or weeks after the first epiphragms were laid down. This implies that the dormant snail periodically arouses, moves to within 2 to 4 mm of the last epiphragm and forms a new epiphragm only to retreat to its original dormant position. The close packing of the last epiphragms in a series is a necessary consequence of the limited space available to the snail if dormancy is prolonged.

The purpose of epiphragm formation is unknown. Epiphragms could serve as barriers to water loss during dormancy, and obviously multiple epiphragms are more effective than single ones. However, recent evidence suggests that the mantle rather than the epiphragm is the primary barrier to water loss (Machin, 1968, 1972). Epiphragms could serve as barriers to parasite invasion during dormancy as well. Alternatively, epiphragms may be merely temporary storage sites for mineral products. Changes in electrolyte composition of body fluids accompany or precede dormancy in many species. Changes in Mg/Ca ratio are well documented in mammalian hibernation where dormant animals have depressed blood calcium levels (Riedesel, 1960). In species such as the little brown bat the blood calcium level even varies with the depth of hibernation. Is it possible that multiple epiphragms are formed as

hemolymph calcium levels are lowered for prolonged dormancy in snails? Finally, it is noteworthy that snails arousing from dormancy usually eat their old epiphragms and presumably conserve calcium supplies.

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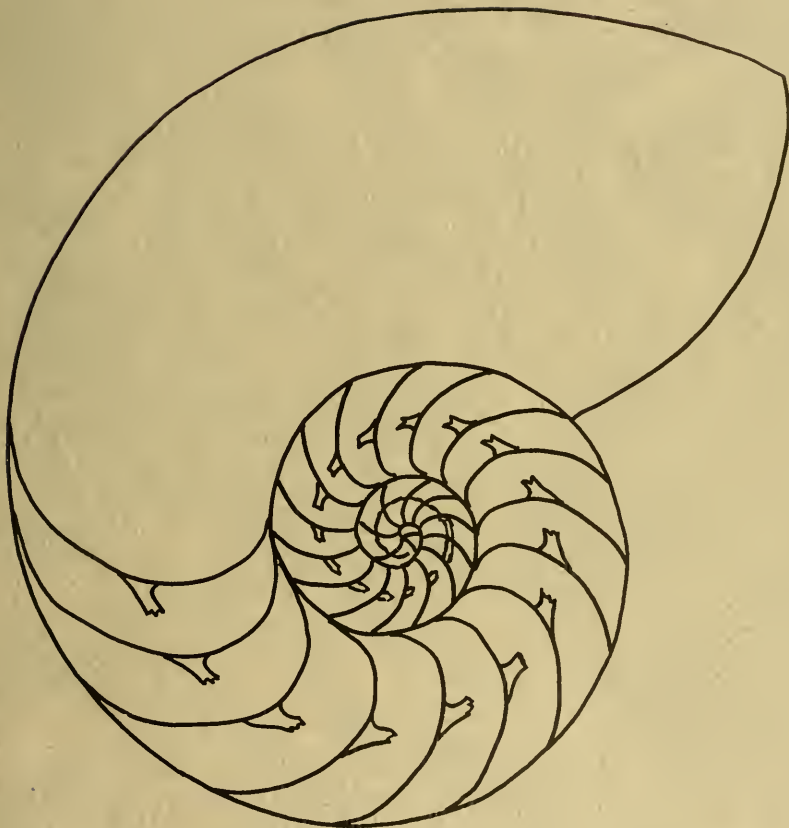
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FORMATION OF EPIPHRAGMS BY THE LAND SNAIL *OTALA LACTEA* (MÜLLER) UNDER VARIOUS ENVIRONMENTAL CONDITIONS

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ABSTRACT

The production of epiphragms by land snails is related to the environmental conditions under which the snails are maintained. Active *Otala lactea* (Müller) are more likely to become dormant and form epiphragms at low relative humidities and low temperatures than they are at high relative humidities and high temperatures. The transparent epiphragms which are laid down during the early phases of exposure to experimental conditions are gradually replaced by calcified epiphragms. Multiple calcified epiphragms are secreted with increasing frequency as exposures to "drying conditions" increase in duration. X-ray studies of dormant populations of snails lend further support to the suggestion that the total number of epiphragms secreted by a snail depends on the length of the period during which it has been dormant.

INTRODUCTION

Land snails retire into their shells and remain dormant for varying lengths of time (Comfort, 1957). Survival during prolonged periods of dormancy (lasting for months and even for years at a time) is made possible by reductions in water loss and metabolism during these periods of inactivity (Grassé, 1968).

The mantle collar (the only exposed tissue of a withdrawn snail) has been credited with regulating water exchange between snails and their environment during dormancy (Machin, 1972). In addition, the membranes (epiphragms) which are often secreted across the aperture of the shells of inactive snails reduce water loss below that observed for snails without epiphragms (Machin, 1967; Herreid, unpublished observations).

The factors which bring about secretion of an epiphragm have not yet been clearly identified. Field data on epiphragm production is limited; the only experimental work (other than that presented here) has been that of Bonavita (1961, 1964) who observed epiphragm formation as a function of various ambient temperatures and relative humidities.

The present study evaluates the influence of ambient temperature and relative humidity on

epiphragm formation by *Otala lactea* (Müller) and identifies the conditions under which several epiphragms are formed by the same snail.

MATERIALS AND METHODS

Adult *Otala lactea* (Müller) were imported from Morocco in the dormant condition. They were aroused from dormancy by placement in a humid atmosphere; snails which aroused overnight became the subjects for the studies described below.

The influence of relative humidity and temperature on epiphragm formation was studied by placing aroused snails in controlled relative humidity chambers which were kept in a constant temperature unit. Appropriate relative humidities were achieved by the use of anhydrous calcium chloride (12% RH), a solution of potassium hydroxide (58% RH), or a saturated potassium sulfate solution (98% RH); (Solomon, 1951; Winston & Bates, 1960). Both 24-hr and 5-day exposures were arranged at each of the experimental temperatures. Lengthened exposures to various environmental conditions were designed to determine the extent of multiple epiphragm formation. The number of epiphragms formed by a given snail was determined by the sequential removal of its

epiphragms at the end of the exposure period.

The analysis of epiphragm number in populations of snails that were dormant since their arrival from Morocco was accomplished via a radiographic technique. Groups of dormant snails were X-rayed using Kodak No-Screen Medical X-ray film and 12 mAs-exposures to irradiation provided by a Universal X-ray Products dental unit. Two different populations of snails were X-rayed. One group spent 6-9 months in the laboratory following collection from the field during the summer of 1970. A second group was X-rayed 8-10 wk following arrival in the laboratory; this group was collected during the winter of 1970-71.

RESULTS

Aroused snails form epiphragms soon after exposure to "drying conditions." Approximately 40% of the snails studied formed epiphragms

within the first 24 hr of exposure to either 12 or 58% RH at 31.5°C (Table 1). There was a progressive increase in the percentage of snails that formed epiphragms through time. However, even at the end of the experiment a few snails still had not formed epiphragms. It should also be noted that the transparent epiphragms formed during the first 24 hr of exposure were replaced by calcified epiphragms; this tendency persisted for the duration of the study. No apparent difference in the incidence of epiphragm formation occurred at the two relative humidities. In addition, there appears to be no difference in the ratio of calcified to transparent epiphragms at the two humidities.

To examine epiphragm formation in more detail, snails were observed over a 5-day period at 12, 58 and 98% RH at temperatures ranging from 10-40 C. In these experiments epiphragm formation was higher at 12 and 58% RH than at 98% RH (Fig. 1). This trend, aside from being poorly defined, was complicated by occasional arousals and returns to dormancy that took place during the 5 days. In spite of this handicap, the trend toward decreased epiphragm production with increased temperature is clear. Linear regression analysis of the data obtained after the first 24 hr of each exposure shows a well-defined relationship between temperature and the occurrence of epiphragm production (Fig. 2).

A second set of experiments wherein only a 24 hr exposure was arranged, produced results that confirmed those obtained after the first 24 hr of the 5-day series. In both cases, epiphragm formation is most frequent among snails kept at 12 or 58% RH and least frequent among those kept at 98% RH (independent of ambient temperature). The low incidence of epiphragm formation at the upper temperature limit in Fig. 2 is partially due to the deaths of large numbers of snails at that temperature.

During the course of many experiments, some snails were observed to form several epiphragms. In order to examine the possibility that multiple epiphragm formation is a function of the length of dormancy, the following experiment was set up. Groups of snails were kept at 12% RH and 25°C for up to 7 wk. It was found that epiphragm formation does in-

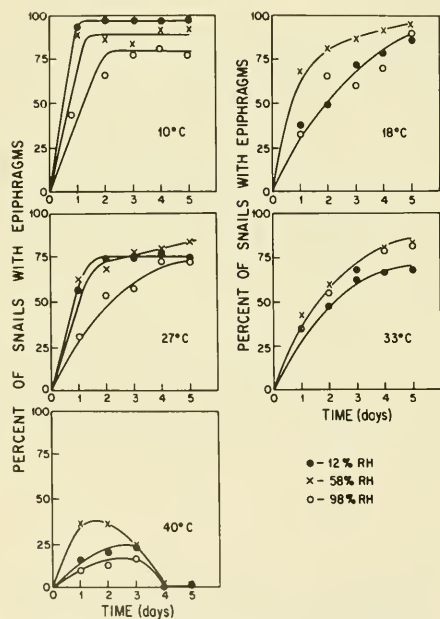


FIG. 1. Epiphragm production under controlled environmental conditions. $N=32$ at each temperature and relative humidity.

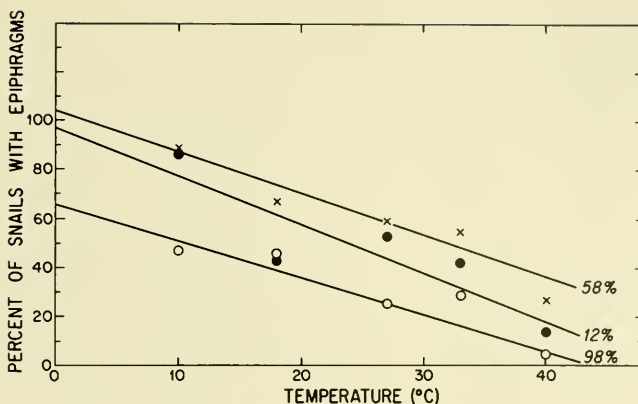


FIG. 2. Epiphragm formation as a function of ambient temperature. The correlation coefficient and regression line equation for the relative humidities studied are:

12%RH: $r=0.878$, $y=96.60-1.91x$;
 58% RH: $r=0.953$, $y=104.11-1.76x$;
 98% RH: $r=0.928$, $y=65.01-1.34x$.

crease as dormancy is prolonged (Table 2). This clearly indicates that the snail periodically lays down new epiphragms as dormancy progresses.

Table 3 is a summary of epiphragm formation at two different temperatures and two relative humidities. It shows that at 25°C the fraction of the population that formed multiple epiphragms at 12% RH is similar to that recorded at 58% RH. The same table also reveals no significant difference in the appearance of single and multiple epiphragms at 12 and 58% RH at an elevated temperature of 31.5°C. There is, however, a marked shift toward maintaining a single epiphragm instead of constructing additional epiphragms at the higher of the two temperatures. A comparison of Tables 1 and 2 will also show that the general rate of epiphragm formation was much higher at 25°C than at 31.5°C.

Analysis of epiphragm formation for longer periods using an X-ray technique indicates that epiphragm formation continues throughout dormancy. Snails which were dormant for 8-10 wk showed a higher frequency of single epiphragms than did the snails which were dormant for 6-9 months. The frequency distribution of the two populations were similar. Most of the snails had single epiphragms, followed progressively by

lower percentages of snails with 2, 3, 4, 5, 6 and 7 epiphragms.

DISCUSSION

The periods of heat and drought which characterize Moroccan summers make the creation of a favorable microclimate a virtual necessity for *O. lactea*, land snails which abound in the areas surrounding Rabat and Casablanca. Retirement into a shell which is "sealed" by means of one or more epiphragms presumably creates a niche which favors survival during periods of stress. If a significant function of an epiphragm is the prevention or reduction of water loss from a dormant snail, then one would expect epiphragm formation to occur in anticipation of, or in response to the onset of conditions which would increase water loss. As expected, epiphragm formation by *O. lactea* occurred with the highest frequency at low relative humidities (Figs. 1 and 2). There appears to be some threshold humidity above which epiphragm formation rarely occurs and below which epiphragm formation is almost a certainty. Observation of epiphragm formation at a larger number of experimental relative humidities would test this suspicion.

TABLE 1. *Epiphragm formation at different relative humidities. ($T_A = 31.5^\circ\text{C}$)*

Length of exposure (days)	Percent snails with epiphragms	
	at 12% RH	at 58% RH
1	42.9 (23.2)	36.2 (29.2)
2	70.6 (52.9)	62.7 (57.2)
3	77.1 (63.4)	74.2 (65.7)
4	78.8 (66.1)	80.0 (71.0)
5	81.8 (69.3)	83.5 (72.5)
6	81.4 (68.9)	87.5 (73.5)
7	81.6 (68.9)	89.5 (74.4)
8	83.2 (69.3)	91.5 (75.5)
9	84.5 (70.5)	91.5 (75.9)
10	85.7 (71.7)	91.5 (75.9)
16	87.5 (73.5)	87.5 (73.5)
23	91.4 (76.8)	97.0 (78.6)

(N.B.) - Numbers in parentheses represent percent calcified epiphragms.

* N at 12% RH = 228 on day 0 and 216 by day 23; at 58% RH, N = 202 on day 0 and 196 by day 23. Differences are due to deaths.

TABLE 2. *Epiphragm production over a 7-week period. (RH = 12%; $T_A = 25^\circ\text{C}$.)*

time (days)	N*	percent snails with a single epiphragm	percent snails with multiple epiphragms
1	15	100	0
4	22	95	5
7	29	86	14
14	29	66	34
21	61	43	57
49	200	52	48

* All of the snails produced epiphragms, either calcified or transparent or both.

The effect of ambient temperature on epiphragm production is a surprising one. Larger numbers of snails laid down epiphragms at low temperatures than at high ones (Figs. 1 and 2). Since higher ambient temperatures favor increased water loss from dormant snails, one would expect that epiphragms would be produced by snails kept at high temperatures. Observation to the contrary either reinforces the notion that epiphragms are not particularly important as barriers to water loss or suggests that mobilization of materials required for the construction of an epiphragm is more difficult

at high temperatures.

Prolonged exposure to a constant ambient temperature and relative humidity results in epiphragm formation by increasing numbers of snails as the length of the exposure period increases. Similarly, the total number of epiphragms secreted by a dormant snail increases as the duration of dormancy increases. It appears that the laying down of a single epiphragm is followed by the retraction of the dormant snail into its shell. During extended periods of dormancy, periodic arousals accompanied by the laying down of additional

TABLE 3. *Formation of single and multiple epiphragms under different ambient conditions.*

	Relative Humidity			
	12%		58%	
Temp (°C)	single	multiple	single	multiple
25.0	43% (N = 61)	57% (N = 61)	53% (N = 267)	47% (N = 267)
31.5	88% (N = 185)	12% (N = 185)	87% (N = 179)	13% (N = 179)

The percentages are based on the fraction of the appropriate population that formed either single or multiple epiphragms. Exposures at 25.0°C lasted 21 days; those at 31.5°C lasted 23 days.

epiphragms may take place. The purpose of these arousals (which cannot be observed since they do not involve rupture of the original epiphragm) is not clear. They may represent an attempt to more effectively conserve a water supply which is gradually reduced throughout the course of dormancy. The reinforcement of a single epiphragm by additional epiphragms may provide a more effective barrier to water loss and would thus prolong dormancy. Horne (1973) proposed that the chambers between epiphragms may reduce evaporation by decreasing air circulation within the spaces created by multiple epiphragms. Alternatively, multiple epiphragm secretion can be viewed as a physiological event which enables the snail to remain dormant for a longer period. If the release of calcium and other inorganic materials from the hemolymph has an effect on the neuromuscular excitability of the snail, then release of additional material for the construction of several epiphragms should theoretically provide for a more profound state of dormancy. Both of the above considerations are discussed in greater length in a companion paper (Rokitka & Herreid, in preparation). Finally, the observation that fecal matter is often found in the compartments created by multiple epiphragms leads one to suspect that periodic arousals occur as metabolic wastes accumulate.

Spontaneous arousal during periods of hibernation and torpor are common among mammalian species. Mrosovsky (1971) reviews accounts of periodic arousal. He evaluates the metabolic end-product theory which explains spontaneous arousal on the basis of a need to re-establish normal homeostatic levels of

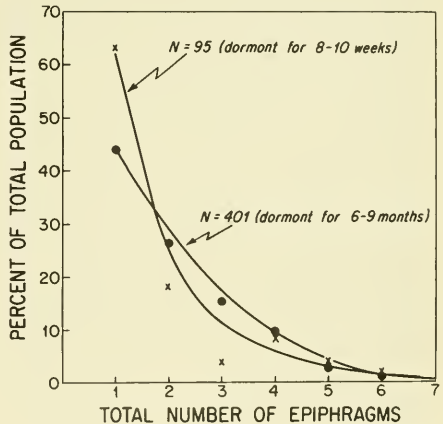


FIG. 3. Differences in the total number of epiphragms secreted by snails which were dormant for different lengths of time.

metabolic waste products. While a number of investigators are pursuing the arousal phenomenon, none has advanced a theory to explain the function of spontaneous arousal that could arousal that could replace the currently-held metabolic end-product theory.

Epiphragm formation has been observed in the laboratory during periods that do not coincide with Moroccan summers and under conditions which do not simulate the climatic variables to which snails are exposed in the field; this raises an interesting point. It is highly probable that epiphragm formation is not merely a function of the environmental conditions to which snails are exposed. It is far more likely that the availability of internal organic and inorganic reserves dictates whether or not an epiphragm can be laid down. The concentrations of epiphragm components may quite possibly vary with season. If this is the case, then snails exposed to experimental conditions during the summer will not react in the same way as snails exposed to identical conditions during the winter. Kostyuk (1968) reports "a substantial increase in calcium concentration during spring" in the hemolymph of *Helix pomatia*. Hyman (1967) reviews reports of increases of calcium in the midgut gland and nephridium during the summer and a decline of calcium during hibernation. These seasonal variations, while not the subject of this report, must be acknowledged as yet another variable which influences epiphragm production.

Land snails other than *O. lactea* form epiphragms in response to desiccating conditions. Bonavita (1965) made this suggestion while noting that epiphragm production did not occur in a humid atmosphere. The ecological significance of epiphragm production in habitats which differed in dampness was considered by Cameron (1970) who studied three species of land snail. Bonavita (1961, 1964) drew a parallel between geographic distribution of several species of land snail and the incidence of epiphragm formation under various sets of experimental conditions. The findings of these investigators, coupled with the information presented here, constitute evidence for an association between the incidence of epiphragms and the environmental conditions under which they are formed.

ACKNOWLEDGMENTS

We are grateful to D. Adler, R. Ham and A. Harris for their contributions to this study.

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THE VALIDITY OF THE SUBGENUS *SENILIA* GRAY, 1842 (BIVALVIA: ARCIDAE)

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ABSTRACT

The erection of the subgenus Senilia Gray, 1842, was based on five conchological characters, viz. a high trigonal form, an extremely prosogyrate beak and umbo, an oblique break in dentition beneath the umbo, a massive shell with smooth periostracum, and a small number of ribs. Anadara senilis, the only species of the subgenus, shares its internal anatomical features and the first four of these conchological characters with typical members of the subgenus Anadara sensu stricto. The possession of a small number of ribs is here considered inadequate for continued recognition of Senilia as a valid subgenus and the species is here referred to the well-established subgenus Anadara sensu stricto, although the latter is predated by Senilia Gray, 1842.

INTRODUCTION

Anadara senilis, an endemic West African species, was first described as *Arca senilis* by Linnaeus in 1758. In 1842, Gray erected the genus *Senilia* (a genus without species) characterized by a large and massive shell with a smooth periostracum. By subsequent designation of Gray in 1847, *Arca senilis* became the type for the genus.

Thiele (1935) classified *A. senilis* in section *Senilia* of the subgenus *Arca sensu stricto*. Nicklés (1950), Buchanan (1954), Yonge (1955) and Longhurst (1958), following Thiele (*op. cit.*) referred to the species as *Arca (Senilia) senilis*.

Reinhart (1935) assigned the West African bloody cockle to the subgenus *Senilia* of the genus *Anadara*. Because of the wide acceptance of Reinhart's classification of the family Arcidae, the West African bloody cockle has subsequently been cited as *Anadara (Senilia) senilis*.

According to Gray (1842), Thiele (1935) and Reinhart (1935), the subgenus *Senilia* is characterized by the following:

- (a) a high trigonal form
- (b) an extremely prosogyrate (*Cardita*-like) beak and umbo
- (c) an oblique break in dentition beneath the umbo
- (d) a massive shell with a smooth periostracum, and
- (e) a small number of ribs.

The creation of the subgenus by Gray in 1842 was based solely on one conchological character, viz. the possession of a heavy shell with a smooth periostracum. Reinhart (1935) and Thiele (1935) similarly classified the species in the subgenus *Senilia* on the basis of shell characters. Since it has long been recognized that a classification based upon shell characters alone may lead to erroneous phylogenetic conclusions, the anatomy of the species was compared with that of representatives of the subgenus *Anadara sensu stricto* (Yoloye, 1969). Such detailed comparison was considered necessary in order to resolve the prevailing controversy over the validity of the subgenus *Senilia* (Iredale, 1913; Reinhart, 1935).

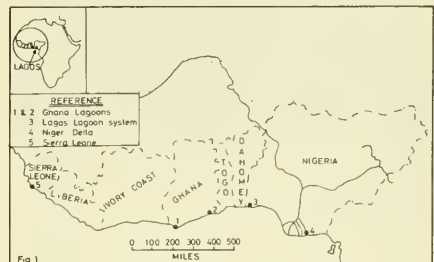


FIG. 1. Map of West Africa showing the localities sampled.

MATERIALS AND METHODS

The specimens used in this work were collected from the following four areas along the coast of West Africa (Figure 1): Bunce River estuary in Sierra-Leone; Princess-town lagoon in Ghana; Kuramo Waters near Lagos, Nigeria; and Andoni Flats in the Niger Delta.

The anatomy was studied in dissections as well as in serial sections of specimens fixed in Bouin's fluid, embedded in paraffin wax and stained in Ehrlich's haematoxylin.

RESULTS AND CONCLUSIONS

The present work (see Yoloye, 1969 for details) shows that the final form of the shell

of the West African bloody cockle is greatly influenced by environmental conditions. Specimens collected from tidal waters such as the Kuramo lagoon and the Andoni Flats of the Niger Delta have a quadrate outline (Figure 2A), while specimens from non-tidal lagoons such as the Princess-town lagoon in Ghana have a high trigonal outline (Figure 2B). In addition, only shells of populations of *Anadara senilis* from non-tidal lagoons have extremely prosogyrate umbones. The two morphotypes, however, grade into one another in localities where environmental conditions are variable. They, therefore, belong to the same species (Nicol, 1964, personal communication).

In view of the fact that all populations of *A. senilis* do not have high trigonal forms or extremely prosogyrate umbones, these two features cannot be regarded as diagnostic nor should they be cited as valid criteria for the creation of the subgenus *Senilia*.

A comparison of the shells of *Anadara senilis* with those of members of the subgenus *Anadara* s. s. shows that an oblique break in dentition below the umbo is found also in *Anadara granosa* (see Purchon, 1956, fig. 2; 1958, fig. 3) and *Anadara antiquata*, the type species of the subgenus (see Grassé, fig. 1735). Similarly, many species in the subgenus *Anadara* s.s. have massive shells with smooth periostracum. It seems, therefore, that of the five conchological characters upon which the erection of the subgenus *Senilia* is based, only the possession of relatively few and wide ribs (9-15) is peculiar to *Anadara senilis*, the only species in the subgenus.

Functional anatomical study shows also that the internal anatomy of *Anadara senilis* is not fundamentally different from that of *Anadara granosa*, *A. biseneris* and *A. trapezia* which are regarded as typical members of the subgenus *Anadara* s. s. (Reinhart, 1935; Heath, 1941).

The structure and ciliary currents of the ctenidia and labial palps of *Anadara senilis* are both essentially as described for *A. granosa* (Purchon, 1956), *A. trapezia* (Sullivan, 1960), *A. anomala*, *A. cuneata* and *A. antiquata* (Lim, 1966). In *Anadara granosa*, however, there is an anteriorly directed current at the ventral edges of the gills (Purchon, 1956). This current is

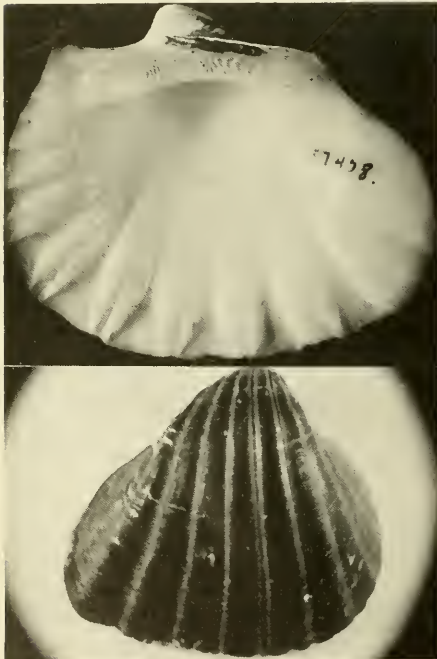


FIG. 2. Quadrate and trigonal specimens of *Anadara senilis* from tidal lagoon (Kuramo lagoon near Lagos, Nigeria) (upper figure) and non-tidal lagoon (Princess-town lagoon in Ghana) (lower figure). Note also the highly prosogyrate beak of the latter. (Photos courtesy of Joseph Rosewater).

posteriorly directed in *A. senilis*, *A. antiquata*, *A. anomala* and *A. euneata* (Lim, 1966). The ciliary currents on the labial palps of *A. senilis* and *A. granosa* differ from those of the three species of *Anadara* s. s. described by Lim (1966) in that the currents in the transverse grooves are rejectory and do not run into the lateral oral groove.

The structure of the stomach, 'kidneys', heart and sense organs of *A. senilis* are also closely comparable with those of *A. granosa* and *A. bisenensis* (Heath, 1941; Sullivan, 1960).

In *Anadara senilis*, the rectum runs through the ventricle. An identical situation occurs in *Anadara trapezia* (Sullivan, 1960). In *A. bisenensis* (Heath, 1941), however, the rectum is ventral to the ventricle. It, therefore, seems that the relationship between the rectum and the ventricle is variable in the subgenus *Anadara* s. s. and *A. senilis* falls within the range of variation.

In view of the facts that most of the significant conchological characters as well as the internal anatomy of *Anadara senilis* is identical with that of members of the subgenus *Anadara* s. s., it is here suggested that the possession of a small number of ribs alone does not justify the erection of a separate subgenus for *Anadara senilis*. This character should be of specific significance only (see also Reinhart, 1935, p. 9). The species should thus be placed with other species in the subgenus *Anadara* sensu stricto.

Senilia Gray, 1842 predates and should normally have priority over *Anadara* Gray, 1847. The popular acceptance of Reinhart's (1935) classification as well as the subsequent established usage of *Anadara* in the literature suggest that the rule of priority should be waived in favor of *Anadara* in this case.

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SCALARIFORMY IN THE POND SNAIL, *LYMNAEA STAGNALIS*

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ABSTRACT

A brief review and a new report of scalariformy in Lymnaea stagnalis (Linné) are presented. Theories dealing with the cause of phenotypic uncoiling in gastropods are reviewed.

Very little is known about the occurrence of scalariformy in *Lymnaea stagnalis* (L.), although this species is common throughout much of its circumboreal range (F. C. Baker, 1928) and has been extensively studied. The scarcity of reports regarding this phenomenon in *L. stagnalis* would seem to indicate that its incidence is very rare.

F. C. Baker (1911) noted that the Lymnaeidae are subject to scalariformy and reported having seen an undetermined number of specimens of *L. stagnalis* exhibiting this anomaly from Spoonbill Slough, Deuel County, South Dakota. Hubendick (1951) provided a line drawing of a scalariform *L. stagnalis* but the locality was not given. Working with material from the U.S.S.R., Zhadin (1952) commented that scalariformy occurs very rarely among the Lymnaeidae but cited no examples. A photograph of a scalariform specimen of *L. stagnalis* was provided by Pip and Paulishyn (1970). This specimen was collected at Jackson's Lake, 3 km southeast of Sidney, Manitoba, in August, 1970. The substrate in this area was sand, with an abundance of vegetation. The authors reported that all other individuals examined from this locality were apparently normal. Subsequently Jackiewicz (1972) figured a specimen that had been collected at Debinie near Poznanie in Poland in 1928. Clarke (1973) noted the presence of one scalariform specimen among the 141 lots of *L. stagnalis* examined from the Canadian Interior Basin; it was collected from a farm pond 6 miles southwest of Abernethy, Saskatchewan. The remainder of the lot from this locality was apparently normal. Another specimen (Fig. 1) was collected in Katharine Lake, Riding Mountain National Park, Manitoba in August, 1974 by Dr. John M. Stewart. The bot-

tom in this area was sand and gravel, with patches of *Potamogeton*, *Myriophyllum* and *Chara*. Again, other individuals of *L. stagnalis* examined from this locality were apparently normal.

The three available figures (Pip and Paulishyn, 1970; Jackiewicz, 1972 and Fig. 1 below) show an abrupt onset of the anomaly in initially non-scalar shells. The rate of forward progression of coiling along the shell axis has apparently been altered, resulting in subsequent disjunction of the whorls and progressive "uncoiling" of the shell.

The cause of scalariformy is unclear (Pip and Paulishyn, 1970). F. C. Baker (1911) postulated that such deformity may be due to disease, accident or parasitism. Jackiewicz (1972) cited evidence of mechanical injury in the shell that she figured; no external evidence of injury is



FIG. 1. Dorsal, ventral and lateral views of a scalariform *L. stagnalis* L. collected in Katharine Lake, Riding Mountain National Park, Manitoba, in August, 1974. Scale is in mm.

apparent in the two Manitoban specimens. The theories dealing with uncoiling in gastropods have been briefly reviewed by Jackiewicz (1972). According to Boettger (1944 in Jackiewicz, 1972), phenotypic uncoiling may be caused by foreign bodies which interfere with the subsequent construction of the shell. According to Rotarides and Schesch (1951 in Jackiewicz, 1972), uncoiling and even breakage of the axis may be due to mechanical injury. Geyer (1929 in Jackiewicz, 1972) has suggested that uncoiling may be due to injury of the axis; he has noted the occurrence of this phenomenon in mollusca associated with the algal stoneworts of the Characeae.

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EATING LAND SNAILS IN PREHISTORIC SOUTHERN TEXAS: ETHNOHISTORIC AND EXPERIMENTAL DATA

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In a previous issue of this journal, Clark (1973) presented a brief review of problems surrounding the occurrence of land snails (*Rabdotus* sp.) in Texas archaeological sites. Clark

outlined four hypotheses which might explain the large concentrations of these snails in prehistoric occupation sites. In his first hypothesis, which is of particular interest to us,

he postulated that "snails were intentionally collected as a source of protein in the diet." He later noted the lack of empirical data supportive of this hypothesis, particularly the absence of ethnographic accounts of Indian consumption of land snails. On this latter account, we should like to point out that at least one ethnohistoric report exists which clearly indicates that Indian groups in southern Texas did, in fact, consider the land snail as a food resource. Cabeza de Vaca, a captive of the Mariame peoples in south central or southern Texas ca. 1529, has provided a detailed discussion of Mariame subsistence patterns. Quoting from Bishop's (1933:95) version of Cabeza de Vaca's narrative: "Then at the end of May we shall go to eat the prickly pear, and snails for garmishing, the best food of all the year". Another analysis of the Cabeza de Vaca narrative by Krieger (1956) also mentions the eating of snails by the Mariames: "Nothing else was eaten during this season (summer) except large numbers of snails."

Archaeological explorations which we have conducted in southern Texas prehistoric campsites have revealed large quantities of land snails in the midden deposits. In particular, we have noted distinct clusters of large, adult *Rabdotus schiedeannus* specimens at several sites. They appear to have been sorted or selected according to size, the largest specimens naturally preferred. (Hester and Hill 1974). None of the shells in these clusters has been broken open or perforated, and we must assume that the snail was extracted by some other means. There is no evidence of the shells having been burned or charred, and no charcoal was associated with the concentrations. Recent experiments by Hill indicate that if snail shells are dropped into boiling water, for a very few minutes, the snail will partially extrude from the shell aperture and can easily be extracted using a mesquite thorn. The shell is not damaged by the boiling,

and in fact, Hill could detect only very minor color change. It seems highly likely that the boiling technique could have been used in prehistoric southern Texas for snail extraction; this is particularly true of the late prehistoric sites which have yielded the large clusters of snails, as the late prehistoric peoples had ceramic vessels.

In summary, we believe that the accumulations of snail shells found in southern Texas archaeological sites result from human agencies. Southern Texas was occupied in prehistoric times by small groups of hunters and gatherers, known collectively as "Coahuiltecan." We have noted an ethnohistoric account of the eating of snails among the Mariames, linked by Newcomb (1961) to the Coahuiltecan linguistic stock. Archaeological excavations in the area have revealed sizable concentrations of *Rabdotus* snails within sites, and we presume these snails to have been collected as a food resource. The shells in these clusters are not broken or perforated, but experimental data indicate the snails could have been easily extracted (without damage to the shells) by boiling the shells in water for a short period.

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A REVIEW OF *SUCCINEA WILSONI*
A COASTAL MARSH SNAIL OF EASTERN NORTH AMERICA

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ABSTRACT

Succinea wilsoni Lea, 1864, a variable coastal marsh succineid, is re-described and compared briefly with closely related species. Along with its genitalia, its wide range of shell variation is discussed and figured. *Succinea bayardi* Vanatta, 1914, *Succinea pronophobus* Pilsbry, 1948, *Succinea crisfieldi* Jackson, 1958, *Succinea aurea* of authors, not of Lea, and *Succinea pyrites* Hubricht, 1960, are here considered synonyms of *Succinea wilsoni*.

***Succinea wilsoni* Lea, 1864**

Succinea wilsonii Lea, 1864, Proceedings of the Academy of Natural Sciences of Philadelphia **16**: 109. Journal of the Academy of Natural Sciences of Philadelphia **2**(6): 177. pl. 24 fig. 105 (TYPE-LOCALITY near Darien, Georgia).

Succinea wilsoni Lea, Pilsbry, 1948, Land Mollusca of North America (north of Mexico) **2**(2): 823-824, p. 824 fig. 445a (type), b (St. Simon's Island, Georgia).

Succinea bayardi Vanatta, 1914, Proceedings of the Academy of Natural Sciences of Philadelphia **66**: 222, figs. 1-3 (TYPE-LOCALITY Indian River, "Kensington", Prince Edward Island). Pilsbry, 1948, Land Mollusca of North America (north of Mexico) **2**(2): 814-815, 818, p. 814 fig. 440, p. 818 fig. 442 G, g, gl.

Succinea pronophobus Pilsbry, 1948, Land Mollusca of North America (north of Mexico) **2**(2): 809-810, p. 810 fig. 437a (TYPE-LOCALITY Wilmington, North Carolina).

Succinea aurea "Lea", of authors, not of Lea.

Succinea aurea "Lea", in part, Pilsbry, 1948, Land Mollusca of North America (north of Mexico) **2**(2): 814-815, 818, p. 818 fig. 441 A, B, fig. 442 E, F.

Succinea pyrites Hubricht, 1960, Nautilus **73**(3): 113 (To replace preceding TYPE-LOCALITY Cape May, New Jersey).

Succinea avara "Say", in part, Pilsbry, 1948, Land Mollusca of North America (north of

Mexico) **2**(2): 818 fig. 442A, a, fig. 445 d (Sea Isle City, New Jersey). Not of Say.

Succinea crisfieldi Jackson, 1958, Maryland Naturalist **28**(1-4): 17 (TYPE-LOCALITY Crisfield, Somerset County, Maryland).

Description — The shells of mature examples are glossy, smooth, with fine growth lines and occasional fine spiral sculpture, ovate, ranging from short-ventricose to elongate-attenuate; spire acute and tapering, sometimes slightly truncated. The shell color varies, ranging from translucent greenish yellow, through amber, to pale, slightly calcareous orange-yellow. Usually the apices are salmon red, though sometimes they are light pinkish-orange or yellow. The columella is thin, slightly curved to straight, and translucent white. The aperture is oblique and ranges between two-thirds and four-fifths the length of the shell. The suture is moderately impressed, and there are 2.5 to 3.5 whorls. Often, much of the shell is covered with dirt, especially in young examples. Specimens from dry habitats are cleanest.

When alive, the animal has a dull, translucent, whitish grey body, flecked on the sides with black, with darker tentacles and a pale sole. The base color of preserved examples is cream, marked with black. Beneath, and around the pneumostome, the mantle is shaded with grey. The edge of the mantle is pale whitish, streaked with conspicuous zones of black which

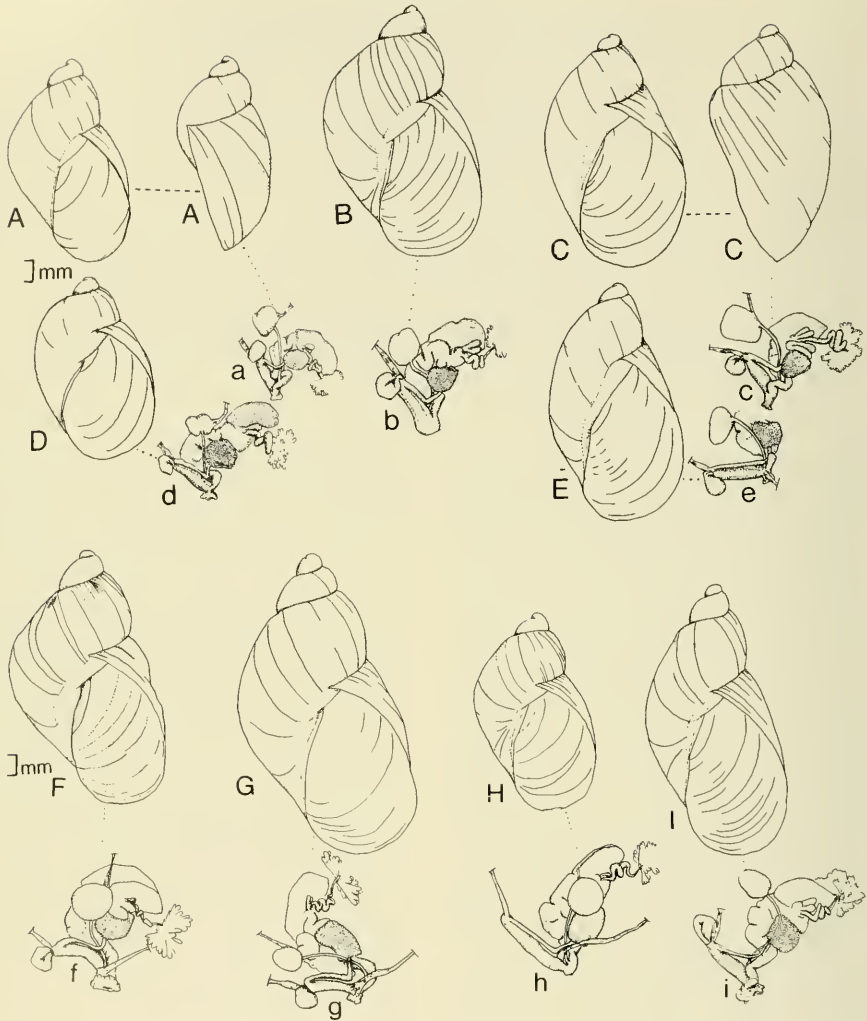


FIG. 1. *Succinea wilsoni* Lea, shells and genitalia. **A,a** NMC 64819 Chatham Co., Georgia. **B,b** NMC 64823 Cape May Co., New Jersey. (topotype of *S. pyrites* Hubricht). **C,c** NMC 64818 New Hanover Co., North Carolina. (topotype of *S. pronophobus* Pilsbry). **D,d** NMC 64844 Sussex Co., Delaware. **E,e** NMC 64826 Talbot Co., Maryland. **F,f** NMC 63389 Prince Co., Prince Edward Island. (adult topotype of *S. bayardi* Vanatta). **G,g** NMC 64817 Somerset Co., Maryland. (topotype of *S. crisfieldi* Jackson). **H,h** NMC 69090 St. George's Distr., Newfoundland. **I,i** NMC 64824 Charles Co., Maryland.

coalesce to form large black patches. Over the lung, the mantle is shaded or blotched with dark-grey, and elongate black blotches lie parallel to the kidney, which is yellow or green. Behind the kidney, and over the hepatopancreas, the mantle often bears scattered, irregular, rounded black spots.

Genitalia of mature specimens — The hermaphrodite duct is lightly pigmented with black, crimped, and varies in thickness with the sexual activity of the animal. The seminal vesicle (talon) is variable in size (sometimes quite large), club-shaped, with a median groove

which divides it into unequal sections. It is lightly pigmented with black. At its base is the slightly rounded, small fecundation pouch. The albumen gland is granular, yellow, truncated, and variable in size. The prostate gland is large and located in the middle of the genital mass. It is rounded-truncate and moderately to heavily pigmented with black. Rarely, it is free of pigment. The vas deferens is short, sheathed, and enters the penis behind the apical expansion. The thinly sheathed penis is long, slender, and expanded at the apical end (the "epiphallus"). Usually the apical expansion emerges as a conspicuous terminal loop, but sometimes it is sheathed. The small penial retractor, which is connected to the penis loosely at the base of the loop, also connects to the apex of the sheath. When fully contracted it is short and spindle-shaped, and when relaxed it is long and slender. The spermatheca is large, thin, and globose with a small muscle attached. Sometimes the posterior half of the slender, long, uniform spermathecal duct is stippled with black, and other times it is free of pigment. The atrium and the vagina are very short, and the free oviduct is curved, and often strongly folded immediately behind the insertion of the spermathecal duct. A long muscle is attached to the atrial region.

Measurements (in mm.) —

Length	Width	Length of		Width of	
		Aperture	aperture		
9.67	5.90	6.00	3.50		Chatham Co., Ga.
12.00	6.83	7.33	4.83		Cape May Co., N.J.
11.00	6.33	7.67	4.83		Wilmington, N.C.

Similar species: Succinea urbana Hubricht, 1961, has nearly identical but smaller genitalia. It matures at half the size of *S. wilsoni*. The shell of *S. urbana* is much more calcareous than that of *S. wilsoni*. *S. wilsoni* frequents salt marshes and fresh estuarine marshes, and *S. urbana* lives upon exposed, calcareous ground, often quite far from the sea.

Succinea concordialis Gould, 1848 (= *Succinea unicolor* Tryon, 1866) has very similar genitalia but the prostate is unpigmented. It matures and lays eggs when smaller than *S. wilsoni*, its shell is more rotund, the nuclear whorl is smaller, and the animal is not halophile.

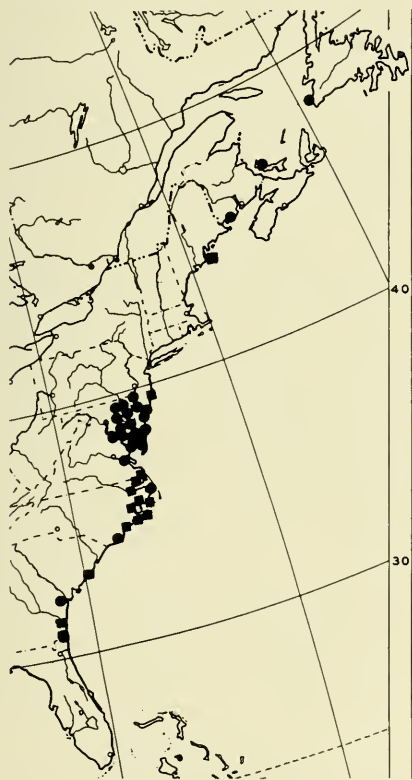


FIG. 2. Map showing range of *Succinea wilsoni* Lea. Closed circle: specimens dissected; solid square: records accepted.

All other species which resemble *Succinea wilsoni* have very different genitalia.

Specimens dissected: All are in the collection of the Mollusc Unit, National Museum of Natural Science, National Museums of Canada, and were collected by the author unless otherwise stated. GEORGIA: Chatham Co., roadside 2 miles west of Savannah Beach (Leslie Hubricht, coll.). NORTH CAROLINA: New Hanover Co., saltmarsh 2 miles northwest of Wilmington (Hubricht) — topotypes of *S. pronophobus* Pilsbry. VIRGINIA: Accomack, Northampton, and Mathews Co. MARYLAND: Baltimore City, Baltimore, Harford, Anne Arundel, Calvert, Charles, St. Mary's, Kent, Queen Anne's, Talbot, Dorchester, Wicomico, Somerset (many localities including foot of North 7th St., Crisfield, — topotypes of *S. crisfieldi* Jackson. DELAWARE: Sussex, Kent, Newcastle Cos; many stations. NEW JERSEY: Cape May, Cape May Co. — topotypes of *S. pyrites* Hubricht. NEW BRUNSWICK: Charlotte Co., saltmarsh, S.E. edge of St. Andrews (F. W. Schueler and M. Hynenick, coll.). PRINCE EDWARD ISLAND: Prince Co., saltmarsh, Indian River, west side of Hwy. 106, — topotypes of *S. bayardi* Vanatta. The town of Kensington is not on the Indian River and has no saltmarshes, but it is the nearest town to the type-locality. NEWFOUNDLAND: St. George's District, transitional fresh-salt marsh, branch of Grand Codroy River at crossroad 0.5 mile southeast of Upper Ferry.

Records accepted: GEORGIA: Near Darien (TYPE-LOCALITY), holotype examined; St. Simon's Island (Pilsbry, 1948, figured); Chatham Co. (Hubricht, 1964, *Sterkiana* 16: 5-10). SOUTH CAROLINA: Charleston Co. (Hubricht, 1971, *Sterkiana* 41: 41-44). NORTH CAROLINA: New Hanover Co., Wilmington (Pilsbry, 1948, type-locality for *S. pronophobus*; Hubricht, 1970, *Sterkiana* 39: 11-15); also Beaufort, Bertie, Brunswick, Chowan, Craven, Dare, Hyde, Onslow, Pamlico Co. (Hubricht, 1970, *loc. cit.*, listed as *pronophobus*, Beaufort Co., listed as *wilsoni*). VIRGINIA: King George and Nansemond Cos. (Hubricht, 1971, *Sterkiana* 42: 41-45). NEW JERSEY: Cape May and Sea Isle City (Pilsbry, 1948, cited, as *S. aurea* and *S. avara*; Hubricht, 1960, *Nautilus* 73(3): 113).

MAINE: Knox Co., Seal Island (N. W. Lermond, Del. Mus. Nat. Hist. no. 96886).

Discussion — *Succinea wilsoni* is an extremely variable species which appears in several distinct forms. It occurs in scattered colonies throughout its known range, and it may be distributed by birds, by storms, and by tides. Its variation does not appear to be geographic, for many forms may be found within a few miles of each other. Usually each colony is fairly uniform, and the extreme forms are connected by intermediate colonies, not by individuals within the same colony. Such variation is characteristic of species which are distributed adventitiously, because each colony may have originated with one or a few chance arrivals. Justifiably, *Succinea wilsoni* has masqueraded under a number of names for quite a long period of time. Fortunately, variation in the genitalia is slight. Small differences in the proportions of the organs are caused by differences in the reproductive cycle or contraction of the organs.

As a rule, *Succinea wilsoni* is an eurytopic halophile marsh-dweller which occurs most frequently in the freshest zone of saltmarshes. Although it usually occupies estuarine marshes, it has been found in a shaded fresh water swamp which supports *Phytolacca*, *Lymnaea*, and *Pisidium*, as well as in saline marshes a few hundred yards from the ocean. Usually specimens may be found on shaded soil at the bases of sedges and reeds, or on bare soil in full sunlight. In the Chesapeake-Delaware Bay region, where thousands of specimens were observed and collected over a period of approximately ten years, the appearance of the shells seemed to be correlated partially with the habitat occupied by the snails. The form which climbs reeds in comparatively fresh marshes is thin and elongate with a short spire and a large aperture. This form was called *Succinea pronophobus* by Pilsbry (1948, *loc. cit.*). Gradually, colony-by-colony, this form grades into one which has a higher spire, a smaller aperture, and a more calcareous shell, and which occupies bare, calcareous, saline ground. Examples of this form have been called *Succinea crisfieldi* by Jackson (1958, *loc. cit.*), and *Succinea wilsoni* by Lea (1864) and Hubricht (1964, 1971, cited). A more rotund form which

occupies saline ground was named *Succinea pyrites* by Hubricht (1960). *Succinea bayardi* Vanatta (1914, cited) was described from immature specimens. Colonies of thin examples may be found on the ground in marshes and swamps which vary greatly in salinity and exposure, but are low in lime. Depauperate examples have been found on dry waste ground near salt marshes, climbing driftwood and vegetation.

The Canadian colonies may have originated with migrating birds. Many marshes were visited in Newfoundland, Prince Edward Island, New Brunswick, and Nova Scotia and only the three colonies reported upon here were found.

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GENITAL ANATOMY AND PHYLOGENY OF THE SNAILS, *BERENDTIA* CROSSE AND FISCHER AND *SPARTOCENTRUM* DALL (STYLOMMATOPHORA: BULIMULIDAE)

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ABSTRACT

The genital anatomy of Berendtia taylori (Pfeiffer) and *Spartocentrum vanduzei* (Hama) are described. Based on anatomical and eonchological evidence it is proposed that *Spartocentrum*, previously considered a subgenus of *Coelocentrum* Crosse and Fischer, be accorded full generic status and that *Spartocentrum* and *Berendtia* be transferred from the *Urocoptidae* to the *Bulimulidae*.

INTRODUCTION

Berendtia Crosse and Fischer, 1869, and *Spartocentrum* Dall, 1895, are two genera of land snails which inhabit the peninsula of Baja California, Mexico, and certain nearby islands. *Berendtia* is a monotypic genus found in the

Sierra de la Giganta of the central region of Baja California. *Spartocentrum* includes several species in the central and southern parts of the peninsula, with additional species occurring on islands in the Gulf of California. It has been considered a geographically isolated subgenus of

Coelocentrum Crosse and Fischer, 1872, a taxon otherwise limited to Central America and southern Mexico. *Berendtia* and *Spartocentrum* have previously been assigned to the family Urocoptidae, subfamily Eucalodiinae; no other representatives of this family are known to occur in Baja California.

Aspects of the anatomy of *Berendtia* have been studied previously. Binney and Bland (1869) and Crosse and Fischer (1870) described and figured the jaw and radula of *Berendtia taylori* (Pfeiffer, 1861). Fischer and Crosse (1872, 1873) also discussed these structures, as well as the reproductive and nervous systems. Unfortunately the description of the genitalia was incomplete and did not include figures. There are no anatomical studies of any species of *Spartocentrum* in the literature.

Knowledge of the structure of the genitalia is

often indispensable in systematic studies of land pulmonates. In the absence of critical data in this area, the systematic position of these taxa has been determined primarily on the basis of shell characters, which have been interpreted as indicating Urocoptid affinities. We have recently collected living representatives of both *Berendtia* and *Spartocentrum* and conclude from study of the genitalia and from reevaluation of the conchological data that these snails have been improperly assigned to the Urocoptidae and are instead members of the Bulimulidae.

Description of genitalia

Berendtia taylori (Pfeiffer, 1861). Fig. 1.

Penis with muscular sheath enclosing vas deferens and cylindrical lower portion of penis; penis above sheath swollen, extending partly



FIG. 1. *Genitalia of Berendtia taylori* (Pfeiffer, 1861). La Purisima Canyon, 4.8 km northeast of San Isidro, Baja California Sur.

FIG. 2. *Genitalia of Spartocentrum vanduzeei* (Hama, 1923). Junealito, Baja California Sur.

FIG. 3. Same, showing enlargement of anterior genitalia.

FIG. 4. *Genitalia of Raddotus inscendens* (W. G.

Binney, 1861). 2.7 km northwest of Valle Perdidó, Baja California Sur.

Abbreviations: ag albumen gland; ec epiphallie caecum; ep epiphallus; hd hermaphroditic duct; pe penis; pr penial retractor muscle; ps penial sheath; sd spermathecal duct; so spermoviduct; sp spermatheca; vd vas deferens.

over lower end of epiphallus; epiphallus cylindrical, continuous with epiphallic caecum, their junction marked by entrance of vas deferens; distal end of epiphallic caecum bearing insertion of penial retractor muscle; vagina short; spermatheca globose or ovate, its duct unbranched, with a slight swelling halfway along its length in some specimens; albumen gland curved, the convoluted hermaphroditic duct entering at its base; ovotestis embedded in digestive gland. Approximate length of structures (in mm): penis 5.5; epiphallus 6.0; epiphallic caecum 19.0; spermathecal duct 33.0; spermoviduct 31.0 mm.

Spartocentrum vanduzeei (Hanna, 1923). Figs. 2, 3.

General description as above. Length of penis 3.5; epiphallus 3.5; epiphallic caecum 7.0; spermathecal duct 33.0; spermoviduct 28.0 mm.

Rabdotos inscendens (W. G. Binney, 1861). Fig. 4.

General description as above. Length of penis 7.0; epiphallus 13.5; epiphallic caecum 8.5; spermathecal duct 42.0; spermoviduct 30.0 mm.

Discussion

As can be seen from the above description and figures, the genitalia of *Berendtia* and *Spartocentrum* are nearly identical to those of the bulimulid genus *Rabdotos* Albers, 1850. The most important similarities concern the male reproductive organs. In all three genera a sheath encloses the vas deferens and lower portion of the penis, the penis above the sheath appears swollen, and the epiphallus is continuous with a long epiphallic caecum which bears the penial retractor muscle at its distal end.

As yet only the gross morphology of these organs has been studied. Of particular interest for future work is the structure of the penis. The enlarged upper region of it, above the penial sheath, may correspond to the complex of penial diverticula reported by Van Mol (1971, 1972) in *Bulimulus* (s. s.) and *Naesiolus*, bulimulid snails from the West Indies and Galapagos Islands, respectively.

The genitalia of several genera of Eucalodiinae have been described and figured; those of *Eucalodium* Crosse and Fischer, 1868, by

Fischer and Crosse (1873), Strebel and Pfeffer (1880, cited in Pilsbry, 1903), and Thompson (1963); of *Coelocentrum* (s. s.) Crosse and Fischer, 1872, by Strebel and Pfeffer (*op. cit.*); of *Anisospira* Strebel and Pfeffer, 1880, by Pilsbry (1903) and Thompson (1968); and of *Dissotropis* Bartsch, 1906, by Thompson (*op. cit.*). Comparison of these accounts with the data given above for *Berendtia* and *Spartocentrum* shows that these two taxa are unlike the Eucalodiinae in their genital structure. Once again, the male genitalia are of primary importance. Unlike *Berendtia* and *Spartocentrum*, the Eucalodiinae have a relatively short penis which receives the insertion of the penial retractor muscle directly on the penis itself or on a short penial diverticulum. There is no

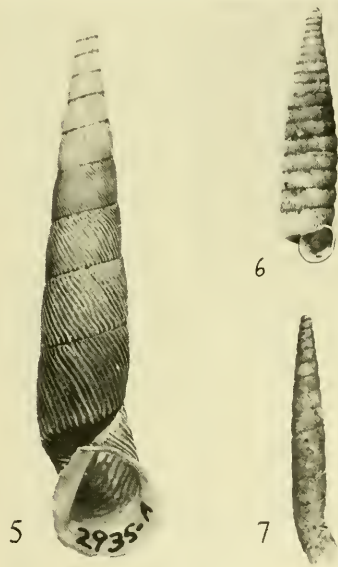


FIG. 5. *Berendtia taylori* (Pfeiffer, 1861). San Javier, Baja California Sur. Length 50.5 mm. FIG. 6. *Spartocentrum vanduzeei* (Hanna, 1923). 1.6 km south of Chuenque, Baja California Sur. Length 24.1 mm. FIG. 7. *Rabdotos ramentosus* (Cooper, 1891). Hills 5.1 km northeast of Santa Catarina, Baja California Sur. Length 23.6 mm.

epiphallie caecum and the penis lacks a sheath.

We believe that the genitalia indicate a close relationship of *Berendtia* and *Spartoecentrum* to *Rabdotus*, in the family Bulimulidae, and conflict with the present assignment of these genera to the family Urocoptidae.

A reexamination of the conchological features of *Berendtia* and *Spartoecentrum* shows that these characters are consistent with the proposed close relationship to *Rabdotus*. The sculpture of the nuclear whorls consists of vertical riblets, as in *Rabdotus*. While the shells of these two genera (figs. 5, 6) are more slender and elongated than those of most species of *Rabdotus*, they are similar to those of the subgenus *Plicolumna* Cooper, 1895, such as *R. (P.) vamentosus* (Cooper, 1891) (fig. 7).

Berendtia and *Spartoecentrum* resemble many Urocoptids in their ribbed sculpture and elongated outline, yet differ from them in important features. Most eucalodiine Urocoptids lose the initial whorls of the shell and close the resulting break with a calcareous plug. *Berendtia* and *Spartoecentrum* retain these whorls throughout life. The *Rabdotus*-like ribbed sculpture of the first embryonic whorls is also unlike that found in the Eucalodiinae. Pilsbry (1903), recognizing these distinctions, termed *Spartoecentrum* an "aberrant" subgenus of *Cocloecentrum*. Hanna (1923) predicted that it would eventually be given full generic status. *Berendtia* has long been recognized as a distinct genus.

CONCLUSION

Based on the anatomical and conchological evidence discussed above, we propose that *Spartoecentrum* be accorded generic status and that it and *Berendtia* be transferred to the Bulimulidae. *Rabdotus* has speciated extensively in Baja California; in view of the fact that no other closely related Bulimulids occur in Baja California or in adjacent regions of mainland Mexico, this group is the probable ancestor of these two unusual genera, which are autochthonous to Baja California. At present insufficient information is available to determine which subdivision of *Rabdotus* is most closely related to *Berendtia* and *Spartoecentrum*. Although similar in form to members of the subgenus *Plicolumna*, *Berendtia* and *Spartoecentrum*

do not seem to be descended from that group, as they lack the keeled nuclear whorls which distinguish that subgenus from other *Rabdotus*.

ACKNOWLEDGEMENTS

We wish to thank Mrs. Margaret M. Vescovi, who prepared the illustrations which accompany this report.

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RADIODISCUS HUBRICHTI (PULMONATA: ENDODONTIDAE)
NEW SPECIES FROM THE OLYMPIC PENINSULA, WASHINGTON¹

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Henderson (1929, 1936), in his rather extensive collecting, failed to disclose the presence of *Radiodiscus* in the state of Washington, as have all subsequent collectors. The generic name was proposed by Pilsbry and Ferriss (1906) to include a small number of small to minute endodontid snails that ranged from western Oregon to Arizona southward to Terre del Fuego in South America; *R. millicostatus*, from the Huachuca Mountains of Arizona, was presented as the genotype. The principal distinguishing feature of the genus are the embryonic whorls which are minutely engraved with spiral sculpture, whereas the remainder of the shell is radially costulate.

H. B. Baker's (1930) discovery of a new species, *R. abietum*, in Idaho extended the range of the genus to that state. Pilsbry (1948) summarized the published information on the two U.S. species, and Brunson and Russell (1967) reported the last-named species from 10 Montana localities, and that is essentially the present state of knowledge of the genus as far as North American species are concerned.

This paper extends that knowledge somewhat, and describes a new species, named in honor of my old friend, Leslie Hubricht, who has spent nearly his entire adult life in the study of terrestrial gastropods.

***Radiodiscus hubrichti* new species**

Figs. 1a, b, c

Description of holotype (U.S. National Museum, USNM 709470): the palehorn colored, nearly transparent shell is minute, 1.59 mm in diameter, 0.87 mm in height, with three whorls; the last whorl is slightly more than two times

wider than the next to the last (0.52mm/0.25mm), and the wide-open umbilicus, exhibiting all volutions to the apex, measures 0.51 mm and goes into the shell diameter three times; the umbilicus is paralleled by a series of minute, spiral sculptures. The spire is slightly everted, its whorls being separated by a moderately channelled suture; first one and one-half whorls marked by minute spiral sculpture, the rest being radially costulate; the costae are rather widely-spaced and extend for only about two-thirds the way on to the base, which is otherwise slightly granular in appearance. The aperture is oblique, and slightly descending. The animal is dead white with the exception of a small black blotch over the lung,

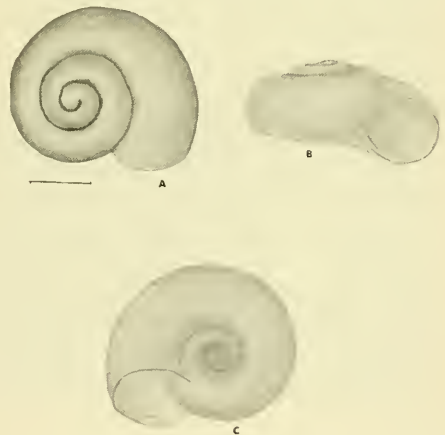


FIG. 1. *Radiodiscus hubrichti*, new species. a, apical view; b, apertural view; c, umbilical view. Scale line equals 1 mm.

¹ Supported in part by a Sigma Xi-RESA travel grant, and in part by Eastern Kentucky University Faculty grants 42-61 and 42-38.

and the foot is very narrow and pigmentless. The following measurements were secured from the several paratypes.

Locality 1: old glacial valley of Sams River, Kloochman Rock Quadrangle, S 34, R 10 W, T 24 N, Olympic Peninsula, Washington. Beneath the canopy of a bigleaf maple in piles of leaf litter and licorice ferns. 7 July 1969. Eastern Kentucky University (EKU 10904).

Locality 2: Mount Storm King, 4,000 feet mean sea level, Joyce Quadrangle, R 8 W, T 29 N, Olympic National Park, Washington, in litter of buckthorn and western hemlock. 5 July 1969. Chicago Field Museum of Natural History (FMNH 175456).

Locality 3: three miles up trail from Hoh Rain Forest ranger station, Mount Tom Quadrangle, S 4, R W, T 27 N, 960 feet mean sea level, in bigleaf maple litter, Olympic National Park, Washington. 11 July 1969. Delaware Museum of Natural History (DMNH 75901).

Locality 4: **Type Locality:** Spruce Mountain Quadrangle, northwest corner of S 30, R 12 W, T 27 N, 400 feet mean sea level, in bigleaf maple litter, Olympic National Park, Washington. 12 July 1969. Holotype and three additional specimens (EKU 10847 and 10954).

Locality 5: mouth of Duckabush River, U.S. Highway 101, Olympic Peninsula, Washington. 18 July 1969. (EKU 10949).

Locality 6: ten miles southwest of Sequim on Palo Alto Road, Tyler Peak Quadrangle, S 30, R 3 W, T 29 N, 1106 feet mean sea level, in red alder and fern litter, Olympic Peninsula, Washington. 15 July 1969. One specimen (EKU 10953).

Locality 7: La Poel Point, Lake Cresecent Quadrangle, S 32, R 9 W, T 30 N, 580 feet mean sea level, in salal litter, Olympic National

Park, Washington. 12 July 1969. Two specimens (EKU 10952).

REMARKS

Radiodiscus hubrichti appears to be most closely related to *R. millicostatus*, from which it differs in being pale-horn-colored rather than chestnut-brown, in having a pale first whorl rather than a bluish white one, in being somewhat smaller, and in having fewer whorls, less deeply channelled sutures. Also, the animal is much paler, and the lung is not mottled.

The new species differs from *R. abietum* in being much smaller, in having a nearly transparent epidermis rather than an opaque one, in color (*R. abietum* is light chocolate-brown), in having fewer whorls, in having 1½ embryonic whorls rather than 2 to 2¼, and in having a much larger umbilicus.

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Locality	Diameter	Height	Umbilicus Width	Whorls	Width Last Whorl	Width Spire
1	1.6 mm		0.50 mm	3 ¹ / ₃		
2	1.5	0.90	0.50	2 ³ / ₄		
3	1.5	0.70	0.60	3 ⁺		
4	1.2	0.46		2 ¹ / ₄		
4	1.7	0.70		31/5		
5	1.39	0.79	0.31	2 ² / ₃	0.46	0.75
5	1.26	0.70	0.35	2 ³ / ₄	0.38	0.70
4	1.50	0.98	0.36	3	0.43	0.86
6	1.60	0.91	0.42	3	0.50	0.84
7	1.68	0.95	0.47	3 ⁺	0.50	0.93
7	1.60	0.96	0.47	2 ³ / ₄	0.43	0.89

THE REDISCOVERY OF *MORUM PRAECLARUM* MELVILL (CASSIDAE)

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ABSTRACT

The previously unlocalized Morum (Cancellomorum) praeclarum Melvill, 1919, inhabits Natal/Zululand waters at depths of 27-250 fathoms. Reasons are given for believing that the holotype was originally dredged in 250 fathoms off Port Shepstone, Natal, by the Cape Government trawler, the s.s. Pieter Faure, in 1901; this is accordingly designated as type locality for the species.

Morum praeclarum Melvill, 1919, was based on a solitary specimen, without locality data, purchased by the describer from the MacAndrew collection. The holotype, now in the National Museum of Wales, Cardiff, U.K. (Dance & Emerson, 1967), has remained supposedly unique to this day, and the species unlocalized. Melvill's figure and description are good, and the shape of the species, notably the constricted nature of the aperture, is quite characteristic, so that recognition presents no problem. In recent years several specimens, clearly representing the "lost" *praeclarum*, have been taken from the stomachs of fishes caught in Natal/Zululand waters. Moreover the series in the collection of the South African Museum (Cape Town) that was recorded by Sowerby (1903) and Barnard (1963) as the Sino-Japanese *Morum macandrewi* (Sowerby, 1888), is also clearly conspecific. From the latter it is possible to muster a sufficient body of circumstantial evidence not only to indicate with a high degree of probability the origin of the holotype of *M. praeclarum*, but even to reconstruct details of the type locality.

In 1900-1901 the Cape Government conducted a survey of the continental shelf off Natal and Zululand, using the trawler s.s. *Pieter Faure*; many of the larger Mollusca obtained were sent to G. B. Sowerby (3rd) for identification and recording. Of these, a certain number (including some types) was retained by him and apparently sold. Now, according to Dance (1966: 216) James J. MacAndrew built up his collection almost entirely by the purchase of shells from dealers, notably Messrs. Sowerby and Fulton. That his purchases included *Pieter*

Faure specimens is proved by a reference in Dautzenberg (1929: 407) to the author having obtained from the MacAndrew collection a syntype of *Nassaria* 1 = *Hindsia* *gracilis* Sowerby, 1902, one of the species described from *Pieter Faure* material. Among the specimens retained by Sowerby was at least one specimen of the species that was recorded by him as *Oniscia macandrewi* (teste Barnard, 1963). It is here contended that this in all probability was the shell that Melvill later described as *praeclarum*. This cannot now be proven (unless MacAndrew's correspondence, if extant, contains some clue), but the alternative is to suppose that no less than two specimens of this striking mollusc were in circulation at about the same time, and that the second not only remained unrecognized by its

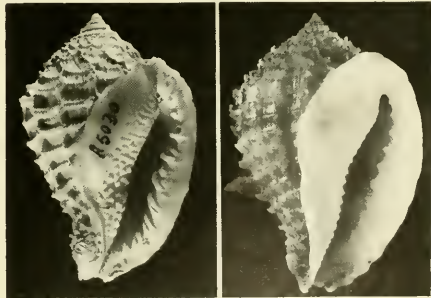


FIG. 1. *Morum praeclarum*. Left, 15 miles off Mvoti River, 56 fathoms. South African Museum coll., ex s.s. *Pieter Faure*. 36.3 × 24.2 mm. Right, off Durban in 160 fathoms, Natal Museum coll., leg. R. Cruickshank. 36.6 × 24.6 mm.

owner, but has subsequently completely disappeared. Simple application of Occam's Razor is sufficient to resolve the issue.

The material of *Morum praeclarum* retained by Sowerby came from 11 miles off Port Shepstone, bearing N.W. by W., at a depth of 250 fathoms. (This was one of the few hauls made off the continental shelf, and one of the last of the survey, which dates it as March or April 1901, *vide* Barnard, 1964). This is here formally designated as the type locality of the species.

Melville's original description of the general form and Barnard's detailed description of sculptural and other details should be read in conjunction. *M. praeclarum* is known from off Neill (O'Neil) Peak (28° 40' S.) in Zululand south to the type locality (30° 44' S.), in 27-250 fathoms. Barnard showed that the Cape St. Blaize locality cited by Sowerby was almost certainly due to a mutilated label.

The chief references to the species are as follows:

- Morum (Cancellomorum) praeclarum** Melville
Morum praeclarum Melville, 1919: 69.
Oniscia macandrewi (non Sowerby, 1888); Sowerby, 1903: 229.
Lambidium macandrewi (non *Oniscia m.* Sowerby, 1888); Barnard, 1963: 15.

ACKNOWLEDGEMENTS

I am indebted to the Director and Mr. B. F.

Kensley of the South African Museum for the loan of their set of *Morum praeclarum*.

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SUBSTITUTE NAME FOR *CONUS*

ORBIGNYI ARATUS

KILBURN, NOM. PREOCC.

R. N. Kilburn

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Pietermaritzburg, South Africa.

Dr. Harald A. Rehder has kindly pointed out that *Conus orbignyi aratus* Kilburn, 1973 (*Ann. Natal Mus.* 21 (3): 575), proposed for the

sulcate southeast African subspecies of the lirate Japanese *Conus orbignyi orbignyi* Audouin, 1831, is a junior homonym of *Conus aratus* Gabb, 1873.

The substitute trivial name *Conus orbignyi elokismenos* ("scratched in furrows") is here proposed in its stead.

Dr. R. Tucker Abbott informs me (*in litt.*) that specimens collected by A. Crosnier from off northwest Madagascar (310 to 428 meters) and by C. P. Fernandes from 400 meters, in mud, off Inhaca, Mozambique, have the character of both typical *orbignyi* and *elokismenos*.

COMPARISONS OF SHELL DIMENSIONS AND VISCERA MASS WEIGHTS IN *CORBICULA MANILENSIS* (PHILIPPI, 1844)

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ABSTRACT

Relationships of shell weight, size and wet and dry viscera weights were computed for Corbicula manilensis. The highest coefficient of correlation was recorded for shell length vs. width (0.9993) and the lowest for shell width vs. viscera dry weight (0.8755). Regression analyses were calculated for each of 10 shell and viscera comparisons.

INTRODUCTION

The present paper is an attempt to determine whether data relating to selected length-weight relationships of *Corbicula* would be useful in determining the biomass of natural or cultivated populations of the Asiatic clam. While this paper constitutes only the second report of *Corbicula* from West Virginia, random collecting in the southwestern portion of the state indicates that *Corbicula* is well-established here.¹

MATERIALS AND METHODS

Seventy-two *Corbicula manilensis* individuals were randomly collected from a riffle area in Mud River, Cabell County, W. Va. (Military grid 901 546, U. S. Geological Survey Map, Boursville Quadrangle, W. Va. — Ohio, N3822.5—W8215—7.5) on 10 October, 1973. The collection area was characterized by gravel of a wide range in size overlying a mixture of sand and silt. At the time of collection the riffle area measured 12 M wide and 30 M long.

A rake was used to turn the gravel and the clams were collected by hand, placed in a container, and immediately transported to the laboratory. Each *C. manilensis* individual was measured for length, the greatest distance

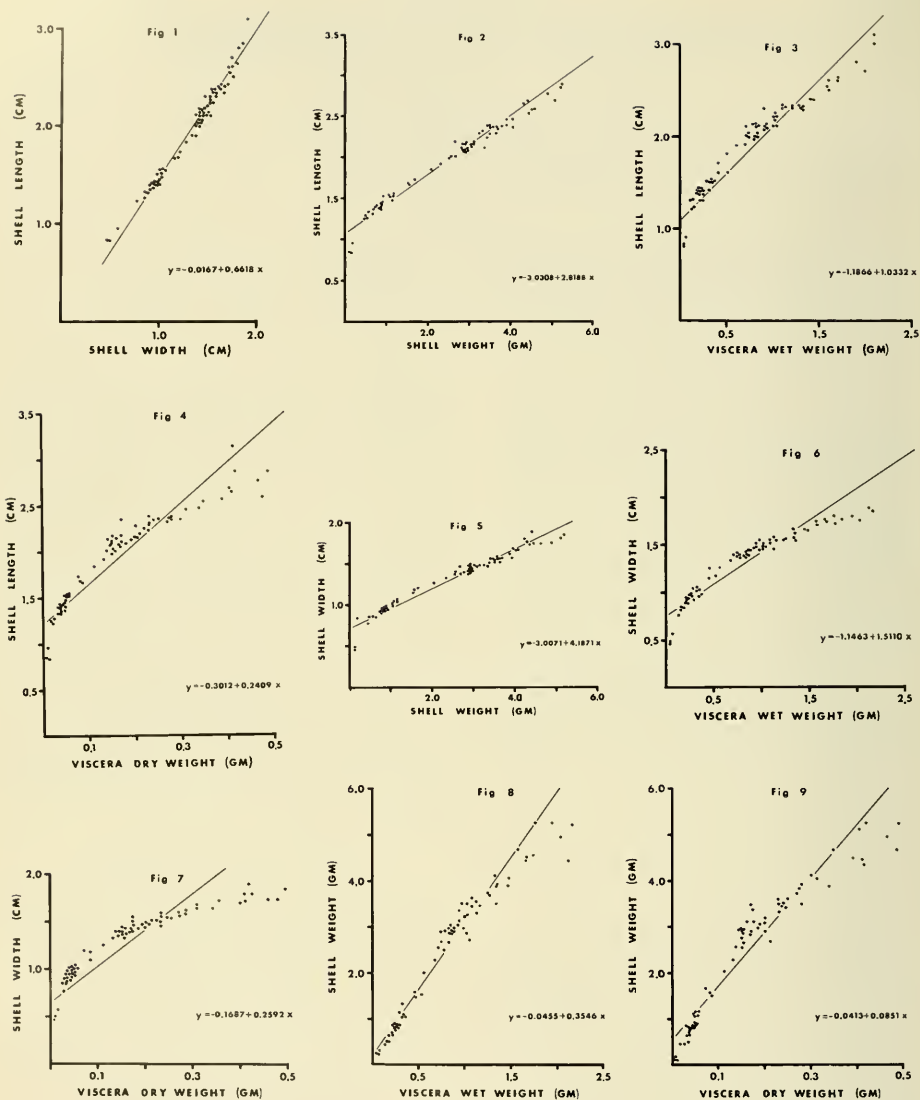
measured on a line perpendicular to a line forming a right angle with the hinge site, and width, the greatest shell dimension from the right to left valve. A razor blade was then inserted between the valves to sever the anterior and posterior adductor muscles (Pennak, 1953). The visceral mass was removed from each clam, blotted dry on a paper towel, weighed and recorded as wet weight. The wet weight samples were then placed in an oven to dry at 80°C. After a 12-24 hour period the samples were removed from the oven, weighed and recorded as dry weight. Shells were blotted and allowed to dry thoroughly at room temperature before weighing. All weights were recorded to the nearest ten-thousandths of a gram on a Bosch S2000 balance. Viscera wet weights and shell weights were recorded on the same day the clams were collected.

RESULTS AND DISCUSSION

Coefficients of correlation were calculated for ten different relationships pertaining to shell size and weight, and viscera weight of *Corbicula manilensis* (Table 1). The highest coefficient of correlation (0.9993) was recorded for length vs. width and the lowest (0.8755) for width vs. viscera dry weight. High r-values represented in Table 1 were anticipated since an r-value of 0.98 for width vs. viscera dry weight was recorded by Rinne (1974) for *Corbicula* from Arizona.

High r-values give investigators the advantage of quickly and accurately determining various parameters of living *Corbicula* individuals by measuring only their shell length or width. It

¹ *Editor's note:* Live specimens of the Asian clam, *Corbicula*, are now being sold by a Florida wholesale aquatic nursery under the name of the "Dwarf Clam", and they have been found for sale in retail fish hobby stores in New Jersey. This will probably speed the distribution of the clam throughout its maximum possible range in the United States and eventually the remaining Americas.—R. T. Abbott.



FIGS. 1-10. Scatter diagrams depicting various relationships between shell dimensions, weight, and wet and dry viscera weights of *Corbicula manilensis*. Each point represents a single individual. The regression analysis equation is included in the lower right corner of each figure.

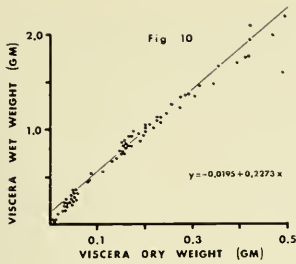


TABLE 1. Coefficients of correlation for various parameters concerning shell size and weight, and viscera weight of *Corbicula manilensis*.

	r-value
Length vs. Width	0.9993
Length vs. Shell Weight	0.9607
Length vs. Viscera Wet Weight	0.9407
Length vs. Viscera Dry Weight	0.9143
Width vs. Shell Weight	0.9599
Width vs. Viscera Wet Weight	0.9370
Width vs. Viscera Dry Weight	0.8755
Shell Weight vs. Viscera Wet Weight	0.9811
Shell Weight vs. Viscera Dry Weight	0.9779
Viscera Wet Weight vs. Viscera Dry Weight	0.9325

should be emphasized that present data was based on clams, taken from a riffle area during the autumn. While seasonal differences in visceral weight will conceivably occur because of changes in available food, depth of collection apparently did not influence data of the present study since Rinne (1974) noted that an "Analysis of variance showed non-significant differences between numbers, sizes, and biomasses relative to depth".

Regression analyses were calculated for each of the ten shell and viscera comparisons upon which r-values were computed (Figs. 1-10). When plotted against a linear regression curve, individual clams exhibit an amazingly direct relationship between shell length and width (Fig. 1). The same strict relationship is also evident, when plotting shell length vs. weight (Fig. 2), shell width vs. weight (Fig. 5), and wet and dry viscera weights (Fig. 10). In the remaining six figures, larger clams, when plotted against the regression curve, tend to fall below the curve, suggesting that the parameter on the axis increased at a greater rate than the parameter on the ordinate. For example, once *Corbicula* attained a shell length of 2.3 cm the rate of increase in wet weight became greater than the rate of increase in shell length. Prior to a length of 2.3 cm, the reverse was true (Fig. 3). The same pattern was evident when viscera weight was compared with shell weight. Viscera weight in larger clams increased at a greater rate than shell weight (Figs. 8 & 9). This was not altogether unique, however, since Kabayashi and Watable (1959) found that the rate of shell deposition in pearl oysters decreased with age. Another interesting facet concerning weight of *C. manilensis* was that dry viscera weight increased at a greater rate than wet visceral weight, resulting in proportionally higher dry weights in larger clams (Table 2, Fig. 10). Moreover, higher r-values in viscera wet weight than viscera dry weight indicate noncombustible mineral uptake varied more per individual than water content (Table 1).

Additional work (unpublished) in our laboratory by Mr. John Dingess has indicated

TABLE 2. Dry weight expressed as a proportion of wet weight relative to shell length.

Shell length (cm)	No. <i>Corbicula</i> in sample	Mean dry wt. expressed as a percentage of mean wet wt.
> 2.50	9	23.23
2.01 - 2.50	34	20.29
1.51 - 2.00	11	17.57
1.01 - 1.50	15	16.71
< 1.01	3	9.27

that comparisons of shell dimensions of *Lampsilis radiata luteola* (Lamarck, 1819) are not correlated as closely as those of *Corbicula*. For example, shell length vs. width in *L. r. luteola* has an r-value of 0.6907 for males and 0.6757 for females, both considerably below the calculated 0.9993 for *Corbicula*.

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TYPE MATERIAL OF SOME CUBAN HELICINIDS

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During a recent inspection of the Antillean land shells in the Newcomb Collection of Recent Mollusks, Department of Geological Sciences, Cornell University, assembled by Dr. Wesley Newcomb (1811-1892) and presently stored in the building formerly occupied by the Paleontological Research Institute at 109 Dearborn Place, Ithaca, New York, the writer located some type material of Cuban helicnids which should be called to the attention of interested students. The locality of all the lots consists solely of the word "Cuba" but Newcomb added "ex auct." to the labels, thereby verifying their status as syntypes. In several revisions of the Cuban helicnids, Clench

& Jacobson (1968, 1970, 1971) and Boss & Jacobson (1973) designated lectotypic specimens from material in the collection of the Museum of Comparative Zoology in Harvard University. In three cases, as noted below, these authors were unable to locate some typological material. The availability of the Newcomb Collection now permits the selection of additional types. Other data cited below add to our knowledge of some poorly known taxa, mainly specimens of species described by Poey. There is presumably more such material in the Museo Poey in Havana, and a report that a catalog of this material may soon appear in print is very welcome.

The Newcomb Collection was described by

Clarke (1960), to whom the author of this report is obligated for having called his attention to the Cuban shells in the Collection.

I am much indebted to the kindness of Dr. John W. Wells, Professor Emeritus of Cornell University, who provided me with every facility to examine the Newcomb Collection. Dr. William K. Emerson of the American Museum of Natural History discussed certain problems with me and checked the manuscript.

The list of these types follows:

nodae Arango, **Helicina**. 1862: Jour. de Conchyl. **10**: 409 [non Sowerby, 1866] (Guane [Pinar del Río]). Newcomb Coll. 24076, 4 cotypes. Syn. of *Troschelviana (Cubaviana) rubromarginata* (Gundlach, 1858). NOTE: Clench & Jacobson (1971: 426) selected as lectotype MCZ 73781 ex Arango.

politula Poey, **Helicina**. 1852: Memorias sobre historia natural isla de Cuba **1**: 113 (Santa Cruz en tierra de D. Francisco Adolfo Sauvalle [Pinar del Río?]). Newcomb Coll. 24207, 4 cotypes. Syn. of *Troschelviana (Cubaviana) pyramidalis* (Sowerby, 1842). NOTE: Clench & Jacobson (1971: 424) supposed that the type was in the Museo Poey, not seen.

proxima Gundlach MS Pfeiffer, **Helicina**. 1858: Malak. Blätt. **5**: 49 (Buena Vista, Oriente). Newcomb Coll. 24188, 2 cotypes. Syn. of *Alcacia (Penisoltia) minima* (Orbigny, 1842). NOTE: Type previously reported as destroyed (Boss & Jacobson, 1973:338).

rubella Wright MS Pfeiffer, **Helicina**. 1864: Malak Blätt. **11**: 107 [non Green, 1833] (Cayos de San Felipe [Pinar del Río]). Newcomb Coll. 24117, 4 cotypes. Syn. of *Troschelviana (T.) erythraea* (Sowerby, 1866). NOTE: Clench & Jacobson (1971: 418) selected as lectotype MCZ 73779 ex Wright.

stellata Velásquez MS Poey, **Helicina**. 1851: Memorias sobre historia natural isla de Cuba **1**: 117 (Sierra de Casas, [sic] Isla de Pinos). Newcomb Coll. 24212, 5 cotypes. Is *Priotrochatella stellata* (Poey). NOTE: Type reported as "not seen" by Clench & Jacobson (1970: 70). Poey erroneously transposed the

names Sierra de Casas and Sierra de Caballos (Clapp, 1918: 48).

subglobulosa Poey, **Helicina**. 1851: Memorias sobre historia natural isla de Cuba **1**: 115, pl. 12, figs. 17-21 (Trinidad [Oriente]). Newcomb Coll. 24140, 3 cotypes.

subunguiculata Poey, **Helicina**. 1857: Memorias sobre historia natural isla de Cuba **2**: 34 (Sierra de Guane [Pinar del Río]). Newcomb Coll. 24214, 4 cotypes. Is *Viana regina subunguiculata* (Poey). NOTE: Clench & Jacobson selected as lectotype MCZ 73672 ex Poey.

suturalis Gundlach MS, Pfeiffer, **Helicina bellula**. 1860: Malak. Blätt. **6**: 80 (La Cubana, Yateras, Guantánamo, Oriente). Newcomb Coll. 23955, 5 cotypes. Syn. of *Alcacia (Idesa) spectabilis* (Pfeiffer, 1858). NOTE: Boss & Jacobson (1973: pl. 6, figs. 7-9) figured MCZ 74029 ex Anthony ex Gundlach.

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SEASONAL MIGRATION AND DENSITY PATTERNS OF
THE FRESH WATER SNAIL *AMNICOLA LIMOSA*Thomas J. Horst¹ and Robert R. Costa²Department of Biological Sciences
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ABSTRACT

The life cycle and dispersion of the freshwater snail *Amnicola limosa* (Say) were studied with interest in seasonal migration patterns. It was initially hypothesized that seasonal migration between shallow and deep water would be adaptive for snails living in temperate lakes with seasonally fluctuating benthic environments. The thickness of ice would preclude them from shallow water in winter. During summer months snails would be concentrated in shallow water. This pattern of seasonal migration was supported by studies of a small lake in western New York. Migration was found to be associated with changes in water temperature at the sediment interface and variation in the hydrophyte community. The life cycle was found to have two periods of high mortality. One occurred in newly-hatched snails and the second in post reproductive adults.

INTRODUCTION

Cheatum (1934) suggested a seasonal migration pattern for pulmonate gastropods in Douglas Lake, Michigan. He concluded that this migration to shallow water during spring and to deep water during fall was in response to the changes in water temperature.

Seasonal migration between shallow and deep water probably would be adaptive for the freshwater prosobranch snail, *Amnicola limosa* (Say) (Hydrobiidae) living in temperate lakes with seasonally fluctuating benthic environments. The thickness of ice would preclude them from shallow water in winter and thereby concentrate them in deeper water. Ice on McCargo Lake reached a maximum thickness of one meter for the 1969-1970 winter. During summer months snails would be concentrated in shallow water. This is where aquatic macrophytes and the algal community associated with them would be located.

Shallow water was defined as the area from shore to a depth of 1.0 meter. Deep water was

defined as the area from 1.5 to 2.0 meters deep. A mid-water station was also sampled which was located at depths between the other two stations (1.0 to 1.5 m). Migration was defined as a change between successive months in the proportion of the population in either deep or shallow water.

MATERIALS AND METHODS

The study area, McCargo Lake, is located on the Fancher Campus of the State University of New York College at Brockport in western New York. The lake has a surface area of 3.2 hectares, a maximum depth of 5.75 m. and a mean depth of 2.6 m. The average Secchi reading for 1970 was 1.4 m. Rooted vegetation extends to a depth of about one meter (Horst 1971).

The lake was partitioned into seventeen transects each oriented from shore to a depth of 2.0 m. Previous work indicated the gastropod community in McCargo Lake was restricted to depths of 2.0 meters or less (Horst and Costa 1971). Three stations which were sampled in duplicate were designated along each transect.

Transects were sampled one per week. The order of sampling the transects was such that at monthly intervals a north, south, east and west facing location were involved. Differences in population density had been previously

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recognized at the north and south facing transects (Horst and Costa 1971). Monthly estimates served to integrate these differences within the lake and therefore, preferable for detection of migration patterns.

Macrobenthos were sampled with a fifteen centimeter square Ekman dredge. Snails were removed from dredge samples using the techniques of Duncan (1959). A least squares analysis of variance (ANOVA) was performed with a square root transformation of count data to provide a statistical basis for conclusions.

The benthic environment at each station was characterized by determinations of water and sediment temperatures, dissolved oxygen concentration and percent organic matter in the sediments. Water samples were collected at the mud-water interface at each station. Dissolved oxygen was determined by the azide modification of the Winkler method. Percent organic matter in the sediments was estimated by weight loss upon ignition at 600°C.

Randomized complete block ANOVA's were performed to test for differences in each of these variables at the three locations. Time in

months was used as a blocking factor in the analyses to remove seasonal fluctuations.

RESULTS

Significant differences in *Ammnicola* density were detected between months ($p < 0.007$) and between depths ($p < 0.014$). The depth by month interaction was also significant ($p < 0.0002$) indicating the depth pattern was dependent upon the month.

Further analysis was performed using the least significant difference test (LSD), and significant differences ($p = 0.05$) in the population density were detected for all successive months from June to October. During spring and early summer (April to June) and the fall to early winter (October to December) there were no detectable differences in the population (Fig. 1).

LSD analysis of depth showed no significant difference between shallow and mid-depth; or between mid and deep water. The proportion of the population in shallow and deep water was therefore, compared for analysis of seasonal migration due to the significant difference ($p = 0.05$) detected by this analysis.



FIG. 1. The density of *Ammnicola limosa* April to December 1970; averaged over all depths in McCargo Lake.

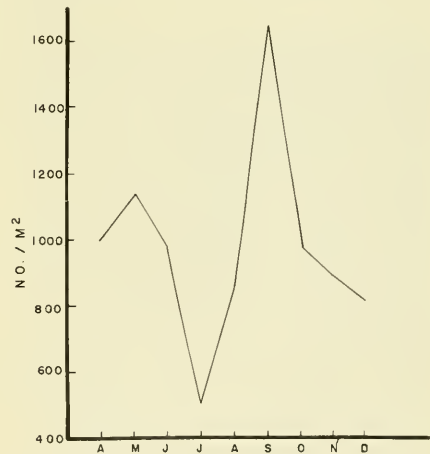


FIG. 2. The percentage of the *Ammnicola* population in the shallow and deep water areas, April to December, 1970; McCargo Lake.

Proportions of the population found at shallow water and deep water stations varied throughout the year (Fig. 2). For example, August samples had the greatest proportion of any month in shallow water (68%) and the smallest proportion of any month in deep water (2%). December samples demonstrated a reverse pattern with 64% of the population in deep water and 17% in shallow water.

The ANOVA's of environmental variables detected no significant differences in dissolved oxygen, sediment organic matter, water and sediment temperatures at the three depth areas. The mean dissolved oxygen concentration was 7.1 ppm. Sediments had an average of 30.4% organic matter. The greatest range in water temperature between depths was 2.8°C, which was detected during summer stratification. A typical seasonal fluctuation in sediment and water temperature was recognized with a winter minimum of 1.0°C (January) and a summer maximum of 25°C in August.

DISCUSSION

The *Ammicola* population for any month at any depth is dependent upon the population the previous month (birth, death, immigration and emigration). It is assumed that immigration and emigration take place only between depths. This is a reasonable assumption, as the population was found to be concentrated at depths of 2.0 m. and less in the lake (Horst and Costa, 1971). Any movement at the same depth will not alter the population at that depth. Any change in the population averaged over the three depths (Fig. 1) is therefore, dependent upon only birth and death in the population.

Birth to the population will be a factor only during egg-hatching months and can be ignored at other times. Post (1971) reported the first *Ammicola* eggs in McCargo Lake on June 23 and the last ones on August 25, 1970. They reached a maximum density of 40 eggs per 100 cm² of artificial substrate on July 7. Eggs were observed only to a depth of 1.0 m. which corresponds to stations in shallow water.

A lag period between observation of eggs and young in the population should reflect the development time of eggs. Berry (1943) reported a development time of ten days at about 24°C. The first increase in the population was be-

tween July and August during which time water temperature was above 25°C. Another increase in population density between August and September reflected hatching of later eggs. Thus it appears the increase in population density between July and September is the result of eggs hatching.

Two periods of high mortality have been suggested during gastropod life cycles. One period of high mortality occurs following the hatching of eggs (DeWitt 1955, Hunter 1961). The reduced population density observed between September and October is interpreted as a reflection of this mortality.

Another period of reduced density in this study occurred between June and July. Eggs were first detected in late June which suggests from June to July there was no birth and post-reproductive adults were dying. DeWitt (1955) reported high mortality for post-reproductive adult pulmonate snails.

Analysis of mean shell size at the three depths by month also supports this contention (Horst 1971). The maximum mean for shell size (3.3 mm) occurred in July in shallow water and the minimum shell size (1.1 mm) was observed at the same depth in August. It therefore appears that the large adults in July samples have either died or moved to deeper water.

The rather high mean shell sizes (2.0 mm) in deeper water stations during August and September suggests those snails which hatch late in the summer do not reach maturity by the next breeding season and overwinter the second time (Horst, 1971). Houp (1970) has reported a lag in growth of the late hatch of *Pleurocera acuta*.

Migration took place from deep water to shallow water from June to August (Fig. 2), although some of the increase in density was a result of birth to the population in shallow water (Fig. 1). From September to December a reverse migration pattern, from shallow to deep water, took place.

Migration to shallow water in June followed an increase in water temperature during April and May. Movement to deeper water in September also corresponded to a change in water temperature. Water temperature could have stimulated the response as suggested by Cheatum (1934).

Growth of the hydrophyte community began during April and continued into September. Migration to shallow water followed the spring growth of aquatic plants. Fall migration took place about the end of the growing season for the plants.

Aquatic vascular plants support rich algal communities upon which *Ammicola* feed (Berry, 1943). These plants also provide a three-dimensional environment as compared to the two dimensional nature of the substrate in deeper water. This increase in space can be significant as these plants provide the substrate upon which the snails feed and lay their eggs. Since Post (1971) observed eggs only in shallow water this area may serve as a nursery area for *Ammicola limosa*.

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SIZE DISTRIBUTION OF THE BIVALVE *MULINIA LATERALIS* (MACTRIDAE) AND ENERGY LEVEL OF SOME PLEISTOCENE SEDIMENTS

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ABSTRACT

*The size distribution of the clam *Mulinia lateralis* in Pleistocene sediments from North Carolina is closely related to the energy level of the depositing medium as measured by sand percentage of the sediment. The strata which were sampled show little or no evidence of a high energy paleoenvironment when examined in the field, but the effect on the fossil populations is obvious in the detailed analysis.*

INTRODUCTION

The clam *Mulinia lateralis* (Say) is the most abundant megafossil in the Pleistocene Neuse Formation (Fallaw and Wheeler, 1969) in southeastern North Carolina. It is a shallow burrower, common in modern lagoons and estuaries (Stanley, 1970). The sediments of the formation are mostly fine-grained and very fine-grained quartz sands, with varying amounts of silt and clay. They were deposited in shallow bays and estuaries and in the shallow shelf environment. There is a significant variation in the size of *M. lateralis* in different beds of the formation, even in those beds which appear to be very similar in texture when examined in the field.

The relationship between size of the clam and its enclosing sediments was investigated by analyzing six samples in detail. Two samples were obtained from each of these localities: Alliance and Flanner Beach, North Carolina, described by Fallaw and Wheeler (1969), and the Waccamaw Brick Company outcrop near Myrtle Beach, South Carolina, described by DuBar (1971). The length (maximum dimension) of fifty valves from each locality was measured by a micrometer to 0.01 mm. The sand percentage of the clastic portion of the samples was determined by dissolving carbonates in hydrochloric acid, rinsing, dispersing with dilute Calgonite solution, and pouring the sediment through a 0.062 mm screen which retained

sand-size particles. Sorting was calculated according to the formula of Folk and Ward (1957), that is,

$$\sigma_1 = \frac{P_{84} - P_{16}}{4} + \frac{P_{95} - P_5}{6.6}$$

The striking thing resulting from this study is that differences in energy level of the depositing medium had a major effect on the size distribution of the fossil populations, but little effect on the sediments themselves as far as major structural and textural properties are concerned. The sand percentage in the six samples ranged only from 83% to 94%, the remaining material being silt and clay. There is little structural evidence of transportation in those beds which were sampled. No cross-bedding, unconformities, or ripple marks were observed. The sand was mostly in the very fine-grain and fine grain classes, less than one percent being in the greater-than-coarse-grain classes (Wentworth scale). There is enough silt, clay and organic matter in the sediments to give them an olive gray or greenish-gray appearance. Indeed, the first impression on looking at the deposits is that they formed in a quiet, low energy environment. The shells show little evidence of transportation, broken and abraded ones being rare, and some clams (not *Mulinia*) were found with both valves still together.

Figure 1 shows several parameters of the length distribution of *Mulinia* populations plotted against sand percentage, a crude measure of the energy level of the environment of deposition. For the parameters minimum length, mean length, and maximum length, the three relatively low sand samples fall into one field and the three high sand samples fall into a distinctly different field. For minimum length, the valves in the high sand field are at least 30% longer, for the mean length parameter, the valves in the high sand field are at least 19% longer, and for the maximum length, they are at least 9% longer.

Another interesting result of the analysis is that sorting, shown by "S" on the graph, is not closely related to energy level, even though high energy levels tend to produce good sorting in the shallow marine environment.

Investigators of age and size distributions of fossil populations should be aware that even in studies of materials that show little evidence of

transportation, the energy level can have a significant effect on the populations.

ACKNOWLEDGMENTS

I wish to acknowledge the assistance of Linda Heatwole who compiled much of the data for this study.

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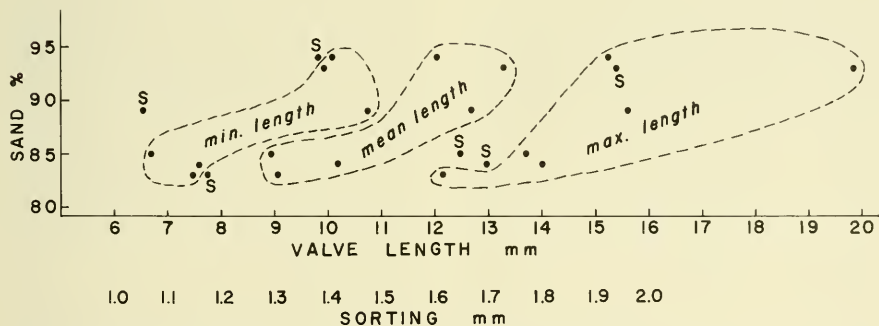


FIG. 1. Graph showing relationships of *Mulinia* valve length distribution parameters and sand percentage. "S" denotes sorting values. Other points are for areas labeled.

NOTES ON LAND SLUGS, 22:
 A CATALOGUE OF THE GENUS *LYTOPELITE* (LIMACIDAE)
 AND A NOTE ON *L. KANDAHARENSIS* (ALTENA)

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I am indebted to Mrs. Dochita Lupu for calling my attention to the fact that *Deroceras kandaharensis* Altena (1970) belongs to the genus *Lytopenelte*. The generic transfer means that this species should be called *Lytopenelte kandaharensis* (Altena).

Kandahar, Afghanistan, the type locality, is more than 500 km. south of the area from which *Lytopenelte maculata* (Koch & Heynemann) is known, and also more than 500 km. southwest of the localities from which *L. boettgeri* Rosen and *L. transcaspia* Rosen were reported. All of these differ from *L. kandaharensis* in having the keel on the whole dorsum and in color. Only *L. maculata* has been dissected. It differs also in penial structure. They all belong to *Lytopenelte* s. str. Since the keel in *L. kandaharensis* extends over at most half the dorsum, it must be placed in the subgenus *Liolytopenelte*. The nearest geographic representatives of this subgenus are *L. caucasica* Simroth and *L. grusina* Simroth. Both of them lack the white line on the dorsum and they have a collateral protuberance on the penis that is lacking in *L. kandaharensis*.

The species with the most similar penis structure is *L. moldavica* Grossu & Lupu from Romania, but it has a longer oviduct that is sharply reflected, and the calcareous plate on the penis stimulator differs in shape from the "dunce's cap" found in *L. kandaharensis*. This latter structure is more similar to the calcareous plate found in *L. caucasica*.

The following list of named taxa in *Lytopenelte* is thought to be complete. After each listing, the correct genus and subgenus reference is listed in brackets.

Genus Lytopenelte O. Boettger, 1886

G. Radde, Die Fauna und Flora des süd-westlichen Caspi-Gebietes, p. 266 (as section of *Amalia* Moquin-Tandon); O. Boettger, 1886, Jahrb. d. malak. Ges., 13: 241. Monotype. - *Amalia (Lytopenelte) longicollis* Boettger, 1886.

Proposed subgeneric names are:

Platyoxon Simroth, 1886. Jahrb. d. malak. Ges., 13: 311, 316 (subgenus of *Agriolimax* Mörch). Monotype: *Agriolimax (Platyoxon) maculatus* (Koch & Heynemann, 1874). = [*Lytopenelte* s. str.] A synonym of *Lytopenelte* s. s.

Liolytopenelte Simroth, 1901. Nacktschneck. russ. Reiches, p. 174 (subgenus of *Lytopenelte*). Included species were: *Lytopenelte caucasica* Simroth, 1901 and *L. grusina* Simroth, 1901. Type species: *Lytopenelte caucasica* Simroth, 1901 by subsequent designation of Hesse, 1926. = [*Lytopenelte (Liolytopenelte)*]

Tropidolytopenelte Simroth, 1901. Nacktschneck. russ. Reiches, p. 174 (subgenus of *Lytopenelte*). Syntype: "*Lytopenelte maculata* Koch et Heynemann nebst denübrigen von Böttger und Rosen beschriebenen Arten." = [*Lytopenelte* s. str.]

Proposed species names are:

boettgeri Rosen, 1892, *Lytopenelte*. Nachrichtsbld. malak. Ges., 24: 124-Suluklü [at the southeastern corner of the Caspian Sea.] = [*Lytopenelte* s. str.]

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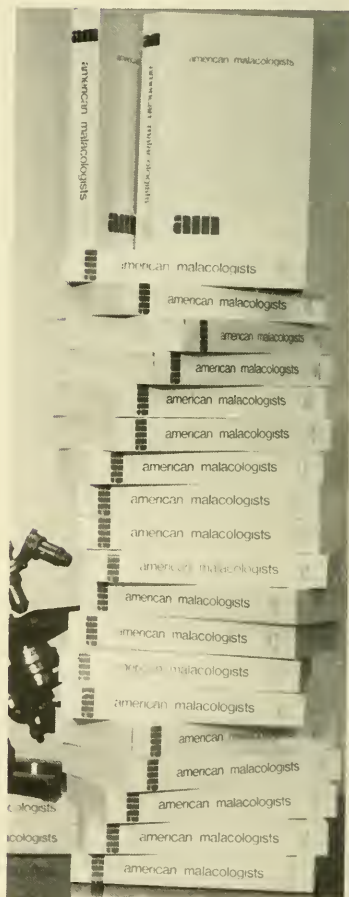
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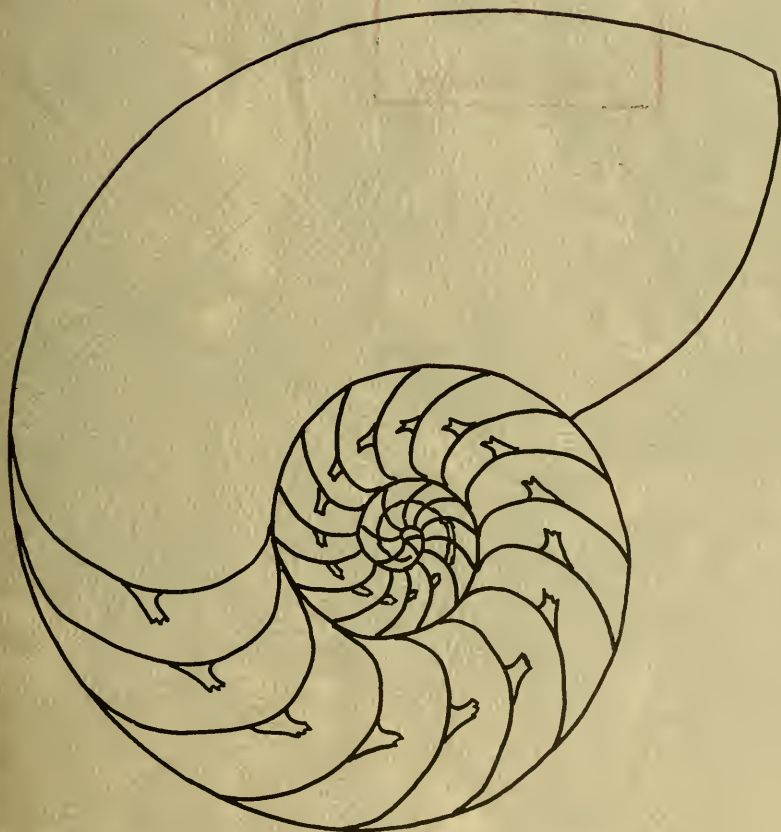
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FLUORIDE ACCUMULATION IN THE LAND SNAIL *OREOHELIX SUBRUDIS*
FROM WESTERN MONTANA

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ABSTRACT

Land snails of the species Oreohelix subrudis ("Pfeiffer" Reeve, 1854) were collected and analyzed for their fluoride content. The snails were collected within a region in western Montana that is known to be contaminated with gaseous and particulate fluoride emissions from an aluminum reduction plant. Analyses of the specimens revealed that fluoride accumulation had occurred within the shells and to a lesser degree in the body tissues of the snails. Fluoride levels 9-12 times control levels were observed in shells of snails collected nearest the aluminum plant, whereas fluoride levels 2-3 times control levels were observed in shells of snails collected eleven air-miles from the aluminum plant.

On August 15, 1955, the Anaconda Company formerly dedicated a new aluminum reduction plant at Columbia Falls, Montana. The plant uses the Vertical Stud Soderberg Pot system for reducing alumina to pure aluminum. During this electrolytic process, sodium fluoride (NaF) and aluminum fluoride (AlF₃) are released as airborne particulate waste, and hydrogen fluoride (HF) and carbon tetrafluoride (CF₄) are released as gaseous waste. NaF, AlF₃, and HF are accumulated by and cause injury to plants.

The work of Carlson and Dewey (1971) and Carlson (1973) documented fluoride air pollution over nearly 214,000 acres of private and public lands in the vicinity of the aluminum reduction plant. Carlson (Op. cit.) reported elevated fluoride content and fluoride-induced necrosis on some of the vegetation which he studied. Dewey (1972) observed elevated fluoride levels in both herbivorous and carnivorous insects, whereas Gordon (1972) observed abnormalities of the bones and teeth of cattle and deer which had fed on fluoridated vegetation.

Figure 1 (from Carlson, 1972) shows the extent of fluoride pollution for August, 1971. Ten ppm fluoride or less was accepted by Carlson as the level which could be expected to occur in unpolluted vegetation in this region.

Inasmuch as fluoride accumulates in plants and is carried through the food chain to her-

bivores and carnivores, the authors postulated that the herbivorous land snail, *Oreohelix subrudis* ("Pfeiffer" Reeve, 1854), might also have accumulated large amounts of fluoride after it had fed on polluted vegetation.

According to Pilsbry (1939, p. 490-491), two-banded *O. subrudis* shells are widely spread in Montana, and a high, beehive-like form has been recorded in Glacier National Park, in the Mission Range, and near Flathead Lake. *O. subrudis* has been collected extensively in and around western Montana by the authors.

Control levels of fluoride for the snails were established by analyzing shells from the authors' collection and from several collection sites in western Montana. Four collection sites were established near the aluminum plant in order to determine the extent of fluoride accumulation in the snails.

Shells which were collected empty were rinsed under running tap water (unfluoridated) and scrubbed with a brush to remove particles of soil before being air-dried 72 hours at 32°C in a forced draft drying oven. After drying the shells were ground to a fine powder in a mortar with a pestle. Living snails were placed in boiling tap water for 90 seconds to kill and loosen the bodies from the shells. These shells also were rinsed and scrubbed with a brush under running tap water, whereas the bodies were

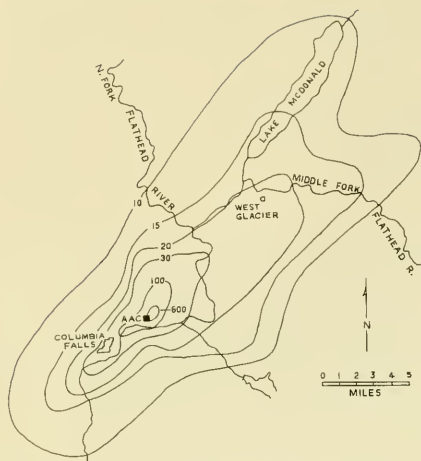


FIG. 1. Isopols of fluoride pollution at Columbia Falls, Montana, August, 1971. Values represent mean ppm fluoride in the vegetation.

placed on paper toweling to blot dry. At this time the body was separated into a portion consisting of the head, foot, and proximal portion of the visceral mass and a remaining portion consisting primarily of the midgut gland ("liver") and the ovotestis. These shells and body portions also were air dried at 32°C and ground as previously described.

Mature (4 1/2 whorls) shells from the study area weigh approximately 0.8 gram; therefore, one shell is adequate material for the standard 0.500 gram sample. Approximately five snails were needed to make up a 0.500 gram sample of the head, foot, and lower visceral mass. Approximately ten snails were needed for an adequate sample of the liver portion.

The determination of fluoride content in snail shells and body tissues was done the same except where noted in the following procedure: Standard 0.500 gram portions of each sample were weighed into nickel crucibles. Body tissue samples, only, were supplemented with 0.050 gram of low fluorine calcium oxide. All samples were then slurried with distilled water and then charred in an infrared oven. After being charred, the samples were ashed for approximately 16 hours at 600°C in a muffle fur-

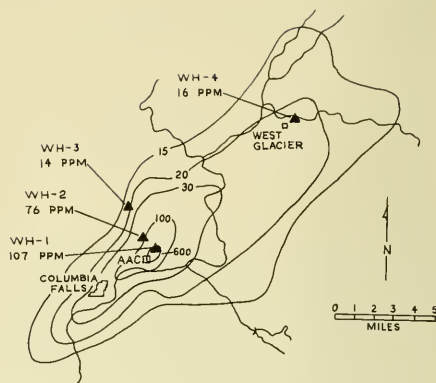


FIG. 2. Location of snail collection sites and the mean fluoride content of the shells of snails collected at these sites relative to Carlson's 1971 isopols of fluoride pollution.

nace and then cooled in a desiccator. Each sample subsequently was moistened with distilled water. To dissolve the moistened ash, 2 ml of 30 percent perchloric acid were added to the ash of the body samples, whereas 2 ml of 19 percent hydrochloric acid were added to the ash of the shell samples. The dissolved samples were then brought to 100 ml volume by adding TISAB (from Orion Research) diluted 50 percent by distilled water. Fluoride activity was determined using an Orion Ionalyzer and Orion fluoride and reference electrodes.

Levels of fluoride in the control shells ranged from 2 ppm to 8 ppm with a mean of 5 ppm on the basis of 22 analyses. Six samples of shells from collection site WH-1 contained from 84 ppm to 127 ppm with a mean of 107 ppm. The bodies of the WH-1 snails contained an average of 38 ppm. Eleven shells from collection site WH-2 contained from 58 ppm to 90 ppm with a mean of 76 ppm. The bodies of the WH-2 snails averaged 31 ppm. Thirteen samples of shells from site WH-3 contained from 9 ppm to 19 ppm with a mean of 14 ppm. The body tissues of the WH-3 snails contained an average of 16 ppm. The ten shell-samples which were analyzed from collection site WH-4 contained from 13 ppm to 21 ppm with a mean of 16 ppm. The body tissues of these snails averaged

TABLE 1

Controls:	Sample No.	Ppm Fluoride			
			Head, foot, and lower viscera from WH1a-d:	WH1g	40
				WH1h	35
				WH1i	41
			Midgut gland-ovotestis portion from WH1a-d:	WH1j	37
<i>Anguispira</i> , St. Regis, Mineral Co., Mont., April, 1973:	WH53a (shell)	4			
	WH53b "	3			
<i>Anguispira</i> , Yellow Bay State Park, Lake Co., Mont., June, 1973:	WH57a (shell)	9			
	WH57b "	6			
	WH57c (whole bodies)	5			
				Sample No.	Ppm Fluoride
<i>Oreohelix</i> , Troy, Lincoln Co., Mont., June, 1973:	WH58a (shell)	7			
	WH58b "	5			
	WH58c "	7	Mature shells found empty:	WH2a	83
	WH58d "	5		WH2b	96
	WH58e "	8		WH2c	86
<i>Oreohelix</i> , Noxon, Sanders Co., Mont. T25N, R32W, sec. 10, May, 1956:	M156a (shell)	4	Mature shells:	WH2d	67
	M156b "	4		WH2e	68
				WH2f	71
				WH2g	61
				WH2h	58
				WH2i	81
<i>Oreohelix</i> , Yellow Bay, Mont., T24N, R19W, sec. 3, Lake Co., September, 1947:	IM114, 47a (shell)	5			
	IM114, 47b "	3			
	IM115, 47a "	1	Half-grown shells:	WH2j	87
	IM115, 47b "	5		WH2k	82
<i>Oreohelix</i> , Swan Mtns., T28N, R19W, sec. 35, Flathead Co., Mont., July, 1947:	IM120, 47 (shell)	2	3 mm to 6 mm dia. shells:	WH2l	143
<i>Oreohelix</i> , Moose Creek Canyon, Jackson Hole, Wyo., 1947:	IM379, 47a (shell)	7	Head, foot, and lower viscera from WH2d-f and WH2g-i, respectively:	WH2m	32
	IM379, 47b "	3		WH2n	32
<i>Oreohelix</i> , Mission Canyon, T18N, R18N, sec. 7, Lake Co., Mont., May, 1948:	IM106, 48 (shell)	4	Midgut gland-ovotestis portion from WH2d-i:	WH2o	29
<i>Oreohelix subrudis</i> , Sapphire Range, Missoula, Mont., May, 1948:	IM172, 48 (shell)	4			
				Sample No.	Ppm Fluoride
<i>Oreohelix</i> , Woods Bay, T20N, R19W, sec. 21, Lake Co., Mont., June, 1948:	IM190, 48a (shell)	5	Mature shells found empty:	WH3a	18
	IM190, 48b "	4		WH3b	16
				WH3c	14
				WH3d	9
WH-1. Collection site approximately 1/2 mile N. E. of the aluminum plant in the S. W. 1/4 of sec. 35, T31N, R20W, Flathead Co., Mont. Collection made in April, 1973:					
			Mature shells:	WH3e	17
				WH3f	13
				WH3g	13
				WH3h	18
				WH3i	13
				WH3j	14
				WH3k	16
				WH3l	19
				WH3m	14
Mature shells:	WH1a	97			
	WH1b	118			
	WH1c	127			
	WH1d	104			
Half-grown shells:	WH1e	114	Head, foot, and lower viscera from WH3e-g, WH3h-j, and WH3k-m, respectively:	WH3n	20
	WH1f	84		WH3o	14
				WH3p	15

Midgut gland-ovotestis portion from WH3-m: WH3j 18

WH-4. Collection site located at West Glacier, Flathead Co., Mont., near the abandoned bridge across the Middle Fork of the Flathead River. The collection was made in June, 1973:

	Sample No.	Ppm Fluoride
Mature shells:	WH4a	17
	WH4b	13
	WH4c	16
	WH4d	17
	WH4e	16
	WH4f	17
	WH4g	13
	WH4h	15
	WH4i	20
Whole bodies from WH4a-i:	WH4j	11

11 ppm fluoride. The results of the chemical analyses appear in Table I. Figure 2 shows the locations of the collection sites WH-1, 2, 3 and 4 and the mean fluoride content of the shells from these sites in relation to Carlson's 1971 isopols of fluoride pollution.

O. subrudis is an herbivore and has been observed during the course of this investigation to feed on fallen leaves of *Populus tremuloïdes*, *P. trichocarpa*, *Betula papyrifera*, *Acer glabrum*, and *Physocarpus malvaceus*. Both fresh and partially decayed leaves were eaten. *Anguispira kochi occidentalis* (Von Martens, 1882), a land mollusc incidentally studied, is also an herbivore and has been observed feeding on the above mentioned plants and, also, on the green foliage of *Asarum caudatum*. It is probable that *O. subrudis* accumulates that fluoride which is in and on the vegetation on which it feeds.

On the basis of the small number of samples analyzed there was no significant difference in the fluoride content of the midgut gland-ovotestis portion and that of the head, foot, and lower visceral mass.

It is interesting to note that one sample consisting of shells 3 mm to 6 mm diameter contained 143 ppm fluoride (from collection site WH-2). No explanation is available for this

phenomenon. However, the original shell is largely organic periostracum (Hyman, 1967, p. 606) and this material is easily eroded away and often absent from mature shells. Thus the latter consist almost entirely of calcium carbonate (op. cit., p. 157).

The variable ratio of shell-to-body fluoride content suggests separate accumulation rates and accumulation thresholds for shell and soft tissue.

The authors gratefully acknowledge the assistance of Dr. Richard H. Russel, University of Arizona, Department of Biology, for his identification of representative specimens. Dr. C. C. Gordon, University of Montana, Department of Botany, is thanked for supplying the laboratory space, equipment, and supplies used for the chemical analysis of the specimens.

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AGGREGATIVE BEHAVIOR IN VERONICELLID SLUGS

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ABSTRACT

Aggregative behavior exhibited by veronicellid molluscs led us to suspect the action of one or more pheromones. Several series of experiments demonstrate that a pheromone exists, and is suspected to be a volatile compound. The identity of the pheromone is being sought through biochemical means at the present time.

In collecting veronicellid slugs, it quickly becomes obvious that one cover object (board, stone, paper or such) hides many slugs whereas another, which appears to be equally suitable, has none. This repeated observation led us to suspect some type of pheromone as the basis for this aggregative behavior.

Pheromones have been demonstrated to be used as guides to food (Bossert and Williams, 1963), guides to aggregative behavior in insects (Kaufman, 1966), possible guides to moisture in snakes (Dundee, 1968), guides for ant movements (Hangartner, 1970), guides to proper areas for oviposition (Norris, 1970) as well as for similar uses in various organisms. Wells and Buckley (1972) showed that the aquatic snail, *Physa*, follows trails which other *Physa* have laid down. Our premise was, then, that it might be that veronicellids use a similar mechanism resulting in aggregative behavior. The following experiments were designed to test this.

MATERIALS

Slugs: Two local, introduced slugs, *Veronicella ameghini* (Gambetta) and *Veronicella floridana* (Leidy) were used because of their aggregative behavior in the field and because they are locally abundant and easily available for laboratory testing.

Container and Discs: Circular plastic bowls, 25 cm in diameter with fitted lids were used. Into these was placed enough moist sterilized sand to cover the bottom. Circular discs of 5.5 cm diameter were cut from masonite and placed in a circle on top of the sand so as not to touch the container and so that each was equidistant from the next. The discs were let-

tered. This experimental design was patterned after that devised by H. A. Dundee (1968) for use with small snakes. The reason for keeping all materials circular in shape was for the purpose of eliminating angles which might provide attractive resting places for the slugs. These containers were kept on a lab table at room temperature. There was light from windows on one side. At intervals the containers were rotated and/or placed in a dark box so as to exclude light as a factor. Only during times when experiments were in progress were the slugs allowed in these containers: they were housed separately when not being used in experiments.

Sand: After trying various substrates it was determined that substrate had no bearing on the aggregative behavior; the same results could be obtained using dirt, sand or paper as substrate. Sand was selected since it was easier to handle and could be easily autoclaved. The autoclaving was simply a precautionary measure in case the sand contained any extraneous influencing factor. The reason for a substrate was to provide a means whereby the moisture could be retained for several days.

METHODS AND DISCUSSION

Each experiment was initiated by placing twenty slugs of one species in a container such as described above. They were placed in the center and left undisturbed for as long as necessary, usually about 72 hours. Table I presents a summary of the results.

In Experimental Series I (Table I) slugs, given a selection of cover objects, almost always

TABLE 1. *Summary of experiments. Each series was run separately with Veronicella ameghini and V. floridana.*

Experimental Series	Container Arrangement	Animals	Usual Result	General Observations
I (15 expts. with each species)	New sand. New discs.	20 in center for each experiment	By 48 hours most were under one disc. By 72 hours all were under it.	Slime trails all over
II (2 expts. with each species)	New container. New sand. Discs from E.S.I. used (those where the aggregation had occurred)	20 in center for each experiment	72 hours of "milling around" with most settling under F (the discs from E.S.I. which had the aggregations under them—in this series they were labeled "F")	Discs do become "conditioned"; thus new ones are needed for each experiment
III (10 expts. with each species)	"Conditioned" sand from under disc where all had aggregated prior was placed under disc F in new containers: (1) using "used" discs (2) using new discs	20 in center for each experiment	(1) Most under F when "used" discs were used. Some elsewhere. (2) All 20 under disc F in 24 hours with new discs	(a) fewer slime trails than in E.S.I. (b) if "used" discs used, appearance of confusion (c) if new discs used, exp. more decisive
IV (8 expts. with each species)	"Conditioned" sand and new discs used in new container. Conditioned sand placed on top of disc F	20 in center for each experiment	In 48 hours all 20 had moved to sand adjacent to disc F. By week later all had scattered	No slime trails under any discs. Trails on sand on disc F.
V (5 expts. with each species)	(1) "Conditioned" sand put under B and E (2) "Conditioned" sand put under B and on top of E	20 in center for each experiment	(1) In 48 hours: 18 under B, 2 in center. In 72 hours: 4 on roof over B, 16 under B (1 exp. only—others similar) (2) In 72 hours: 1 on wall by B, 1 between A & B on wall, 18 on wall near E (1 exp. only—others similar)	(1) tracks all over— including on E (2) tracks all over

all came to rest under the same object after a short period of time. This lent support to field observations which indicated aggregative behavior.

Experimental Series II, consisting of two experiments with each species, substantiated the belief that the slugs do aggregate as a result of some chemical attractant. The use of one "used" disc (those under which aggregation occurred in previous experiments) and the resulting selection of that disc by the slugs points out that some attractant had been left on that disc by slugs in the previous experiments. It also demonstrated that discs do become "conditioned" and therefore new ones must be used in each experiment in order to make the experiment valid.

Experimental Series III was designed as follows: new containers with new sand were used. Two types of experiments were done: (1) using all new discs except the one marked F; it was a disc from a previous experiment

and one under which aggregation had occurred (2) using all new discs. In addition, in each of these types of experiments (5 of each type experiment was run for each species) "conditioned" sand (sand from under a disc where aggregation had occurred previously) was placed under disc F. In all experiments all slugs came to rest under disc F—no matter whether disc F was "used" or new; however, when disc F was a "used" one the time to aggregation was longer and the trails indicated more confusion.

The next logical step was undertaken in Experimental Series IV wherein the "conditioned" sand was placed on top of the disc instead of beneath it. The reasoning here was that perhaps they aggregated beneath the disc for some reason other than the presence of an attractant. It was expected, therefore, that, if our supposition of an attractant was correct, they would not go under the disc but, rather, they should go on top of it. Sixteen such experiments were run (eight per species) and in each case in

no longer than 48 hours all of the slugs had moved to the sand adjacent to the disc with the conditioned sand on top. No slime trails were found under any disc. Why the slugs did not go directly to the top of the disc cannot be explained at this time. We suspect the reason is that the pheromone is volatile and elicits a response when in the air rather than when on the surface. Why the slugs selected the sand adjacent to the disc is also unexplainable at this time. The container was closed so it should not have been a matter of air currents; also the slugs were not always found in the same direction from the disc (this would have been expected had air currents been involved). Another significant factor to be noted in Experimental Series IV is that the slugs scatter about the container (de-aggregate) within a week, sometimes regrouping elsewhere, sometimes not. In our "housing" containers they seem to leave the aggregation only rarely and then they usually return to it. This behavior in the Experimental Series IV led to the conclusion that the attractant is one which is gradually inactivated.

Experimental Series V was a perplexing one for which we do not yet have answers. It was conducted in two parts: (1) conditioned sand was placed under discs B and E. As Table I shows, all of the slugs went to disc B but even then not all of them went under it. None selected disc E although there were slime trails over it indicating that they had been there. The second phase of this series consisted of placing "conditioned" sand under disc B and on top of disc E. Five such experiments were run for each species and, while the numbers varied in the different experiments, the overall results were similar: at the end of the usual 72 hour period most (but not all) slugs were on the container wall near disc E with none under disc B. Two significant observations arise from these experiments: (1) again, it would appear that a volatile is involved and that it has much more influence on the slugs when out in the open as opposed to being beneath an object (2) one wonders if the volatile is released only when suitable habitat is found. If it is released at all times it appears that mass confusion should result.

The only difference in behavior between

Veronicella ameghini and *V. floridana* in these experiments was that *V. floridana* seems to respond much more quickly and has the habit of digging at the site of the aggregation.

CONCLUSIONS

In view of the results of these preliminary experiments, it seems evident that the aggregative behavior exhibited in *Veronicella ameghini* and *Veronicella floridana* is mediated by a pheromone, unidentified at the present time. The pheromone appears to be of a volatile nature as evidenced by the fact that when placed on a disc, aggregation results above or around the disc but not upon it. However, when the pheromone is placed under a disc the aggregate forms beneath the disc thus indicating that perhaps the pheromone becomes trapped beneath the disc. The identity of the pheromone is being sought through biochemical means at the present time.

The possible function of aggregation in these slugs lends itself to considerable speculation. In sexually reproducing organisms it is easy to see how aggregation may facilitate reproduction, in that it insures the presence of a mate. If this were not so, the slow movement of these slugs would prove a detriment to reproduction and survival of the species. This, then, presupposes the presence of pheromones in many of the other molluscs as well.

Since these aggregates usually involve much contact between organisms, surface area exposed to the elements is effectively reduced and thus such attractants may function to aid in prevention of desiccation. This would be an adaptive advantage. Dainton (1954) found that a loss of 17% of slug body water resulted in inactivity and that slugs have to absorb moisture from a moist surface to replenish that lost in producing slime trails. Aggregation, therefore, may be a water conservation measure.

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NORTHERN RANGE EXTENSION OF THE BIVALVE, *PARAMYA SUBOVATA* (SUPERFAMILY MYACEA)

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The bivalve *Paramya subovata* (Conrad, 1845) was found (dead) in Indian River Bay, Delaware, at 38°36'30" north latitude and 75°6'35" west longitude. The sample was collected with a Petersen grab in muddy sand at a depth of approximately 1.8 m. Its range had previously been reported from North Carolina to the west coast of Florida (Morris, 1951). This constitutes a northern range extension of approximately 820 km and crosses a major zoogeographic boundary (Cerame-Vivas, and Gray 1966). The specimen which is 1 cm in length agrees with the description of Abbott (1974, p. 537, fig. 5989).

Paramya subovata was reported by Jenner and McCrary (1970) as being a commensal bivalve, host specific with the echiuroid *Thalassema hartmani*. This commensal behavior takes on special interest since it is characteristic of another superfamily (Leptonacea). Also the occurrence of *T. hartmani* has not been report-

ed from Delaware, so this specimen of *P. subovata* could well be a subfossil. We would like to thank Dr. R. Tucker Abbott, who graciously checked the identification and encouraged us to develop this account.

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THE DISTRIBUTION AND ECOLOGY OF COMMON MARINE AND ESTUARINE GASTROPODS IN THE DELAWARE BAY AREA

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INTRODUCTION

Increased attention locally to pollution problems has intensified interest in benthic ecology. In order to deal with these problems, a number of taxonomic surveys were conducted in the Delaware Bay area (Kinner, *et al.*, 1974; Leathem, *et al.*, 1973; Maurer and Watling, 1973 a and b; Maurer, *et al.*, 1974 a, b, and c; Watling and Maurer, 1972 a and b; Watling, *et al.*, 1973; Watling, *et al.*, 1974). This paper represents a synthesis of results from these and other surveys on the distribution and ecology of gastropods in the Delaware Bay region. Lowden (1965) provided an annotated checklist of the marine mollusks of Delaware Bay and New Jersey ocean beaches, while Wass, *et al.*, (1972) provided a checklist of the biota of Chesapeake Bay. A guidebook for the Delaware Bay region fauna, which includes marine and estuarine mollusks, was prepared by Watling and Maurer (1973).

METHODS

Samples were collected from 1970 to the present with a variety of sampling gear: epibenthic dredge, Petersen bottom grabs (0.1 m², 1/15 m²), Van Veen bottom grab (0.1 m²), and oyster dredge. Several areas which received intensive sampling both quantitatively and qualitatively are: a site 1 km off Cape Henlopen and South Bethany Beach, Delaware; a site 67 km east of Ocean City, Maryland; 26 transects across Delaware Bay from the capes to Woodland Beach; Cape Henlopen sand flat; Rehoboth, Indian River, and Little Assawoman Bays. All quantitative samples were sieved through a 1.0 mm mesh screen and the residual on the screen was preserved in 10% buffered formalin. Selected organisms from the

qualitative (dredge) samples were preserved in a similar manner.

Standard hydrographic data (temperature, salinity, and dissolved oxygen) were collected for many of the samples along with sediment aliquots. The sediment samples were dried and sieved to determine sediment particle size.

RESULTS AND DISCUSSION

The gastropods in this paper are grouped according to Carriker's (1967) salinity distribution for organisms in estuaries to facilitate comparison with other estuaries. This designation represents the most common distribution of the species rather than the exceptional or marginal occurrences. The distributions recorded in our studies agree with Carriker's (1967) scheme in that the euryhaline marine group contained the largest number of species — 31 (67%), while the true estuarine and stenohaline species accounted for 8 (17%) and 7 (15%), respectively. There were no oligohaline species present in this study.

TRUE ESTUARINE SPECIES

(Salinity 5-30 ‰)

Intertidal

Melanopus bidentatus is abundant at the marsh's edge slightly above the high tide line where it is occasionally flooded, but is often more abundant slightly further from the water as reported by Allen (1954). This species hibernates and is generally absent from the marsh surface during the winter (Allen, 1954; Apley, 1970; Hauseman, 1973). *Detracia floridana* (Pfeiffer), also a member of the family Melampidae, is often confused with *M. bidentatus*, has not been collected in our surveys. However, it may be expected, as it has been reported from Delaware by Abbott (1974, p. 332). *Ryanassa obsoleta* occurs extensively on fine, silty sand

¹ Contribution No. 97

flats in Delaware and Indian River Bays and in tributaries of salt water marshes. This species may, however, be incorrectly classified in the family Nassariidae (Abbott, personal communication) as it differs from other nassariids in having a crystalline style digestive rod (Jenner, 1956) and no caudal cirri; however, Fretter and Graham (1962) believe this is not a true style but a protostyle. Reproduction and feeding studies of this gastropod have been reported by Scheltema (1961, 1964a and 1964b).

Subtidal

The prosobranch gastropod, *Nassarius vibex*, occurs abundantly in Indian River with scattered occurrences throughout Delaware Bay. It feeds as a scavenger and as a deposit feeder.

Mitrella lunata, which Bird (1970) placed in his *Macoma balthica* community, has been found in the Cape Henlopen area living in association with *Tubularia crocea* and various algae where the salinity range is 29 ‰ - 32 ‰. This species crawls on sunken logs and pilings throughout Delaware Bay and has also been collected extensively in Rehoboth Bay. This columbellid feeds mainly on soft algae (Abbott, 1968) and possibly ingests animal detritus as it clings to seaweeds. Bird (1970), Young and Rhoads (1971), and Russell-Hunter and Brown (1964) have classified it as a carnivore, preying on small sessile invertebrates.

Three species of the family Cerithiidae, *Seila alamsi*, *Cerithiopsis greeni*, and the sinistral-shelled *Triphora nigrocincta*, are rather rare in this area; and, as yet, only their shells have been collected in our surveys. These species range from near shore to 74 m and feed mainly on detritus, diatoms, and sponges (Abbott, 1968; Bird, 1970).

EURYHALINE MARINE SPECIES (Salinity 15-40 ‰)

Intertidal

The members of the family Littorinidae, *Littorina saxatilis*, *L. obtusata*, and *L. irrorata*, are common. *L. saxatilis* and *L. obtusata* occur most commonly at or slightly above the high tide line grazing on algae among barnacles on rock jetties of the Harbor of Refuge (Delaware Bay) and Indian River Inlet. Another local

species, *L. littorea*, also occurs on rocks at Indian River. *L. irrorata* is particularly characteristic on grass in salt and brackish water marshes. The exposure times for Littorinidae as reported in Fretter and Graham (1962) are between 5-65% for *L. obtusata* and *L. littorea* and 50-100% for *L. saxatilis*.

Subtidal

Most estuarine species are euryhaline (Carriker, 1967), although the acclimation of some of these to low estuarine salinities has been reported by Schlieper (1957). The most economically and ecologically significant euryhaline species (Hanks, 1953; Loosanoff, 1956; Carriker, 1951, 1955; Wells, 1959; Wood, 1968; Mackenzie, 1970; and Manzi, 1970) found in the Delaware Bay region are: the pyramidellids, *Odostomia impressa*, *O. trifida*, *O. willisi*, *O. gibbosa*, *Turbonilla stricta*, *T. interrupta*; the melongenids, *Busycon canaliculatum*, *B. carica*; the muriceans, *Urosalpinx cinerea*, *Eupleura caudata*; and the naticid, *Polinices duplicatus*. The majority of these occur in association with the local oyster communities as well as some southern oyster communities (Watling and Maurer, 1973; Wells, 1959, 1961). The ectoparasitic mode of existence of the pyramidellids was documented by several workers (Fretter and Graham, 1949; Loosanoff, 1956; Hopkins, 1956). Nevertheless, pyramidellids may not be species specific as previously thought by other workers (Allen, 1958; Scheltema, 1965). The abundance of pyramidellids in Rehoboth and Indian River Bays where certain "specific hosts" are absent confirms this.

Busycon canaliculatum and *B. carica* have primarily been collected on bottoms of fine to medium sand near the mouth of Delaware Bay. Wells (1961) found that *B. carica* occurred primarily on sand flats feeding on hard clams. Carriker (1951) observed the predation of *Busycon* on these and other bivalves. Maurer and Watling (1973 a) estimated an occurrence of 800 whelks per acre on the southern edge of Delaware's oyster beds; however, they were not considered as a limiting predator for that area. *Polinices duplicatus* also occurs sporadically near the mouth of Delaware Bay and like the Melongenidae, it is carnivorous on bivalves. A

detailed account of predation by these gastropods can be found in Ansell (1960, 1961).

Probably the most economically important gastropods in our study area are the carnivorous Muricidae, *Urosalpinx cinera* and *Eupleura caudata*. Allen (1963) and Carrier (1955) have summarized the research on their biology and control. Distribution of drills in the local rivers is spotty and unpredictable (Maurer and Watling, 1973a); however, local oystermen consider them to be a serious problem, especially on young spat in the planted beds. On the New Jersey side of Delaware Bay, drill predation is of even greater consequence to the oyster industry; so much so that the New Jersey Shellfish Commission periodically scrapes the oyster beds with a specially designed bore dredge to help reduce oyster mortality rates caused by these borers.

Although the genera *Anachis* and *Mitrella* are closely related, *Anachis* occurs in a higher salinity range (27-35 ‰) than does *Mitrella* (18-32 ‰). This was also reported by Bird (1970) and Wigley and Stinton (1973). Two species, *Anachis avara* and *A. lafresneyi*, are not abundant in our collections. We have, however, found numerous shells of these species together with *Haminocia solitaria*, *Acteocina canaliculata*, and *Acteon punctostriatus*. Scheltema (1968) reports that *Anachis avara* and *A. lafresneyi* prefer eel grass and firm substrata, respectively. Despite their preference for different substrata, they are often confused. These species have been redescribed by Scheltema (1968).

The Epitoniidae are locally represented by *Epitonium humphreysi* and *E. rupicola*. They inhabit sandy bottom and are generally found in association with sea anemones upon which they feed (Abbott, 1968). Wass (1972) reported finding as many as 30 *E. rupicola* per square meter. We have collected a few scattered specimens; however, *E. rupicola* may be found to be quite abundant as more research is done in Indian River.

A few species found relatively infrequently living in the Delaware Bay region are *Skenopsis planorbis* and *Kurtziella cerina*. *S. planorbis* are abundant in the summer on weeds below midtide level to 16 fathoms. Breeding occurs in

the spring and summer with egg capsules being attached to filamentous algae (Fretter and Graham, 1962). Live specimens of *Marginella rosula* were collected on the New Jersey side of the ship channel in the vicinity of Brandywine Shoal and on the Delaware side in the Anchorage area which would agree with the description of Abbott (1968) of depth and substrate preference.

Species of the genus, *Crepidula* (family Crepidulidae), are among the most abundant snails in the Delaware Bay region. The young slipper shells are fairly active in moving about; but as adults (2 years), normally remain attached for life. *Crepidula plana*, *C. fornicata*, and *C. convexa* are found most abundantly in salinity above 20 ‰. Since they are filter feeders and require a firm substratum to attach, they can provide serious competition for food and space (Mackenzie, 1970; Loosanoff and Engle, 1941). Unlike the oyster, however, *Crepidula* can do well on a variety of substrata such as the horseshoe crab (*Limulus*) and the whelks (*Busycon*). Franz (1970) has described the shell shape of *C. convexa* in relation of the substratum diversity. Maurer and Watling (1973 a) found *C. plana* and *C. fornicata* living on the same substrate, but in different clusters. *C. fornicata* was the dominant organism in one sector of Greenwich Bay (Stickney and Stringer, 1957).

A widespread species in the Delaware Bay region is *Nassarius trivittatus*. Though it is found most often subtidally, it may also occur intertidally (Scheltema, 1964b; Scheltema and Scheltema, 1965). In our surveys, this species was found in sediment types ranging from silt-sand to fine sand and at depths from 1 m in Indian River to 35 m at a site 67 km east of Ocean City, Maryland.

STENOHALINE MARINE SPECIES (Salinity 25-40 ‰)

Most of the stenohaline species such as *Cobus pygmaeus*, *Calyptrea centralis*, and *Margarites groenlandicus* are found subtidally in the deeper, cooler waters offshore; however, species such as *Lunatia heros*, *L. triseriata*, and *Natica clausa*, although found more abundantly subtidally, occur intertidally on sand. When present intertidally, they usually occur in lagoons or tide pools. The above naticids are

less resistant than *Polinices duplicatus* to higher temperatures and lower salinities (Russell-Hunter and Brown, 1964). *Lunatia heros* is the most abundant stenohaline species occurring from the mouth of Delaware Bay to the 120 km site.

Colus pygmaeus is one of the main foods for cod fish and may be dredged offshore to 275 m. As many as 7 in 0.1 m² in a fine sand bottom were found; however, it has been collected live at only two stations. *Margarites groenlandicus* is also a source of food for the bottom-feeding fish. Our sampling areas have produced numerous shells of this species, but so far only three live specimens have been recorded.

SUMMARY OF ECOLOGY

In summary, there are approximately 46 common species of marine and estuarine gastropods in the Delaware Bay region — the majority being euryhaline marine species. As stated previously, a few of the species listed below have scattered occurrences in either the true estuarine or stenohaline marine ranges. However, this grouping represents their most common occurrence.

The following list contains a summary of the species. Salinities and other ecological information in parentheses represent data from published literature, while those not in parentheses represent our data. The substratum is classified by median size of sediment in mm: fine sand, 0.063-0.25; medium sand, 0.25-0.50; coarse sand, 0.50-2.00.

Acteocina canaliculata (Say): Salinity (18-35 ‰); euryhaline; silty-sand; burrower; carnivorous.

* *Acteon punctostriatus* (C. B. Adams).

Anachis avara (Say): Salinity (28-35 ‰); euryhaline (on algae); carnivorous.

Anachis lafresneyi (Fischer and Bernardi): Salinity (27-35 ‰); euryhaline; prefers firm substrata; carnivorous.

Busycon canaliculatum (Linné): Salinity, 20-35 ‰; euryhaline; fine and medium sand; carnivorous; spawning months, May through September.

* Ecological information unavailable at the present time.

Busycon carica (Gmelin): Salinity, 20-35 ‰; euryhaline; fine-medium sand; carnivorous.

* *Calyptrea centralis* (Conrad).

Cerithiopsis greeni (C. B. Adams): Salinity (28-32 ‰); true estuarine; substrate, mud-fine sand; carnivorous.

Colus pygmaeus (Gould): Salinity, 30-35 ‰; stenohaline; medium sand; scavenger; deep water (20-250 m).

Crepidula convexa (Say): Salinity, 15-32 ‰ (18-35 ‰); euryhaline; attached to solid substrate; suspension feeder.

Crepidula fornicata (Linné): Salinity, 15-32 ‰ (19-35 ‰); euryhaline; attached to solid substrate; suspension feeder.

Crepidula plana (Say): Salinity, 15-32 ‰ (25-35 ‰); euryhaline; attached to solid substrate; suspension feeder.

Epitonium humphreysi (Kiener): Salinity, 18-32 ‰; euryhaline; carnivorous.

Epitonium rupicola (Kurtz): Salinity, 18-32 ‰; euryhaline; carnivorous.

Eupleura caudata (Say): Salinity, 18-32 ‰; euryhaline; carnivorous.

Haminoea solitaria (Say): Salinity (18-30 ‰); euryhaline; sand, shallow waters.

Ilyanassa obsoleta (Say): Salinity, 15-30 ‰ (18-32 ‰); true estuarine; substrate, intertidal flats; spawning months, June through August.

* *Kurtziella cerina* (Kurtz and Stimpson).

Littorina irrorata (Say): Brackish water; true estuarine; on marsh reeds.

Littorina littorea (Linné): Intertidal, true estuarine; on rocks and clinging to sea weed; spawning months, June through August.

Littorina obtusata (Linné): Salinity, 28-35 ‰; euryhaline marine; rock jetties near high tide, herbivorous.

Littorina saxatilis (Olivieri): Salinity, 28-35 ‰; euryhaline marine; rocks, jetties, and side of wharves near high tide line; herbivorous, ovoviviparous.

Lunatia heros (Say): Salinity, 25-35 ‰; stenohaline; fine-medium sand, carnivorous.

Margarites groenlandicus (Gmelin): Salinity, 30-35 ‰; stenohaline; medium sand (10-210 m); herbivorous.

Marginella roscida (Redfield): Salinity, 20-32 ‰; euryhaline; fine-silty sand.

Melampus bidentatus (Say): Salinity, 10-25 ‰ (11-30 ‰); true estuarine; intertidal salt marsh-

es, most abundant above high tide line; spawning months, late May through July.

Mitrella lunata (Say): Salinity, 25-32 ‰ (18-32 ‰); true estuarine substrate, algae-hydroids, silty-sand.

Nassarius trivittatus (Say): Salinity, 15-35 ‰: euryhaline; mostly on sandy bottoms.

Nassarius vibex (Say): Salinity, 15-30 ‰ (9-32 ‰); true estuarine; substrate, sandy-mud.

* *Ostostomia gibbosa* (Busch).

Ostostomia impressa (Say): Salinity (11-35 ‰); euryhaline, ectoparasitic on oysters and other bivalves.

* *Ostostomia trifida* (Totten).

* *Ostostomia willisi* (Bartsch) (may be *seminuda* C. B. Adams).

Polinices duplicatus (Say): Salinity, 23-33 ‰ (27-35 ‰); euryhaline; carnivorous; fine-medium sand; spawning months, June through August.

Seila adamsi (Lea): Salinity (25-30 ‰); true estuarine; substrate, mud-fine sand; herbivorous.

Skeneopsis planorbis (Fabricius): Salinity (18-35 ‰); euryhaline; on weeds below mid-tide; spawning months, May through July.

Triphora nigrocincta (C. B. Adams): Salinity (20-35 ‰); true estuarine; substrate, mud-fine sand.

Turbonilla interrupta (Totten): Salinity (25-35 ‰); euryhaline; fine sand.

* *Turbonilla stricta* (Verrill).

Urosalpinx cinera (Say): Salinity (11-35 ‰); euryhaline; oyster beds, carnivorous; spawning months, May through October.

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CORRECTIONS TO RECENT PAPERS ON NEW SPECIES OF *VOLUTOCORBIS* FROM SOUTH AFRICA

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Mr. Richard N. Kilburn of the Natal Museum in Pietermaritzburg has called my attention to some transpositions of data in the two papers on *Volutocorbis* that I published in a recent issue of *The Nautilus* (vol. 88, no. 2, pp. 31, 32 and 33-37, April 1974).

The locality data and catalogue number of the holotype of *Volutocorbis semirugata* Rehder and Weaver, 1974 (loc. cit., pp. 31-32) should read (on p. 32) as follows: Holotype: off Ilha Bazaruto, Mozambique, 180 fathoms; ex A. Visage; Natal Museum Moll. no. G769. Catalogue number for figs. 1 and 5 in the illustration on page 31 should be changed to read: Natal Museum Moll. G769.

Similarly, the locality data and catalogue number of Paratype No. 2 of *Volutocorbis kilburni* Rehder (loc. cit., p. 36) should read: SE of the Bluff, Durban, in 120 fathoms; collect-

ed by G. Scott, August 1972 [not 1872]. Natal Museum, Moll. No. 9939.

It is obvious that the data for these two specimens were somehow inadvertently transposed.

In a personal communication, Mr. Kilburn has informed me that he is doubtful of the Natal records given by me for *Volutocorbis semirugata*. The specimens recorded as coming from off Durban and the mouth of the Tugela River were probably brought up by fishermen trawling in waters further north, off southern Mozambique. The range of this species should, therefore, be given as off southern Mozambique.

This correction of the locality data alters also the range for *Volutocorbis kilburni* Rehder, which is now known to occur only off Durban, Natal.

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POLYGYRISCUS VIRGINIANUS (BURCH, 1947)
A HELICODISCID LAND SNAIL (PULMONATA: HELICODISCIDAE)

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ABSTRACT

Dissection and scanning electron microscope studies of the Virginia land snail, Polygyriscus virginianus (Burch, 1947), show that this species, previously associated with either Polygyra or Helicodiscus, is related to Helicodiscus and Stenopylis. The family group Helicodiscidae is redefined and differences from possibly related family units noted.

INTRODUCTION

Shortly after it was described as *Polygyra virginiana* P. R. Burch (1947), Pilsbry (1948: 1097-1098, fig. 584) proposed a new subgenus, *Polygyriscus*, and stated "This very peculiar snail is probably not nearly related to *Polygyra*, but is left in that family temporarily." Solem (1957: 9) raised *Polygyriscus* to generic rank and placed it in the endodontid subfamily, Helicodiscinae. J. B. Burch (1962: 148, fig. 363) presented new figures and Hubricht (1972: 16-17), who had collected some living specimens, also suggested that it was related to *Helicodiscus* on the basis of the spiral epidermal fringes seen on the juvenile and some adult shells. The only known locality for this species, near Radford, Virginia, was visited by the author in 1974, but only one dead fragment observed.

Through the courtesy of Leslie Hubricht, it was possible to dissect and illustrate the anatomy (Field Museum of Natural History 173197) and to illustrate a shell (FMNH 173234) with periostracal fringes intact. I am indebted to Carole W. Christman for the drawings in Fig. 1 and to Elizabeth Liebman who prepared the drawings in Fig. 2 with support from Office of Endangered Species Contract No. 14-16-0008-764. The scanning electron microscope photographs (Figs. 3-8) were taken in the course of cooperative research with the American Dental Association Research Institute. The assistance of John Lenke and George Najarian is gratefully acknowledged. The prints were prepared by Fred Huysmans.

This is one of the rarest and most unusual North American land snails. Recommendations have been made to the Office of Endangered Species (OES) that *Polygyriscus virginianus* be declared an endangered species and given protection against both collecting and habitat disturbance. This paper, publication of which is supported by the Office of Endangered Species, was prepared as one result of contract work on potentially endangered species of Eastern North America. I am grateful to the OES staff, particularly Marc Imlay, for their support and encouragement.

SHELL STRUCTURE AND FORM

The presence of deciduous periostracal spiral fringes (Fig. 2 *a*) is characteristic of *Helicodiscus* (see Pilsbry, 1948: figs. 339, 341, 342, 344) and *Stenopylis* (see Solem, 1957: 11, fig. 4). In *Polygyriscus* there are remnants of 8 to 10 such spiral rows on the body whorl above the periphery. Those on the shell base usually are completely eroded. The fringes have a very characteristic "comb-like" pattern (Fig. 2 *c*) when viewed under high magnification. In *Helicodiscus*, *s. s.*, and *Stenopylis* the rows are more numerous and lower, while in *Helicodiscus (Hebetodiscus)* the fringes are absent.

In pattern of whorl coiling and umbilical shape, *Polygyriscus* (Fig. 2 *a, b*) is the same as both *Helicodiscus* and *Stenopylis*. The genera differ in apertural armature and lip edge characters. In *Helicodiscus* (see Pilsbry, 1948: 622-640) the lip is not reflected and simple,

while there are usually pairs of tubercles deposited at intervals on the parietal and/or palatal walls (see Hubricht, 1975: 2-4). In *Stenopylis* the outer lip is thickened and reflected, the parietal callus is raised and curved outwards so that it forms a crescent narrowing the aperture, and there are an internal lamellar extension on the parietal wall and a separate

parietal nodule (see Solem, 1957: 11, fig. 4 c). In *Polygyriscus* the last fraction of the body whorl is strongly deflected downwards (Fig. 2 c) and it is narrowed by the deflection. There is a strong inward growth of the basal margin (Fig. 2 b) and an equivalent invagination of the parietal wall that produces either a nodular effect (Fig. 2 c) or, in the case of actual parietal wall detachment (Pilsbry, 1948: 1098, fig. 584), this becomes a U-shaped margin. In addition to the apertural constriction, there are two barriers present: a transverse ridge just inside the basal lip that was first reported by Hubricht (1972), and a long barrier on the upper palatal wall (Fig. 2 c) that is moderately recessed (Fig. 2 b). The pattern of apertural constriction is different from that seen in *Stenopylis*, and the barrier positions and shapes are very different from the patterns found in *Helicodiscus*. While the three genera share a common growth pattern and basic shell sculpture, they are quite distinct in apertural form and barrier details.

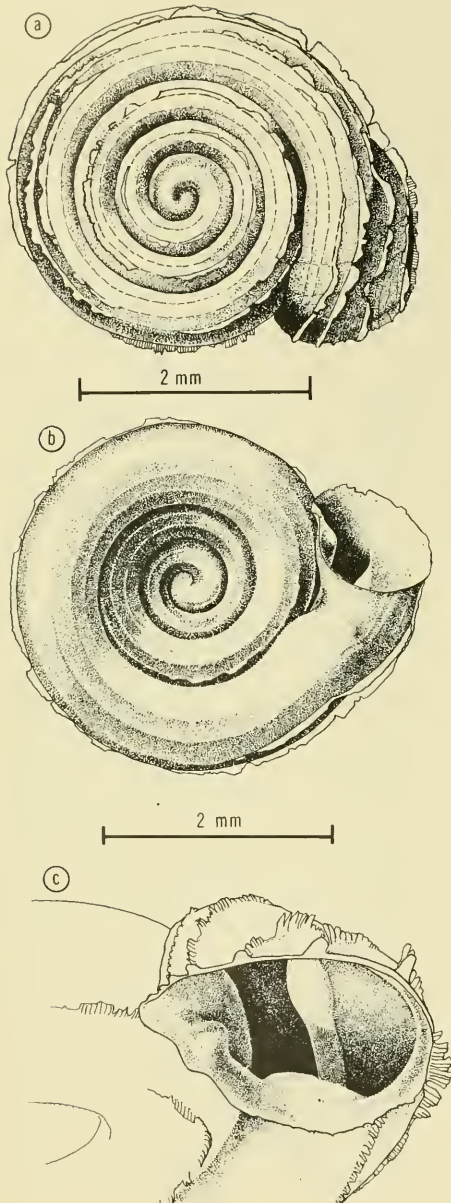
GROSS ANATOMY

All available data on the anatomy of *Helicodiscus* are summarized or repeated in Pilsbry (1948). Rather than presenting a formal description of the anatomy of *Polygyriscus*, I provide comparative remarks and emphasize the features in which they differ from the other major groups of endodontoid land snails. The pallial complex (Fig. 1 c) is exactly comparable to that of the Endodontidae, in having a weak rectal arm to the kidney (K) and a slightly reflected ureter (KD) that opens posteriorly. There is no differentiated urinary groove leading to the pneumostome. The heart (H), intestine (I), hindgut (HG), unbranched principal pulmonary vein (HV), anus (A), and mantle collar (MC) are exactly as in *Helicodiscus* (Pilsbry, 1948: 628, fig. 340 b) and agree with the Endodontidae. The Punctidae and Charopidae differ in usually having a completely closed secondary ureter and often a strongly bilobed kidney, while the Discidae have a very simple triangular kidney that does not reach the hindgut at any point and a complete secondary ureter.

Differences in the genitalia are fundamental and obvious at first inspection. Both



FIG. 1. Anatomy of *Polygyriscus virginianus* (P. R. Burch): a, dissected genitalia showing origins and insertions of structures; b, interior of penis showing verge (PV) and major pilasters (PP); c, pallial region. Scale lines equal 1 mm. Field Museum of Natural History no. 173197. Other abbreviations explained in text.



Helicodiscus (Pilsbry, 1948: 624, fig. 338) and *Polygyriscus* (Fig. 1 a) have a long, unbranched ovotestis (G) that occupies about one whorl in the upper digestive gland. In most Punctidae and Charopidae there are one or two main lobes to the ovotestis that lie pointing apicad. Each of them is split into several fingerlike subsidiary lobes. In larger species the number and orientation of these lobes can change, but the basic cluster pattern is preserved. In the Endodontidae the ovotestis contains many follicles strung in a line along a single duct, with the follicles angled apicad from the shell axis, rather than pointing directly apicad. In the Discidae, there are a number of multi-branched follicle bundles at spaced intervals along a duct. These bundles lie nearly perpendicular to the shell axis. All of these families except the Endodontidae agree in having the prostate-uterus at least partly fused with a common lumen, while the Endodontidae have these ducts completely separate for their entire length.

Family level differences in the terminal genitalia will be discussed elsewhere, since confusing patterns of convergent evolution make simple definitions impossible without first presenting considerable illustrative material. The several families do show distinct differences in this region, but surveys of these differences are beyond the scope of this paper.

The talon in the Charopidae and Punctidae has a globose head on a short shaft; in the Endodontidae it is an elongately oval expansion on a usually longer shaft; in the Discidae it is a tripartite complex structure (Pilsbry, 1948: 568, fig. 304, D) very similar externally at least to that found in the Succineidae; and in both *Helicodiscus* (Pilsbry, 1948: 624, figs. 338, A, C, D) and *Polygyriscus* (fig. 1 a) the talon (GT) is a very long, often recurved shaft with only a slightly enlarged head.

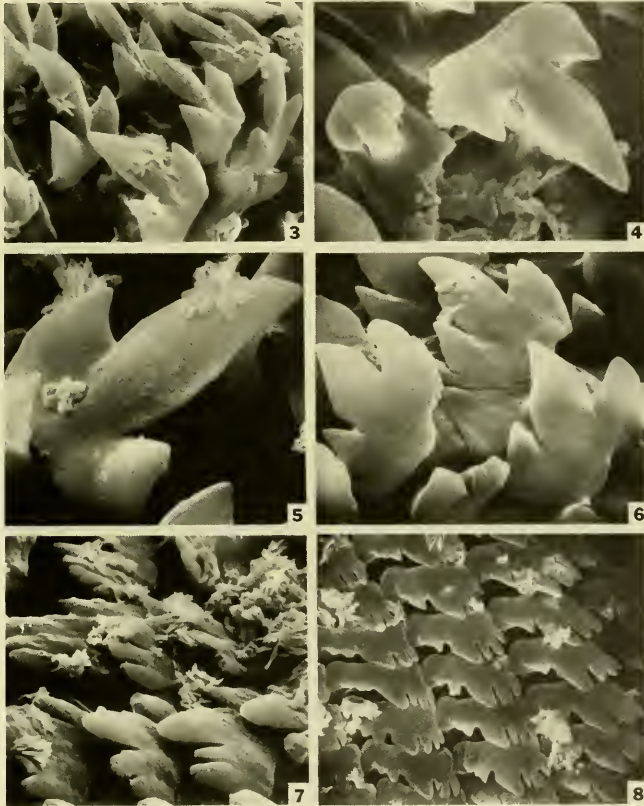
The hermaphroditic duct (GD), albumen gland (GG), carrefour (X), uterine area (UT) of the prostate-uterine tract, free oviduct (UV), vagina

FIG. 2. Shell of *Polygyriscus virginianus* (P. R. Burch). Field Museum of Natural History no. 173234. Scale lines equal 2 mm.

(V), spermatheca (S), atrium (Y), and prostate (not shown, in fig. 2) of *Polygyriscus* are as in *Helicodiscus*. Both *Helicodiscus* and *Polygyriscus* have a muscle, the epiphallic retractor (fig. 2 a, b, EM), that has no analog in the other endodontoid families. The presence of a well differentiated epiphallus (E) is a characteristic of the Helicodiscidae and most Charopidae, but this

structure usually is absent in the Endodontidae, Discidae, and Punctidae. The penis retractor muscle (PR) originates from the diaphragm and inserts on the penis-epiphallus junction, as in many endodontoid taxa.

The penis of *Polygyriscus* (fig. 2 a, P) is short, and internally (fig. 2 b) has an apical verge (PV) with subterminal epiphallic pore



FIGS. 3—8. *Radula* of *Polygyriscus virginianus* (P. R. Burch). Field Museum of Natural History no. 173197. FIG. 3. Central (lower left) and early lateral teeth. 2550 \times FIG. 4. Central and first lateral tooth. 3950 \times . FIG. 5. Third lateral tooth on left side of radula. 6000 \times . FIG. 6. Early marginal teeth from right side of radula. 4325 \times . FIG. 7. Mid-marginal teeth from left side of radula. 4225 \times . FIG. 8. Outer marginal teeth from left side of radula. 2375 \times .

(EP) and two high, irregular pilasters (PP) in the lower two-thirds of the chamber. This differs markedly from the penis of *Helicodiscus parallelus* (Say, 1921) (see Pilsbry, 1948: 628, fig. 340, a), where the epiphallus opens through a small valve and there are glandular linings to the wall, but no pilasters present. Within the Charopidae and Endodontidae, differences of this magnitude are indicative of generic separation and these structural differences alone are sufficient to warrant separating *Helicodiscus* and *Polygyriscus*.

RADULAR STRUCTURE

The Punctidae have a radula in which there is no distinction between lateral and marginal teeth, but all the side teeth have a bicuspid structure with minute accessory cusps (Pilsbry, 1948: 642, fig. 349, d). The Charopidae basically have tricuspid centrals and laterals, although this situation is secondarily modified in many taxa. The Endodontidae have a tricuspid, large central, and bicuspid laterals (for example, see Solem 1973: figs. 5-8, 13-14). The Discidae agree in the bicuspid nature of the lateral teeth, but their structure differs from that found in the Endodontidae (Solem, unpublished).

The radula of *Helicodiscus* (Pilsbry, 1948: 623, fig. 337, a, p. 624, fig. 338, B) has a minute, tricuspid central tooth, large tricuspid laterals, and multicuspid marginals. The only note on the radula of *Stenopylis* (Hedley, 1896: 221, fig. C) showed tricuspid lateral teeth and marginals. Hedley "failed to distinguish the dentition as clearly as I wished" and probably overlooked the minute central tooth. In addition, Hedley referred to the marginals as "serrated", although they are drawn as tricuspid.

The radula of *Polygyriscus* (figs. 3-8) is of the helicodiscid type. The central tooth (lower left of fig. 3 and left third of fig. 4) has relatively large ectocones and a small mesocone. The basal plate is far longer than the cusps and the tooth itself is much smaller than the first lateral (fig. 4). Early laterals (figs. 3, 4) are tricuspid with the ectocone and endocone equal in size (fig. 4). The mesocone is long and tapering, with all three cusps elevated at about the same angle (fig. 3). By the third lateral, the endocone has become much larger than the ectocone (fig. 5).

The fourth lateral (fig. 6) or first marginal tooth, depending on how they are defined, shows reduction in mesoconal size, a change in tooth angling, the beginning of endoconal splitting, and an unusual situation to the anterior margin on the endoconal side (right side in figure). Seen from a different angle (fig. 7), the mid-marginal teeth show splitting of both ectocone and endocone, with continued reduction in mesoconal size and a change in angle of tooth elevation. Outermost marginal teeth (fig. 8) are short and broad, with the mesocone barely larger than the split side cusps and the ectocone greatly reduced in size. There are thus three or four lateral teeth and six or seven marginal teeth on each side of the central tooth. They are virtually identical in structure to the teeth of *Helicodiscus*.

AFFINITIES OF POLYGYRISCUS

Polygyriscus is clearly related to *Helicodiscus* on the basis of shell form, sculpture, and apertural features; pallial region organization; gross genitalia; and radular features. *Polygyriscus* differs from *Helicodiscus* in possessing two prominent barriers in the shell aperture, having the aperture narrowed, deflected, and often detached when adult; having a penial verge and two prominent pilasters; and in having a much shorter pallial region. The suggestions of Solem (1957) and Hubricht (1972) that *Polygyriscus* is not a polygyrid, but a helicodiscid land snail are confirmed by these dissections.

The subfamily unit Helicodiscinae was credited to Pilsbry in a paper by H. B. Baker (1927: 226, 230). It was defined on the basis of kidney position, with *Helicodiscus*, *Radiodiscus*, and *Chanomphalus* included. Thiele (1931: 568-569) and Pilsbry (1948: 622-640) excluded *Radiodiscus* and defined the subfamily on the basis of the ovotestis, shell coiling, and radula. On the basis of studies on Pacific Island and Austro-Zelanic endodontoid snails (Solem, unpublished), I consider that *Helicodiscus*, *Stenopylis*, and *Polygyriscus* form a sharply defined family unit within the endodontoid complex. The questions of phyletic relationships to the other families and the exact divisions that will be recognized within other family units are beyond the scope of this paper. It is

desirable to offer the following emended characterization of the Helicodiscidae.

Family Helicodiscidae Pilsbry, 1927

Shell under 5 mm in diameter, consisting of flatly coiled whorls, few in number, that do not increase rapidly in size. Umbilicus widely open, shallow. Sculpture of spiral ridges, usually deciduous, reduced in some taxa. Aperture normally with barriers or nodules, sometimes deflected and/or thickened when adult. Pallial region with kidney reaching hindgut, a slight rectal extension, ureter opening next to hindgut at posterior of pallial cavity. Ovotestis a single lobe, talon very elongated and without expanded head. Prostate and uterus apparently united into a spermoviduct. Epiphallus large and with a separate retractor muscle. Penial retractor muscle originating from diaphragm. Penis with or without verge and pilasters. Radula with very small, tricuspid rachidian tooth, three or four tricuspid laterals, and several marginals that become shortened, broadened, and multicuspid near the outer edge of the radula.

The three genera included are *Helicodiscus* Morse, 1864 (plus the subgenus *Hebetodiscus* H. B. Baker, 1929 and the section *Pseudiscus* Morrison, 1942), *Polygyriscus* Pilsbry, 1948, and *Stenopylis* Fulton, 1914 (= *Coarctatio* Haas, 1945). I consider that *Chanomphalus* Strebel & Pfeffer, 1880 and *Radiodiscus* Pilsbry & Ferriss, 1906 belong to the charopid complex and are not related to *Helicodiscus*. Their exact affinities are still uncertain.

Helicodiscus is known from Jamaica, Cuba, Northern Mexico, and much of Eastern North America, with one species in the Columbia River drainage, but the genus is absent from California. *Polygyriscus* is restricted to a single locality in Virginia. *Stenopylis* has a wide and unusual distribution, extending from the Philippines and Indonesia to the Solomon Islands, Queensland, the MacDonnell and Krichauff mountains in Central Australia, and northern areas of Western Australia (Solem, 1957: 9-11 and unpublished). There is only one species, which has been described several times, most recently from Bach-Long-Vi or Nightingale Island in the Gulf of Tonkin (Saurin, 1960, as *Microphyura nightingali*; see Solem, 1957 for

earlier synonymy). It has not, to my knowledge, been collected on the Asian mainland.

The family units of the endodontoid complex, which are classified in the superfamily Arionacea, are, in the order of their description, Punctidae Morse, 1864; Charopidae Hutton, 1884; Endodontidae Pilsbry, 1895; Helicodiscidae Pilsbry, 1927; and Discidae Thiele, 1931. While a total of 19 family level names have been proposed for members of this complex (Solem, In Press), probably all of these can be grouped into the above categories. The most obvious anatomical differences from the Helicodiscidae have been covered in the discussion of structures found in *Polygyriscus*. Shell differences are more subtle and will be reviewed elsewhere.

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THE MARINE COMMENSAL GASTROPOD, *CALEDONIELLA MONTROUZIERI* (PROSOBRANCHIA: HIPPONICACEA) IN THAILAND

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R. L. Caldwell, University of California, Berkeley, and H. Dingle, University of Iowa, deposited 9 specimens of the crustacean, *Gonodactylus viridis* Serene, 1954¹, in the collection of Mollusks, each infested with two specimens of *Caledoniella montrouzieri* (Souverbie) (Rosewater, 1969). Caldwell and Dingle, who collected the *Gonodactylus* in Phuket, Thailand, stated that about 25% of the stomatopods were infested (pers. comm.). In all cases the location of the snails was exactly as previously described: males were between the pereopods near the ventral posterior end of the thorax, females between the 4th and 5th pereopods on the ventral posterior abdomen. The pereopods were liberally covered with the snails' egg capsules.

This discovery adds the following new information to that summarized in my earlier

paper: the sexual dimorphism apparent in the male and female shells illustrated on plate 55 of that paper is confirmed, females being larger and helicoid, males are smaller and cap-shaped; there is strong position preference in the two sexes; an additional stomatopod species is infested in addition to the 3 known previously, *G. chiragra*, *G. platysoma* and *G. smithii*; a new country is recorded as domicile for *C. montrouzieri*, although Phuket, Thailand, is less than 500 miles from the Andaman Islands where it was previously collected.

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¹ R. B. Manning identified the stomatopod.

FURTHER STUDIES OF THE MOLLUSCA OF THE OTSEGO LAKE AREA

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ABSTRACT

*Five years of collecting have resulted in the completion of a survey of the molluscan fauna of the State University of New York, College at Oneonta, Biological Field Station at Cooperstown and adjacent Otsego Lake. Fifty-eight species representing nineteen families of freshwater and terrestrial mollusks occur there. Several traditional techniques, in addition to the use of Tullgren drying funnels, pit can traps and the examination of the stomach contents of the terrestrial stage of the common newt, *Notophthalmus viridescens*, were used to amass the collections. The latter was the most effective method of obtaining small, terrestrial forms, while pit cans were extremely effective for the collection of slugs.*

INTRODUCTION

In 1967 an area for the establishment of a biological research station and laboratory was acquired a short distance north of Cooperstown, Otsego County, on the west shore of Otsego Lake. More than 149 hectares of mature second-growth hemlock-hardwood forest, old plantations of larch, spruce, and pine, and wet forested lowlands are included on the site as well as two ponds, a swamp and a senescent bog.

The climate is of the humid-continental type with prevailing westerly winds. Precipitation is evenly distributed throughout the year and averages between 75 and 100 cm annually. The freeze-free season has an average length of 123 days with the warmest weather normally less than 32°C. The highest temperature ever recorded (1854-1974) was 38°C.

The parent rocks in this area were deposited as sands, silts, clays and carbonates in the Appalachian geosynclinal sea during the Lower and Middle Devonian Period. Although the local sandstones and shales are low in calcium and other elements important in metabolic processes, the north end of Otsego Lake and the greatest portion of its watershed lie on the Onondaga limestone formation and drain areas of older limestones to the north. Therefore, the lake is much more productive than the smaller, natural aquatic and terrestrial biotopes occurring locally.

This report is a synthesis of data concerning

the molluscan fauna of the station accumulated over the past 5 years as a result of several major studies and the ongoing research projects on Otsego Lake (Harman, 1970, 1971, 1974; Herrmann and Harman, 1975), studies on Moe Pond (Harman, 1972b; Katsigianis and Harman, 1973, Katsigianis and Harman, 1974; Herrmann and Harman, 1975a, 1975b). New Pond (Harman, 1973) the terrestrial sites (Butts, 1971) and accumulation of unpublished data from collections of undergraduate and graduate students involved in research.

DESCRIPTION OF COLLECTION AREAS

Otsego Lake lies in the glacially overdeepened headwaters of the Susquehanna River in Otsego County, New York (42°40'N — 70°00'W). It is oriented, with its main axis north to south, in a valley about 1.6 km in width and approximately 13 km long. The basin is enclosed on the east and west by truncated slopes rising to the divide at the height of about 610 m. The northern end of the lake is bounded by the Richfield Springs Drumlin Field and on the south by an end moraine and outwash plain that dammed the valley and impounded the waters trapped in the basin. It is unique, being the only Finger Lake in the Susquehanna Drainage Basin. The morainic dam at the south end of the lake was formed when the ice lobe that deepened and widened about 13 km of the upper Susquehanna River to the present village

of Cooperstown, stopped and then receded northward as melting exceeded southward flow. Otsego is a morphometrically oligotrophic, chemically eutrophic, lake. It exhibits typical temperature stratification in the summer and when it is ice-covered in the winter, with limnological characteristics as follows: Elevation 364 m, maximum length 13 km, maximum width 2.5 km, surface area 1,702 hectares, maximum depth 50 m, mean depth 25 m, average Secchi transparency 4.7 m, average pH 8.1, and average alkalinity as CaCO_3 115 ppm (Harman, 1972a).

Moe Pond is a shallow (3.7 m) eutrophic body of water with an effective width of 330 m and effective length of 750 m. The highly productive nature of the pond appears artificial in origin and is possibly related to 51,000 kg of pulverized limestone that was added to the pond water while it was being utilized for irrigation of a nearby golf course in 1966 and 1967 (Harman, 1972b). However, alkalinity remains low, varying between 19 and 40 ppm in 1971. The pH varies between 7.3 and 11.3, and Secchi transparency is normally less than 0.5 m. Most aquatic macrophytes grow along the shoreline in 0-12 cm of water, probably because of shallow compensation points resulting from the chronically turbid water due to algal blooms. The substrate is mostly channery, silt and sand derived from Devonian shales and glacial deposits (Herrmann and Harman, 1975a, 1975b).

New Pond is a small (ca. 0.5 hectares surface area, maximum depth 4 m) body of water with no natural outlet. Greatly fluctuating water levels annually increase the surface area and depth by greater than 100%. An abundance of aquatic macrophytes occur in the shallow water which maintains remarkably low populations of phytoplankters (Harman, 1972b).

Although terrestrial mollusks have been collected from several sites on station lands, most were obtained from a poorly drained area of northern hardwood forest approximately 150 m east of Moe Pond at an elevation of about 396 m. The dominant trees are red maple (*Acer rubrum*) and sugar maple (*A. saccharum*) with lesser amounts of red oak (*Quercus rubra*), white ash (*Fraxinus americana*), and basswood (*Tilia americana*). The subcanopy (1-10 cm

diameter breast height) is composed of sugar maple, hemlock (*Tsuga canadensis*), and red maple. The shrubs are dominated by poison ivy (*Rhus toxicodendron*) but also include numerous ferns and herbaceous plants. The water-table is close to the surface with standing water in many depressions during the spring and fall. A layer of decomposing deciduous leaf litter is present throughout the year. The soils are acid shales and clays with a pH of about 5.3.

METHODS

Several techniques were utilized in order to collect aquatic mollusks. In shallow waters they were obtained with a common household sieve or picked by hand from the substrate with forceps. In Otsego Lake, collections were made at 51 stations around the shores in waters from 0 to 1 m in depth. Using diving equipment, collections were taken at 35 of these locations reaching a depth of 8 m. Six deeper dives (to 23 m) were made. Approximately 125 Ekman dredge samples were taken at various depths from the surface to the deepest points in the lake. At all aquatic collection areas the following data were recorded: alkalinity as CaCO_3 , pH, ppm of oxygen, ppm of carbon dioxide, surface temperature, effective width, effective length (if applicable), depth, current wave action, particle size and character (organic or inorganic) of the substrate, air temperature, wind velocity, soil type, and elevation.

Collection of terrestrial mollusks was done in several ways. For general survey work hand picking from the soil, decaying wood, under sticks, logs, bark, stones and in leaf litter or pit can traps (No. 2 cans buried with their open tops flush with the soil surface primarily for collection of various types of arthropods) were used. The latter were particularly effective for obtaining slugs.

Collections were also made from leaf litter samples processed in a series of modified Tullgren type dry funnels (Edwards and Fletcher, 1970). In this apparatus heat and lack of moisture force most invertebrates to move down through the litter until they finally drop into a collecting vial filled with 70% ethanol. For the purposes of this study a 25 watt electric light bulb placed over each sample served as the heat source. Samples were left in the funnels for

three days. Only six pulmonate snails, all in the order Basommatophora, were collected by this method. By hand searching through the dried samples of litter, we were able to gather organisms that died before they reached the collecting vial. Several hundred fingernail clams (Sphaeriidae) were recovered in this way.

The most effective method of amassing small terrestrial mollusks was by the examination of the stomach contents of the red eft, the terrestrial stage of the common newt, *Notophthalmus viridescens*. One hundred twenty efts were collected from the poorly drained area previously described in the months of June and July 1973. Each stomach was opened and examined with a 45× binocular dissecting microscope. Two hundred thirteen mollusks, representing 25 species, were obtained.

Aquatic Mollusca were determined by the junior author. The terrestrial mollusks were identified by F. Wayne Grimm, Canadian National Museums, Vanier, Ontario.

TABLE 1. List of mollusks collected in the vicinity of Otsego Lake, N.Y.

OTSEGO LAKE

Lampsilis radiata (Gmelin)
Elliptio complanata (Lightfoot)
Anodonta cataracta (Say)
Anodontoides ferussacianus (Lea)
Strophitus undulatus (Say)
Alasmidonta undulata (Say)
Pisidium compressum (Prime)
Pisidium subtruncatum (Malm)
Sphaerium sulcatum (Lamarck)
Lymnaea humilis (Say)
Lymnaea palustris (Müller)
Lymnaea emarginata (Say)
Lymnaea columella (Say)
Helisoma trivolvis (Say)
Helisoma anceps (Menke)
Helisoma campanulata (Say)
Gyraulus parvus (Say)
Promenetus exacuus (Say)
Physa heterostropha (Say)
Viviparus georgianus (Lea)
Spirodon carinata (Bruguière)
Valvata tricarinata (Say)
Valvata sincera (Say)
Annicola limosa (Say)

Annicola lustrica (Pilsbry)
 MOE POND
Helisoma anceps (Menke)
Physa heterostropha (Say)
Ferrissia paralella (Haldeman)
 NEW POND
Lymnaea humilis (Say)
Helisoma anceps (Menke)
Gyraulus parvus (Say)
Physa heterostropha (Say)
 NORTHERN HARDWOOD FORESTS
Pisidium casertanum (Poli)*
Aplexa hypnorum (Linnaeus)*
Lymnaea humilis (Say)*
Carychium exiguum (Say)*
Gastrocopta pentodon (Say)*
Vertigo bollesiana (Morse)*
Succinea ovalis Say*
Catinella vermeta (Say)*
Anguispira alternata (Say)*
Discus catskillensis (Pilsbry)*
Discus cronkhitei ((Newcomb)*
Discus patulus (Deshayes)*
Punctum minutissimum (Lea)*
Nesovitreia binneyana (Morse)*
Mesomphix inornatus (Say)*
Eucomilus chersinus polygyratus (Pilsbry)*
Ventridens intertextus (Binney)*
Zonitoides arboreus (Say)*
Striatura milium (Morse)*
Striatura exigua (Stimpson)*
Stenotrema fraternum (Say)*
Triodopsis dentifera (Binney)
Triodopsis denotata (Ferrussac)
Triodopsis tridentata (Say)
Mesodon sayanus (Pilsbry)*
Triodopsis albolabris (Say)
Arion fasciatus (Nilsson)
Deroceras laeve (Müller)
Deroceras cf. agreste (Linnaeus)
Philomycus flexuolaris (Raf.)
Philomycus togatus (Gould)
Pallifera dorsalis (Binney)

DISCUSSION

The species collected are listed in Table 1 according to the habitats in which they were found. The distribution of the aquatic Mollusca

* mollusks removed from stomachs of *N. viridescens*.

in field station biotopes correlates directly with the types of substrate that occur in these areas. *Helisoma anceps* is extremely abundant in Moe Pond which has silted, flat cobblestones occurring over much of the bottom. This is typical of the biotopes in central New York where this species is found. In New Pond, *Gyraulus parvus* occurs in submergent vegetation that completely fills the low waters in late summer. At those times silty banks rise slowly from the shores and support ephemerally large populations of *Lymnaea humilis*. These again are the usual habitats for the species concerned. *Physa heterostropha* is abundant in both locations, occurring in somewhat shallower water than *H. anceps* on inorganic and organic substrates. *Aplexa hypnorum* occurs in vernal ponds under deciduous forest trees as is typical. This is the first record of this species in the Susquehanna watershed in central New York (Harman and Berg, 1971). Since it is widely separated from population centers in the Finger Lakes region to the west, we assume that its origin is from New England where *Aplexa* is also commonly found.

The high species richness in Otsego Lake compared to New and Moe Ponds can be attributed to several factors: 1. the presence of prosobranch snails and freshwater mussels. The lake is the source of the Susquehanna River which provides access for these water-dependent organisms. 2. the diversity of substrates present compared to both smaller bodies of water. It has been shown by Harman (1972a) that substrate diversity is directly correlated with species diversity of mollusks in central New York State. 3. the high alkalinity (ca 115 ppm in Otsego compared to 19-40 ppm) in Moe Pond and New Pond. Many authors have shown correlations between high alkalinity, reflecting available calcium, and a high species richness of mollusks.

The list of terrestrial mollusks illustrates a greater species richness than we would expect to find on acid shales in the Northeast. We account for this by the apparent efficiency of *Notophthalmus* as a "collector" of small to minute mollusks easily overlooked in general surveys.

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RADULAR ANOMALY IN *UROSALPINX CINEREA*
(GASTROPODA: MURICIDAE)¹

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ABSTRACT

A radular anomaly involving the total absence of the central cusp in the median row of teeth throughout the length of the radula of an adult individual Urosalpinx cinerea follyensis is reported. The remainder of the radula was normal. Although the anomaly may not have interfered with hole-boring, it probably was a disadvantage in feeding. The anomaly may have resulted from a mutation rather than from a physical or biological injury.

INTRODUCTION

Wu in studies of the radula of many species of snails in the family Muricidae found no anomalies, and considers radular deformities very rare in this family (Wu, 1965, 1968; personal communication, 1974). In research on the proboscis of the shell-boring marine snails *Urosalpinx cinerea* (Say), *U. cinerea follyensis* Baker, and *Eupleura caudata etterae* Baker (Carriker, 1943, 1961, 1969; Carriker and Van Zandt, 1972a; Carriker *et al.*, 1972; Carriker *et al.*, 1974), we have examined many radulae and observed a radular anomaly in only one individual of *U. cinerea follyensis* which I feel is worth reporting in view of the rarity of radular anomalies in the Muricidae, and the important use of radulae in gastropod identification.

METHODS

The individual of *Urosalpinx cinerea follyensis* in which the radular anomaly was discovered was collected with others of the same subspecies in Wachapreague, Virginia. Prior to dissection, snails were maintained for some weeks in my laboratory in rapidly flowing seawater (salinity 31-32‰) with an excess of oysters and mussels for food. The snail with the radular anomaly was 40 mm in shell height, normal in external appearance, and actively boring and feeding on prey.

The radula was excised in seawater under a binocular microscope with iridectomy scissors and fine jeweller's forceps. The subradular membrane was cut loose and slipped off the twin odontophoral cartilages (leaving the radular sac and muscles at each end of the membrane still attached), rinsed in distilled water, and dried on a plastic cover slip. The radular membrane was oriented so that transverse rows of teeth were slightly elevated and separated from each other. Anterior and posterior ends of the radula were next secured to the plastic cover slip with Duco cement. After the cement had hardened, a small portion of the cover slip supporting the radula was cut out with scissors and affixed to a scanning electron microscope stub with double adhesive tape. Ends of the radula were then coated with silver paint to minimize charging in the microscope. The preparation was dried in an oven at 60°C overnight, coated with carbon followed by gold in a vacuum evaporator, and studied and photographed in a scanning electron microscope at an accelerating voltage of 20 Kv.

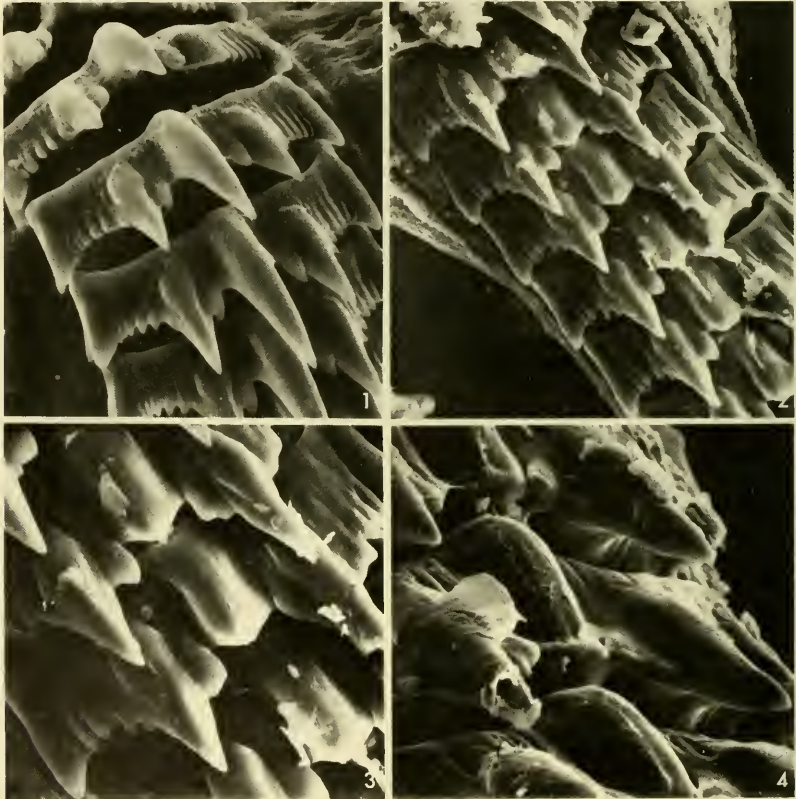
OBSERVATIONS

In normal adult *Urosalpinx cinerea follyensis* ranging in shell height from 38 to 44 mm, the radula varies from approximately 9 to 12 mm in length and from 330 to 430 μ in width, but radular dimensions vary widely among different individuals of the same shell height.

¹ University of Delaware College of Marine Studies Contribution No. 100.

The normal radula of an adult snail contains approximately 250 to 350 transverse rows of nearly colorless teeth (see also Carriker *et al.*, 1972), and each transverse row consists of two slender scythe-shaped marginal teeth separated from a sturdy central rachidian tooth by intermediate grooves (see Carriker *et al.*, 1974, for details). The pattern of radular structure is thus rachiglossan, with the formula $1 + R + 1$.

The rachidian tooth of a normal radula is quinquecuspid, and each of the five prominent cusps arises from a stout basal plate attached to the radular membrane. Unworn cusps in the forward part of the radular sac and atop the odontophore before they come into use in hole-boring, are sharp, slightly hooked, and curve posteriorly. Approximately four to six small denticles protrude posteriorly from the basal plate between the marginal and lateral cusps.



FIGS. 1-4. Rachidian teeth of radula of adult *Urosalpinx cinerea follyensis*. Scanning electron micrographs. Fig. 1. Normal rachidian teeth. Width (side to side dimension) of base plate of each tooth (at anterior end) 115μ . Fig. 2. Anomalous rachidian teeth. Width of base plate of each tooth 114μ . Fig. 3. Anomalous rachidian teeth pictured in fig. 2, higher magnification, dorsal view. Interval between tips of two principal lateral cusps 50μ . Fig. 4. Anomalous rachidian teeth pictured in fig. 3, higher magnification, side view. Interval between tips of lateral cusp 50μ .

and a prominent denticle extends between the bases of the central and lateral cusps (fig. 1).

The anomalous radula was 10 mm long and 350μ wide, dimensions characteristic of radulae of a snail 40 mm in shell height. The major difference between the anomalous radula and normal radulae was the complete absence throughout the length of the radula of the central rachidian cusp (fig. 2). The site of the central cusp was marked by a smooth convexly rounded prominence. The posterior edge of the prominence in some of the teeth when viewed from the top appeared obtusely angled in the transverse plane (fig. 3). In other teeth the edge was rounded or slightly notched. As seen from the side, the prominence appeared obtusely angled in the sagittal plane, with a slight up-turned nodular lip (fig. 4). Large denticles between the central and lateral cusps were slightly misshaped, those on the animal's right (teeth point posteriorly) conspicuously more so than those on the left. All other morphological features of the radula, including marginal teeth, intermediate grooves, and rachidian basal plates were normal and fell within the range of structural variation characteristic of radulae in this species.

DISCUSSION

Rachidian cusps, and especially the prominent central one, function in (a) scraping shell in the borehole during penetration of shell of prey, (b) and, synchronously with the lateral teeth, in biting off fragments of flesh during feeding (Carriker and Van Zandt, 1972a). Absence of the central cusp in the snail with the anomalous radula probably did not affect hole boring significantly as the accessory boring organ does most of the work of shell penetration (Carriker and Van Zandt, 1972b), but probably did decrease efficiency of feeding. As suggested by the fact that the snail grew to a normal size and shape, however, decrease in the rate of ingestion was probably minor. How the anomaly might have affected the rate of growth is not known.

The anomaly may have resulted from (a) a highly localized permanent injury to the odontoblasts which initiate secretion of the central rachidian cusps within the innermost end of the radular sac, or (b) from a mutation. It is

unlikely, however, that an injury, limited to the few cells which produce the central rachidian cusp sheltered inside the radular sac in the cephalic hemocoel, could have resulted from an external blow or puncture. Nor is it likely that the anomaly might have resulted from localized infection, parasitism, or physiological malfunctioning. The highly specific anatomical nature of the anomaly suggests instead that it may have arisen as a mutation. Whether the change was neutral or only mildly deleterious is not known. Morphological and behavioral evidence would indicate that it could not have been beneficial (Carriker and Van Zandt, 1972a), and thus individuals possessing the anomaly would find themselves disadvantaged in the competition for food.

The stability of radular features in gastropods has been recognized for a long time. Fretter and Graham (1962), for example, noted that the number and shape of radular teeth differ from species to species, but remain fairly constant within one species. Abbott (1954) pointed out that radulae are so distinctive in the various families, genera, and species of molluscs that they have been used as a fairly reliable criterion in identification. And Wu (1965) reported that the muricid radula appears to be constant within each species and can be used for diagnosis of species. With the exception of the anomaly reported in this paper, my observations of species of *Urosalpinx* and *Eupleura* support Wu's observations. However, this anatomical stability does not appear to exist in all gastropods. Wu (1972), for example, discovered that the most distinctive features in the freshwater polyploid series of *Bulinus* (Planorbidae) were deformities in teeth. He believes these anomalies could be genetic in origin.

At first glance, and not having examined the proboscis of both sexes, one might consider the anomaly reported here in *Urosalpinx cinerica follyensis* an example of sexual dimorphism. Nevertheless, although sexually dimorphic radulae have been reported in the muricid *Drupella* (Arakawa, 1957), the muricid *Nassa* (Maes, 1966), the buccinid *Pisania* and the archaogastropod *Hiloa* (Robertson, 1971), sexual radular dimorphism, in size or other anatomical features, has never been observed in individuals

of *U. cinerea follyensis* ranging in shell height from 14 to 42 mm (Carriker and Van Zandt, 1972a).

ACKNOWLEDGMENTS

Live specimens of *Urosalpinx cinerea follyensis* were supplied by Mr. Michael Castagna from Wachapreague, Virginia. Preliminary scanning electron microscopy was done with Dr. Virginia Peters on a JOEL JSM-U3 at the Woods Hole Oceanographic Institution (see fig. 1, 4), and final examination was made with Mrs. Takako Nagasi on a Cambridge Stereoscan Mark II in the Department of Geology, University of Delaware (see fig. 2, 3). I am grateful to these persons for their generous help.

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ACADEMY MOLLUSK COLLECTION UP-DATED

Through a generous four-year N.S.F. grant, the extensive and venerable mollusk collection at the Academy of Natural Sciences of Philadelphia has been cleaned and put into better curatorial shape, so that scientists and students may use these facilities to greater ad-

vantage. Loans of specimens and books, photography of types, photocopying, and storage facilities for voucher specimens are being offered to qualified workers. For further details, see *The Veliger*, Vol. 17, no. 4, pp. 414-415 (1975) or write Dr. George M. Davis, Chairman, Dept. Malacology, Academy of Natural Sciences of Philadelphia, Philadelphia, Pa. 19103.

MARSENIOPSIS SHARONAE (WILLETT, 1939) *COMB. NOV.*

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ABSTRACT

The generic placement of Lamellaria sharoni Willett, 1939, is changed to Marseniopsis sharonae (Willett, 1939).

In 1939 George Willett described *Lamellaria sharoni* from Anaheim Bay, Orange County, California. Later, J. Q. Burch (1946) emended the name to *Lamellaria sharonae* because Willett had named it for its discoverer, Ruby Sharon. Apparently neither Willett nor Burch was familiar with Bergh's genus *Marseniopsis* (1886). However, Burch (1946) noted that Willett had not been pleased with his generic placement of the species, but rather than describe a new genus, he placed it in *Lamellaria*.

This animal is unlike any of the other eastern Pacific species of *Lamellaria*. The shell structure is more analogous to that of *Polinices* or *Natica* while the other eastern Pacific species of *Lamellaria* are similar to that of *Sinum*. In the true lamellarians the mantle may or may not cover the entire shell and is either smooth or warty. In *Marseniopsis sharonae* the mantle covers the entire shell and is divided into six areas by low ridges that commence from a raised hexagon in the center of the dorsum. The ridges, flat sides, and flat dorsum give the animal the appearance of a hexadendron. These ridges are not found in any of the other eastern Pacific lamellarians.

Marseniopsis sharonae apparently has a broad north-south distribution. The northern most record is one specimen from Bodega Harbor in Marin County, California. It is in the collection of the Los Angeles County Museum of Natural History. The species has also been found in Monterey Bay, Palos Verdes Peninsula (Los Angeles), Anaheim Bay (type locality), La Jolla, and throughout the Gulf of California. To date,

the species has not been found further south than the gulf of California. However, collection records indicate that it is more common in the Gulf of California than in California proper. It would not be surprising to have the range extended further south.

As Bergh (1886) noted when he named the genus *Marseniopsis*, the features of the radula are mid-way between those of *Marsenia* and *Onchidiopsis* and not particularly close to the type genus of the family, *Lamellaria*.

After their purchase of the Ruby Sharon collection, the Cates (1962) discovered paratypes of this species and distributed them widely among U.S. institutional collections. The holotype had been deposited by Willett in the Los Angeles County Museum of Natural History, Invertebrate Type Collection no. 1059.

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THE IDENTITY OF *PLANORBULA JENKSII* (H. F. CARPENTER)

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ABSTRACT

The freshwater pond snail, *Planorbula jenkinsii*, has been recently accepted by some authors as the "eastern" species of *Planorbula* in North America. A review of the literature however indicates that this acceptance is ultimately based on an interpretation by F. C. Baker of a published statement by Pilsbry (1934). Examinations of specimens of *Planorbula* from north eastern North America show no differences from mid-western *P. armigera* (Say). Specimens identified as *P. jenkinsii* are therefore considered to be *P. armigera*.

Planorbula jenkinsii (Carpenter) has, within the last thirty years, come to be accepted by a few workers as the eastern North American representative of the genus. Recent investigation however, shows that the taxon "jenksii" is incorrect in its present application (see Clarke, 1973).

Carpenter's (1887) original description, a reprint from the Central Falls Visitor (Feb., 1871), was based upon a single broken specimen, apparently since lost, from a pool near "Hammonds Pond," Pawtucket, Rhode Island. The exact location in relation to "Hammonds Pond" has been unclear though Davis (1905: 117) referred to Stump Hill, a presently existing locality. In his description Carpenter did not

mention the lamellar projections within the aperture, a characteristic feature of *Planorbula*, nor had he saved the soft parts for anatomical study. On conchological grounds he placed "jenksii" in *Planorbis*. Immediately following the description of "jenksii," he listed the sympatric *Segmentina armigera* (Say), now in *Planorbula*, as distinct from his nominate "jenksii".

Davis (Loc. Cit.) figured Carpenter's type specimen (fig. 1) and noted two small palatal lamellae on the left side of the aperture and by these alone, placed the species in *Segmentina*. The original drawn figure depicted two views of the shell and although the specimen was damaged to a degree, enough of the apertural area remained to indicate an absence of lamellae on the opposite palatal side and on the parietal surface. These structures have been usually sufficiently strong in examined *Planorbula* specimens to resist breakage.

Johnson (1915) listed *Segmentina jenkinsii* only from its type locality and retained *S. armigera* for all other New England localities. Walker (1918: 100) kept the genus *Planorbis* possibly because he overlooked the account of the type by Davis (1905). Then for about twenty years the taxon *jenksii* disappeared in the literature. Jacot (1923) listed *S. armigera* from Connecticut and Baker (1928) gave the geographical range of *S. armigera* as including New England. Pinney and Coker (1934) recognized *Planorbula* as the genus but retained *armigera* for the New York area and Clench and Russell (1938) listed *P. armigera* from New Hampshire. Then F. C. Baker

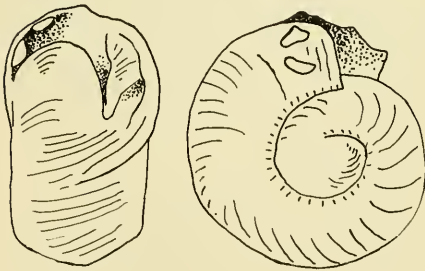


FIG. 1. *Segmentina jenkinsii* (Carpenter). Redrawn from Davis (1905).

(1942: 79) remarked on *jenksii* as having "recently been shown to be a *Planorbula* by Pilsbry (no date). He then subsequently assigned all of his specimens from New Hampshire to *jenksii*."

The only published account on the Planorbidae by Pilsbry (1934) in that period made no specific mention of *jenksii*, however in Footnote 9, p. 54, he recognized a species "allied" to *armigera* as occurring in New York. Shortly after F. C. Baker's (1942) account, Rapp and Rapp (1945) credited an identity of *P. jenksii* to Pilsbry.

The accompanying synonymy follows the subsequent use of *P. jenksii*:

Planorbula jenksii (Carpenter), F. C. Baker (1945), as occurring in New England.

Planorbula jenksii (Carpenter), Robertson and Blakeslee (1948), the eastern species of *Planorbula*.

Planorbula jenksii (Carpenter), Jacobson and Emerson (1971), from south eastern New York State.

Planorbula jenksii (Carpenter), Harman and Berg (1971), from central New York State.

Clarke (1973: 422) has established the range of *P. jenksii* as covering eastern North America. Examinations have been made of *Planorbula* specimens collected in areas lying within the species range. A total of 71 specimens have been inspected from three localities in Massachusetts: Hampshire Co., Northampton (23), So. Hadley (17) and Middlesex Co., Winchester (12), presumably near Baker's (1945) record for Medford; and one locality in Rhode Island: Providence Co., Central Falls (19). The Rhode Island collection is only one mile from Carpenter's "type" locality for *Planorbis jenksii*, as the Stump Hill area indicated by Davis (1905: 117) has been modified to hold a sealed reservoir that is inaccessible.

Six characters were analyzed for each collection including shell diameter, aperture height, shell sculpturing, number of whorls, number of lamellae and their shape. Average values for each character were then determined for the collected lots and compared to the published descriptions of *Planorbula armigera* that appeared in Blatchley and Daniels (1903), Winslow (1921: fig. 1), F. C. Baker (1928) and Clarke (1973). Comparisons were also made with

descriptions of *P. jenksii* in Jacobson and Emerson (1961) and Harman and Berg (1972). In all respects the collected specimens agreed with all of the published descriptions for both "species". In reference to the above characters, none of the specimens resembled Carpenter's description of *Planorbis jenksii* or the figure of *Segmentina jenksii* in Davis (1905).

Due to the existence of only one specimen from a presumably well-surveyed area, it seems reasonable to assume that *Planorbis jenksii* represents an aberrant or pathological example of some other species.

It is proposed therefore, that *jenksii* as described by Carpenter (1887) and as amended by Davis (1905) be considered a *species inquirenda*. Additionally I can find no difference between eastern and mid-western specimens of *P. armigera*.

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Dan Steger (1906-1975)

The many friends of Dan(iel) D(owney) Steger will be saddened to know of his sudden death on May 16, 1975, at age 68, at Tampa, Florida, of a heart attack. Dan was born August 1, 1906, in Fresno, California, and received his education in structural engineering in San Francisco. Early in his life he was active in the opera and was a choral director and symphony conductor. He was director of the Florida Boys Band at the Chicago World's Fair in 1934. During World War II he served as company carpenter for the Army 51st Engineers. He dredged from a shrimp trawler in Florida from 1952 to 1970, and developed an extensive knowledge of the microscopic marine mollusks of the Gulf of Mexico, particularly of Turridae. He was active in the St. Petersburg, Florida, Shell Club and the A.M.U. The bulk of his collection has been given to the Delaware Museum of Natural History. He is survived by his wife, also a keen conchologist, Barbara ("Bobby") Steger.

— R. Tucker Abbott.



FIG. 1. Dan Steger at age 62.

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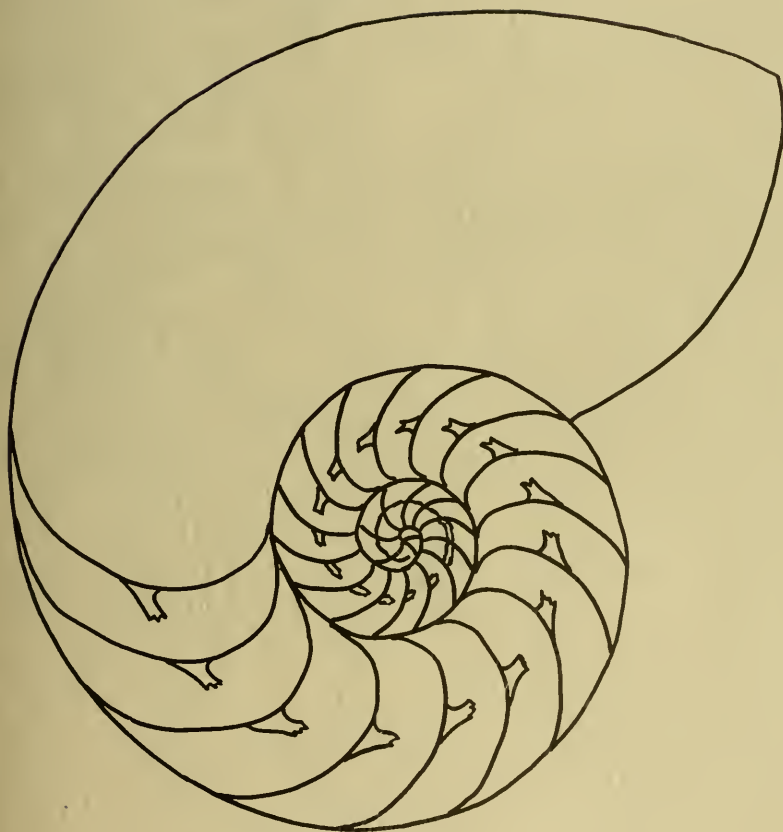
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LIGUUS: THE BOYNTON BEACH COLONY AFTER FORTY YEARS

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In 1970 a colony of *Liguus fasciatus* (Müller) was found in Boynton Hammock, Boynton Beach, Florida. This colony was assumed to be natural (Craig, 1973) in spite of the northern limit having been reported as Yamato Hammock, Boca Raton, Florida (Pilsbry, 1912; 1946). Subsequent investigation indicates that some trees and the *Liguus* were planted in Boynton Hammock (Jones, pers. comm.).

Approximately forty years ago, an experiment was begun which was terminated during the summer of 1974. During the 1930's, then active malacologists P. L. and T. L. McGinty planted trees including the present wild tamarind (*Lysiloma bahamensis*), and aboreal snails, *Liguus fasciatus*, including the color forms *castaneozonatus*, *roseatus*, *septentrionalis*, and *testudinicus* in Boynton Hammock. The snails were taken from the Yamato Hammock, Upper Key Largo and elsewhere in Florida (Jones, pers. comm.). Boynton Hammock, a remnant of a once extensive coastal hammock system is now a mere 800 yards long and 75-80 yards wide (Austin and Weise, 1973). The eastern border is the Atlantic Ocean with the western border formed by U.S. Highway A1A. The southern limit is a public beach and parking lot, while the northern border is a private residence. The recent construction of a condominium apartment building bisects the hammock removing 75-80 yards and presenting a barrier to migrations within the hammock.

Casual observations from 1970 to late 1973 are exemplified by a total of 30 living individuals at four sites by Austin indicating a well established population. Quantitative study from February 1974 to August 1974 revealed a population change from 51 individuals to zero. Counts were made by examination of mastic, paradise, and tamarind trees within a 60 × 60 meter plot located in a dense portion of the hammock north of the construction detailed above.

Liguus has many natural predators including the land hermit crab *Coenobita clypeatus* (Davidson, 1965), the carnivorous snail *Euglandina rosea*, the opossum, and rats (Pilsbry, 1946). Man, however, has been indicted as a factor commonly limiting many organisms by over-collection and/or habitat destruction.

Numerous shells of the carnivorous snail *Euglandina rosea* are strewn about the floor of Boynton Hammock. The presence of *E. rosea* suggests predation on *Liguus* as other species of suitable prey are lacking. *Liguus* shells found in the leaf litter indicate predation by *E. rosea* and/or senescence as many display no shell damage.

On the other hand, *Liguus* fragments are in evidence on the hammock floor as well as in the trees. These fragments range from those with punctures to those that have been shattered. The punctured shells match the dentition of the Florida mink; whereas, shattering may be due to opossums, racoons, and hermit crabs. The above potential predators have been observed or their spoor found in Boynton Hammock.

Perhaps the most devastating influence on the hammock has been man. The present Boynton Hammock is only a remnant bordered by the Atlantic Ocean, man-made structures, and

TABLE I. Identification of dead *Liguus fasciatus* shells collected from Boynton Hammock between 1970 and 1975.

Color Forms	Individuals	Percent
<i>castaneozonatus</i>	48	17.27
<i>elliottensis</i>	4	1.44
<i>luteus</i>	2	0.72
<i>ornatus</i>	1	0.36
<i>roseatus</i>	179	64.39
<i>septentrionalis</i>	3	1.08
<i>testudinicus</i>	4	1.44
unidentifiable,		
bleached	37	13.31
	278	100.01

has been bisected by construction. Tropical hammocks are prime real estate locations for the Florida "Gold Coast" developers; hence, the hammocks are disappearing. Furthermore, foot paths cross the hammock leading to a well used ocean beach and also afford access to the hammock by collectors.

Heavy predation, habitat alteration, and over-collection are the factors to which the Boynton Beach *Liguus* colony succumbed after forty years.

ACKNOWLEDGMENTS

We are grateful for the account of work done by P. L. and T. L. McGinty in Boynton Hammock provided by Archie L. Jones, Coral Gables, Florida.

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REVIEW

Galtsoff, Paul S. 1972. *Bibliography of Oysters and other Marine Organisms Associated with Oyster Bottoms and Estuarine Ecology*. vii + 857 pp. G. K. Hall and Co., 70 Lincoln St., Boston, Mass. 02111. \$74.00. ISBN 0-8161-0945-1.

This is probably the most extensive bibliography ever published on edible and pearl oysters. It represents 43 years of compilation by one of the world's experts on the biology of oysters, and contains 18,000 entries. 6,900 of these are author cards covering a period roughly from the 1860's through 1964. The remaining entries, 11,000, are divided into numerous subjects from "abundance" to "zinc". There are, for instance, 224 references to pearls and pearl oysters, and 172 entries dealing with the taxonomy of oysters.

The bibliography reflects the research interests of Dr. Galtsoff, and one will find very complete coverage in the fields of oil and in-

dustrial waste pollution, biology of oysters, enemies of oysters, fishing laws, "Red Tides" and ostreiculture. There are many references to mussels, scallops and whelks, but these deal largely with papers having some relationship to the study of oysters.

This enormous reference book weighs almost nine pounds and consists of folio-size pages of durable paper upon which have been photo-reproduced the actual cards, with notes, from Dr. Galtsoff's bibliography. Fortunately it has a rugged hardback binding. Although costly, the book is an invaluable tool for any school or marine laboratory interested in bivalves, mariculture, estuarine studies or environmental protection. Let us hope that someone covers the period from 1965 to 1975 in the not too distant future.

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CLAVOCERITHIUM (INDOCERITHIUM) TAENIATUM, A LITTLE-KNOWN
AND UNUSUAL CERITHIID FROM NEW GUINEA

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ABSTRACT

New data on Cerithium taeniatum Quoy and Gaimard are presented. This species becomes the first Recent member referred to the genus Clavocerithium, subgenus Indocerithium. A new description, synonymy, discussion of types and nomenclature are given and scanning electron micrographs of the radula are presented. Comparison with fossil members of the subgenus Indocerithium is made.

INTRODUCTION

While working on a revision of the cerithiid genera *Rhinoclavis*, *Proclava*, *Pseudovertagus* and *Cerithium* of the Indo-Pacific region, I recently examined a series of specimens from the collections of the Academy of Natural Sciences of Philadelphia and the Australian Museum that, at first glance, appear to be variations of *Rhinoclavis vertagus* (Linnaeus, 1767). Close examination showed that these were indeed distinct from *vertagus* and constitute rare examples of an uncommon, little-known and unusual species described in 1834 by Quoy and Gaimard as *Cerithium taeniatum*, collected at Dorey Baai, Netherlands New Guinea (now known as West Irian, Indonesia) by the "Astrolabe" Expedition. Quoy and Gaimard noted the close resemblance between *vertagus* and *taeniatum*, remarked that their species was rare, and that they had not seen the animal. The description pointed out that *taeniatum*, in contrast to *vertagus*, has a more oblique, oval aperture, a shorter, less reflexed siphonal canal, and longitudinal riblets or plaits confined to the upper whorls. The overall yellow color and the orange banding were also stressed in the original description. Quoy and Gaimard's figure (pl. 54, fig. 21) is an excellent representation but exaggerates the color pattern. Kiener's (1841-42) figure of *C. taeniatum* (pl. 19, fig. 2) also is good, but indicates brown rather than orange bands. Sowerby's (1855) figure (pl. 176, fig. 1) is evidently a copy of that in Quoy and Gaimard (1834). Both Kobelt

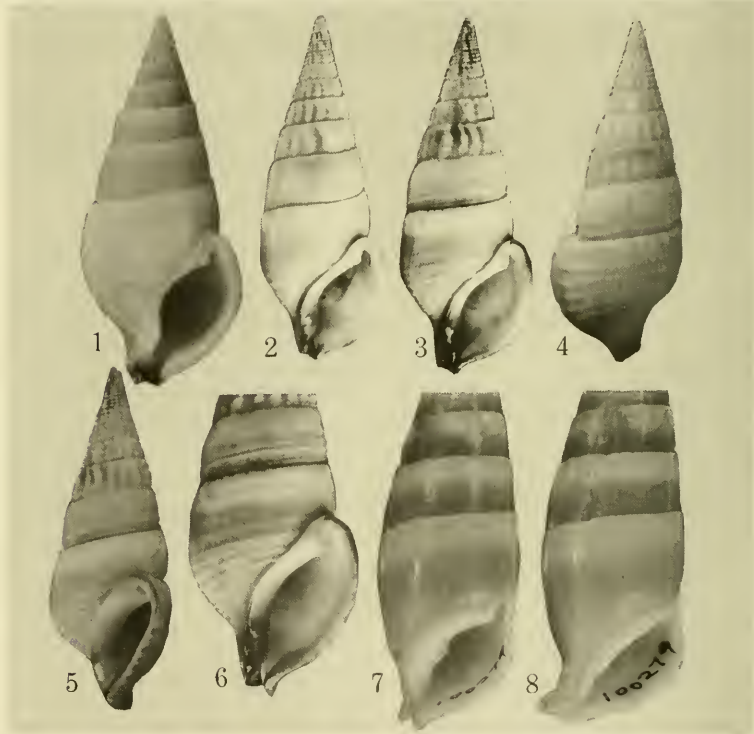
(1898) and Tryon (1887) had little to say of this species and their figures also appear to be merely copies of Quoy and Gaimard. Aside from Cernohorsky (1972), who synonymized *taeniatum* with *vertagus*, no other modern writer has alluded to *C. taeniatum*.

Cerithium taeniatum superficially resembles *Rhinoclavis vertagus* and other nomina in the genera *Rhinoclavis* Swainson, 1840 and *Pseudovertagus* Vignal, 1904. Both genera are characterized by relatively large shells and well-developed anterior canals that are reflexed sharply. *Rhinoclavis* differs from *Pseudovertagus* by the presence of a prominent median columellar plait (fig. 7). *Cerithium taeniatum* superficially looks like *Rhinoclavis vertagus*, the type-species of *Rhinoclavis*; however, it lacks the median columellar plait characteristic of *Rhinoclavis* and does not have the long, reflexed anterior canal prominent in the former genus and *Pseudovertagus* (fig. 8). Thus it cannot be placed into either group and it does not appear to fit into any other closely related Recent cerithiid taxa, such as *Proclava* Thiele, 1931, or *Ochetoclava* Woodring, 1928. Rather than encumber the literature with another new generic name I have reviewed the numerous generic and subgeneric nomina proposed for fossil species of *Cerithium*, sensu lato. The limits of these taxa often are confusing and they are ranked differently by various authors; however, I believe *C. taeniatum* should be referred to the genus *Clavocerithium* Cossmann, 1920. The type-

species of *Clavocerithium*, *C. lacazei* (Vasseur, 1881), resembles *C. taeniatum*, but is an Eocene species described from the Lower Loire, France. Like *taeniatum*, it lacks a columellar plication, has a sinuous outer lip and differs mainly by the absence of axial riblets on the upper whorls. Wenz (1938) considered *Clavocerithium* a subgenus of *Clava* Martyn, 1784 [= *Rhinoclavis* Swainson, 1840], but the radula, anatomical and conchological characters of *C. taeniatum* are distinct enough to indicate that *Clavocerithium* is a good generic group. *Clavocerithium taeniatum* thus becomes the first

Recent species to be referred to this genus. Chavan (1952) assigned an Indonesian Tertiary species, *Cerithium (Vertagus) jonkeri* Martin, 1884, to the genus *Clavocerithium* but believed it differed enough to warrant a new subgenus that he named *Indocerithium*, designating *Cerithium jonkeri* as the type-species of the new taxon. *Cerithium taeniatum* is very closely related to *jonkeri*; consequently, I refer *taeniatum* to the subgenus *Indocerithium* Chavan, 1952.

I have not found additional specimens in any museum collections in the United States but



FIGS. 1-6, *Clavocerithium (Indocerithium) taeniatum* (Quoy and Gaimard): FIG. 1, specimens from Kranket Islands, Madang, N. E. New Guinea (2.5X); FIGS. 2-5, specimens from Japen Id., Geelvink Baai, West Irian, New Guinea (2.5X); FIGS. 5-6, detail of sinuous outer lip, smooth columella and short anterior canal. FIGS. 7-8, *Rhinoclavis vertagus* (Linnaeus), detail of aperture, columellar plait and reflexed anterior canal.

suspect that some may turn up in private collections or in European museums mixed in with lots of *Rhinochloavis vertagus*. The following synonymy, description and remarks are given to alert other workers and solicit further information about this unusual and uncommon species.

Clavocerithium Cossmann, 1920

Cossmann, 1920. Bull. Soc. Sci. Natur. l'Ouest France (Nantes) serie 3, 5:94, pl. 3, figs. 24-25. Type species: *C. lacazei* Vasseur, 1881, by original designation, Eocene of Lower Loire, France.

Description: Shell moderate in size, fusiform elongate, 12-14 whorls, solid. Sutures distinct, slightly channeled. Whorls moderately convex. Upper whorls ornamented with spiral grooves and ridges. Body and penultimate whorls

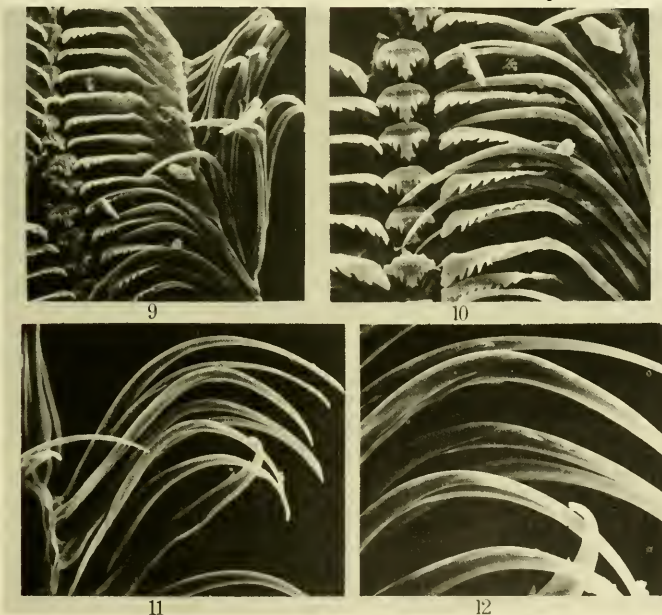
smooth. Aperture oblique, fusiform. Columella concave, with a prominent bulge of the columellar callus near the posterior canal. Anterior canal short and slightly reflexed to the left and upwards. Anal canal broad, bordered with prominent columellar bulge. Outer lip smooth, prominently sinuous and extending over the suture of the previous whorl.

Stratigraphical Range: Eocene.

Subgenus **Indocerithium** Chavan, 1952

Chavan, 1952. Cahiers Geologiques de Thoiry-Seysel, No. 12:104. Type species: *Cerithium (Vertagus) jonkeri* Martin, 1884, by original designation, Pliocene of Java.

Differs from *Clavocerithium* by presence of axial plications or riblets. Lacks bulge on columellar callus. Body and penultimate whorls sometimes ornamented with spiral cords. Anal canal bordered with prominent anal sulcus that



FIGS. 9-12, *Radula* of *Clavocerithium* (*Indocerithium*) *taeniatum* (Scanning Electron Micrographs): FIG. 9, half-row of radula (160X); FIG. 10, view of central and lateral teeth showing tricuspid denticle on central tooth (275X); FIGS. 11-12, detailed view of scythe-like lateral teeth showing tiny denticles (250X and 550X).

extends well within aperture. Periostracum smooth and thin. Operculum corneous, ovate and paucispiral with an eccentric nucleus. Radula with tricuspid central, multicuspid broad laterals and long, hook-like marginals minutely serrated with indistinct denticles.

Geographical Range: Guam, the Philippines, Indonesia (all fossil records) and New Guinea (Recent).

Stratigraphical Range: Pliocene to Recent.

Clavocerithium (Indocerithium) taeniatum
(Quoy and Gaimard)
(Figs. 1-6)

Synonymy —

- 1834 *Cerithium taeniatum* Quoy and Gaimard, in d'Urville's "Voyage Astrolabe", Zoologie, vol. 3, pl. 113, pl. 54, fig. 21 (Dorey Baai, Netherlands New Guinea; holotype and copy, Paris Museum) [non *taeniatum* Eudes-Deslongchamps, 1842; non Sowerby (*in*): Reeve, 1865] 1841-42, Kiener, Coquilles Vivantes, pt. 1, pl. 21, pl. 19, fig. 2; 1855, Sowerby, Thesaurus Conchyliorum, vol. 2, p. 848, pl. 176, fig. 1.
- 1895 *Vertagus implicatus* Brancsik, Jahresheft des Naturwissenschaftlichen Vereines des Trencsener Comitates, vol. 17-18, pl. 217, pl. 5, figs. 2a, b. (NE New Guinea, "Papua"; 3 syntypes, Budapest Museum).
- 1898 *Cerithium (Vertagus) taeniatum* Quoy and Gaimard. Kobelt [*in*] Martini-Chemnitz, Conchilien Cabinet, vol. 1, pt. 29, *Cerithium*, p. 252, pl. 5, figs. 7-8; 1887, Tryon, Manual of Chonchology, vol. 9, p. 149, pl. 29, fig. 70.

Description: Adult shell 27 to 52 mm long, 10 to 16 mm wide, turritid, solid, stout and fusiform consisting of 11 to 13 whorls; nuclear whorls 1½ turns, smooth, white. Upper 11-12 whorls in spire each ornamented with 14-16 longitudinal riblets that are more nodulose on the post nuclear whorls; each whorl in upper spire with three dominant spiral cords that are nodulose where they cross the axial riblets; a fourth, smaller spiral cord is at the base of the whorl near the suture. Numerous microscopic spiral grooves are between spiral cords in upper spire. On the third whorl the axial riblets are broader, smoother and more weakly defined and spiral cords and grooves are weak or absent.

Penultimate whorl relatively smooth, weak axial plications sometimes present near sutures; body whorl usually smooth except for 2-3 weakly defined spiral cords near the lower central portion of the whorl; neck of body whorl with about five small spiral cords. Sutures distinct, slightly channeled. Former varices present on most whorls; prominent former varix opposite outer lip. Aperture oblique, fusiform and mostly white within, stained with brown along edges. Columella concave, smooth with a moderate callous. Anterior siphonal canal short, broad, only slightly reflexed (65-70) degrees) and stained with dark brown at its tip. Anal canal broad and bordered with prominent columella ridge forming a deep sulcus extending well within shell. Outer lip smooth to weakly crenulate, broad, flaring and distinctly sinuous, extending over suture of previous whorl by about one third. Shell color yellowish-white with pink or tan broad band present on upper portion of each whorl; body whorl more darkly pigmented. Banding pattern may be weak or entirely lacking. Periostracum thin, light tan, slightly rust colored on lower whorls. Operculum, corneous, dark brown and ovate with an eccentric nucleus.

Animal (preserved) color yellow-pink; foot and snout darkly pigmented; mantle papillate, flesh colored and with darkly pigmented edge; anterior siphon of mantle muscular, dark brown and with 2 dark spots. Hypobranchial gland long, white; gill large. Eyes close to ends of long tentacles. Anus and opening of genital duct close to mantle edge. Genital ducts open; males aphallic.

Radular ribbon narrow, delicate and short (0.5 mm long), taenioglossate, (2 + 1 + 1 + 1 + 2). Rachidian tooth triangular, bearing prominent tricuspid central tooth with two to three denticles on each side. Base of rachidian with one large central and two shorter longitudinal projections. Lateral tooth large, rhomboid, broad and deeply rooted with a long lateral basal extension; upper portion finely serrated with many small denticles tapering off laterally. Inner and outer marginals long, tapering anteriorly and scythe-like; inner marginals with a few indistinct denticles and outers completely smooth.

Measurements (in mm):

length	width	no. of whorls	locality
52	16	12	N. shore of Maroepi,
44	15	12	Japen Id. Geelvink Baai, West
41	16	13	Irian, Indonesia.
33	13	12	
29	12	12	N. end of Kranket Id., Madang,
27	10	11	N.E. New Guinea

REMARKS

This species is distinguished from *Rhinoclavis vertagus* by its wide aperture, sinuous outer lip, distinctive anal canal, the three spiral cords and nodulated axial riblets on whorls of the upper spire, and by a unique, tiny radula. Anatomically, the eyes are nearer the ends of the tentacles than in *R. vertagus*.

Specimens from Japen Id., Geelvink Baai, West Irian, Indonesia (NW New Guinea) (figs. 2-6) do not have the bright colors depicted by Quoy and Gaimard. They tend to be whitish with brown blotches on the lower whorls and have occasional weak traces of wide, brownish-rose bands near the sutures. The siphonal canals are stained a dark chocolate. Specimens from the Kranket Islands, Madang, N.E. New Guinea (fig. 1) are smaller and white with a chocolate-stained anterior canal. They are quite variable in sculpture; the last three whorls may be entirely smooth or adorned with axial and spiral sculpture. These specimens were collected in the intertidal zone. Although there is no other ecological information, fecal pellets of preserved specimens from both localities consist of fine particles of mud or sand and are arranged in transversely oriented capsule-like pellets stacked in layers in the intestine. This may indicate *Clavocerithium taeniatum* lives on a muddy or fine sandy bottom. It appears to be restricted to shallow bays on the northern coast of New Guinea. I have seen similar fecal pellet arrangement in the intestine of *Proclava sordidula* Gould, 1849 [= *P. pfefferi* Dunker, 1882].

The tiny radula of *Clavocerithium taeniatum*, in marked contrast to that of *Rhinoclavis vertagus*, is unique among most cerithiid radulae. The tricuspid central, the broad, weakly-serrated lateral teeth and the long, scythe-like marginals are quite distinctive and probably reflect a mud-gathering function (figs. 9-12). Although

Proclava sordidula is far removed conchologically from *Clavocerithium taeniatum*, the radula of the former is almost identical to that of *taeniatum*. Undoubtedly this is an example of convergence due to similar function and indicates that cerithiid radulae should not be heavily weighted as reliable characters for supraspecific groupings. An examination of taenioglossate radulae in Troschel (1863) shows similar radulae in *Xenophora trochiformis* Born and *Aporrhais pespelicani* (Linnaeus). *Clavocerithium taeniatum*, however, is anatomically a cerithiid.

TYPES AND NOMENCLATURE

The holotype and paratype of *C. taeniatum* are in the Paris Museum (no register number). Color slides of the types do not show as colorful a shell as that represented by Quoy and Gaimard's figure (pl. 54, fig. 21). The paratype is an immature shell.

There are two primary junior homonyms of *Clavocerithium taeniatum*: that of Eudes-Deslongchamps (1842) and another included by Reeve (1865) in his monograph of *Cerithium* and attributed to Sowerby. *Cerithium taeniatum* Eudes-Deslongchamps 1842, is a fossil species described from the Upper Jurassic of France (Mém. Soc. Linn. Normandie, 7:200, pl. 11, fig. 14). Reeve's description and figure (Conch. Icon. 15, pl. 17, fig. 119) bear no resemblance to the *taeniatum* of Quoy and Gaimard. Moreover, Reeve did not even place Sowerby's *taeniatum* in his *Vertagus* section and his figure looks like a typical *Cerithium* species, *sensu stricto*.

Vertagus implicatus Brancsik, 1895 was described from specimens in a collection made from Kaap d'Urville to Astrolabe Bay (NE New Guinea). Brancsik (1895) noted his species' resemblance to *R. vertagus*, but remarked that *taeniatum* could be separated from the latter by the lack of a columellar plait and by its distinct spiral sculpture. I have not seen the paratypes that are in the Budapest Museum, but Brancsik's figure (pl. 4, fig. 2a, b) and diagnosis unequivocally correspond with *C. taeniatum*.

FOSSIL RECORD

A fossil species described by Martin (1884) as *Cerithium (Vertagus) jonkeri* is identical to

Recent specimens of *C. taeniatum*. Figures of *C. jonkeri* in Martin (1884), Tesch (1920), Wissema (1947) and Ladd (1972) indicate that it is a variable species and is probably conspecific with *C. taeniatum* or a direct ancestor of it. I have not seen Martin's holotype of *jonkeri* and hesitate to synonymize it with *taeniatum*; however, many other Recent cerithiids also were living during the Tertiary and it is not unreasonable to suggest that the two are conspecific.

Clavocerithium jonkeri is known from the Pliocene of Java and other islands in Indonesia and from the Pleistocene of Java (Ladd, 1972). It has also been recorded from the Upper Miocene of Luzon and the Pliocene of Mindanao, Philippines (Wissema, 1947). Ladd (1972) found it in the Mariana Limestone of Guam (Pliocene or Pleistocene). On the basis of this geological evidence, it appears that the present geographic range of *C. taeniatum* is much reduced.

Other related Tertiary species are *C. poetjanganensis* (Altena, 1941), from the Pleistocene of Java, and both *C. altenae* (Wissema, 1947) and *C. escheri* (Wissema, 1947), from the Tertiary and Quarternary of Nias, Indonesia. I refer all of these fossil species to the genus *Clavocerithium*, subgenus *Indocerithium* Chavan, 1952.

ACKNOWLEDGEMENTS

I wish to thank Dr. Joseph Rosewater of the Division of Mollusks, National Museum of Natural History, for critically reading the manuscript and Dr. R. Tucker Abbott of the Delaware Museum of Natural History for his suggestions and comments during the preparation of this paper. I am indebted to Dr. Robert Robertson of the Academy of Natural Sciences of Philadelphia and to Dr. Winston Ponder of the Australian Museum for the loan of specimens in their charge. My thanks to typist Janice Clark and to Richard Hammer for proofing the final manuscript. I acknowledge the Photographic Services Division of the Smithsonian Institution for the photographs in this paper. The scanning electron micrographs were taken on a Cambridge Mark II-A Stereoscan at the Scanning Electron Microscope

Laboratory of the National Museum of Natural History, Smithsonian Institution.

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THE FRESHWATER PROSOBRANCH, *TAREBIA GRANIFERA*,
IN ORIENTE, CUBA

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While determining some gastropods collected in Cuba in 1969 and 1973 by Dr. Stefan Negrea of Bucharest, Romania, I was surprised to find several small lots of *Tarebia granifera* (Lamarck, 1816). The species does not seem to have been recorded previously from that island, although Murray (1971) states that it has been reported from Puerto Rico and the Dominican Republic. The identity of the species was confirmed by Dr. H. D. Murray (personal communication) who has written on the presence of the species in ponds and streams in the San Antonio, Texas Zoo. There it occurs together with the related *Melanooides tuberculatus* (Müller, 1774), and it serves as the intermediate host of the trematode (*Philophthalmus megalurus*) infecting the nictating membrane of aquatic birds (Murray, 1964; Murray & Stewart, 1968; Murray & Haines, 1969). *T. granifera* originally came from China and has recently appeared in southern Florida and Texas (Dundee, 1974: 6). In China it serves as the intermediate host of the Oriental lung fluke (*Paragonimus westermani*) (Abbott, 1952; Murray, 1964, 1971). In addition to their roles as potential vectors of disease, *Tarebia* and *Melanooides* are harmful because with their high reproductive rates they can displace native species (Murray, 1971). Cuban melaniids (genus *Hemisinus*) which could possibly be displaced by the introduced species, occur only in the western half of the Island, where no infestation has as yet been reported.

The Cuban snails are small, the largest being only 16 mm in length, whereas in Guam specimens reach a length of 40 mm (Abbott, 1952: 104). The snails in Lithia Spring, Florida, also reach about 16 mm as they do in Cuba. There was no way of determining if the present Cuban specimens, all of which were collected dead, were fully mature, but enough shells are at hand to indicate that in all likelihood they are at, or very near, their maximum size.

The Cuban snails were taken at the following localities, all in Oriente Province: Río Baracoa at La Tinta, near Cabo Maisí, 7 spms; Río Yumuri, 23 km from Sabanilla, Baracoa, 5 spms; Laguna Baconao, 37 km E of Siboney, 4 spms; Río Mogote, Matías, about 50 km W of Santiago de Cuba, 25 spms; Río Ceiba, tributary of Río Mayarí, Mayarí Abajo, 2 spms; Arroyo Colorado, Venado, near Mayarí Arriba between Seboruco and Alto Songo, 1 spm; Arroyo Jarahueca near Mayarí Arriba, between Seboruco and Alto Songo, 2 spms. Murray (1971) reports that *T. granifera* in the United States appears to be confined ecologically to warmer springs. This does not seem to be the case in Oriente.

Specimens will be deposited in the American Museum of Natural History, the Museum of Comparative Zoology, and in the conchological collection of the Institutul de Speologie 'Emil R. Racovita', Bucharest, Romania.

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TERRESTRIAL SLUGS IN THE VICINITY OF VANCOUVER, BRITISH COLUMBIA¹

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ABSTRACT

Twelve species of slugs were recorded during an extensive survey around Vancouver, British Columbia. There were only three native species. Ariolimax columbianus (Gould), Deroceras laeve (Müller), and Prophysaon andersoni (Cooper). Of the nine introduced species, Arion hortensis Férussac, A. intermedius (Normand), A. subfuscus (Draparnaud) and Deroceras caruanae (Pollonera) are new records for the area. Of the Arion fasciatus complex, A. circumscriptus Johnston was abundant but A. silvaticus Lohmander was not. A. fasciatus (Nilsson) was not found. Notes on the introduction, economic importance and life history of each of the 12 species are included.

Chichester and Getz (1968) emphasized the need for more detailed information concerning the distribution of introduced slugs. Such species have been more intensely studied in eastern than in western North America (Getz and Chichester, 1971). In the west, records from British Columbia are especially scarce (Hanna, 1966).

This paper is a preliminary evaluation of the slugs in the vicinity of Vancouver, British Columbia, with special reference to their economic importance. It is based on collections from 23 locations in and around Vancouver, where we have made extensive surveys since September, 1974. Descriptive works consulted for identification included Ellis (1926), Pilsbry (1948), Likharev and Rammelmeier (1962), Quick (1949, 1960) and Chichester and Getz (1973).

Arion ater (Linnaeus)

A. ater was probably introduced into western North America in the Puget Sound area of Washington (Hanna, 1966). By 1940 it was a recognized garden pest in Seattle (Smith, 1962) and by 1948 it was a major pest in gardens in the lower Puget Sound area (Doucette, 1954). By the 1960's it was nearly as important economically as *Deroceras reticulatum* (Müller) in the Pacific Northwest (Howitt, 1961; Howitt and Cole, 1962; Crowell, 1967).

¹This survey is part of a larger study supported by a research grant from Agriculture Canada.

Hanna (1966) believed that the first record of *A. ater* in British Columbia was Glendenning's (1952), but Glendenning and King (1949) recorded *A. ater* near the port of New Westminster in 1945. Dr. I. McT. Cowan (pers. comm.) recalls observing "large black slugs" crossing sidewalks at Jericho Beach, Vancouver, in 1941 ± 1 year; individuals which were undoubtedly *A. ater*.

In 1955 *A. ater* prevented growth of all garden crops at Hope and Popcum, British Columbia (Forbes *et al.*, 1956). Fulton (1955) observed these slugs traveling to gardens from rough pasture, and estimated the population to be at least one per 0.8m². By 1962, W. M. Draycott recognized this species as one of the worst molluscan pests of southern British Columbia (Hanna, 1966). It occurs through the Fraser Valley from Hope westward to the coast, and it is also established on the valley edges (e.g., at Cultus Lake and at Mission, British Columbia (Anonymous, 1963)).

A. ater was previously considered as two species, *A. ater* (L.) and *A. rufus* (L.) (Quick, 1947, 1949). Cain and Williamson (1958) presented evidence of hybridization, however, and Quick (1960) later recognized *A. ater* and *A. rufus* as subspecies of *A. ater*.

The most common color forms presently in Vancouver range from reddish-brown to greenish-brown dorsally, with red, orange or

yellow foot fringes. Black individuals with pale soles, variety *ater* (L.), and totally black slugs, variety *aterrima* Taylor, are also common. Other color variations include *marginella* Schrank, black with yellow or red fringes; *castanea* Dumont and Mortillet, brown with a paler fringe; *succinea* Müller, yellow with orange or red fringe; and *aurantia* Baudon, orange-colored. Immature individuals show a more variable range in color than adults. Olive green immature specimens with bright yellow fringes were common in winter, but no adults retained this pattern. Immature individuals frequently have lateral bands, and may superficially resemble *Arion subfuscus* (Draparnaud).

Quick (1949) states that most of the brighter-colored forms are probably *rufus* and most of the duller ones *ater*. However, dissection revealed that even individuals referable to variety *aterrima* had genitalia more like *rufus* than *ater* as described by Quick (1947). The figure in Pilsbry (1948) shows the genitalia of an Oregon *A. ater*, which he states are typically black, but this specimen also appears to be *A. ater rufus*.

A. ater is one of the most ubiquitous slugs in Vancouver. At Cultus Lake Park, and in many forested areas about Vancouver it occurs in a sylvan habitat, and may be as numerous as *Ariolimax columbianus* (Gould). It does not, however, appear to displace the latter species, which remains as abundant where *A. ater* is present as in regions where it is absent. R. T. Paine (Getz and Chichester, 1971) believes *A. ater ater* is restricted to more rural areas, whereas *A. ater rufus* is more confined to cities. At Cultus Lake Park, and in forested areas around the University of British Columbia, *A. ater* populations consist entirely of the variety *aterrima* or *ater*, whereas urban gardens and vacant lots usually contain color varieties closer to *rufus*. Thus our area provides some support for the suggested rural-urban division.

The life cycle of *A. ater* in Vancouver is virtually identical to that described by Doucette (1954) for this species in Washington. The life cycle is also similar in Britain and Europe, so that many of the findings of Barnes (1944), Bett (1960), Quick (1949, 1960), and Smith (1966), can

be applied here. Quick (1949) observed that *A. ater rufus* matures later than *A. ater ater* in Britain, but we have not yet been able to corroborate that observation here.

Arion fasciatus (complex)

Chichester (1968) found evidence that *Arion fasciatus* was actually a complex of three species, *A. fasciatus* (Nilsson), *A. circumscriptus* Johnston, and *A. silvaticus* Lohmander. Because the three specific components were previously treated as a single entity, it is not possible to decide which records apply specifically to any one of them (Chichester and Getz, 1973).

Getz and Chichester (1971) record only *A. fasciatus* from British Columbia, stating that the only known records of *A. silvaticus* and *A. circumscriptus* are from northeastern North America. They note that *A. fasciatus* is by far the most abundant and widely distributed member of the complex in the Northeast (Chichester and Getz, 1973). In our survey, only *A. circumscriptus* and *A. silvaticus* were found in the vicinity of Vancouver. Either *A. fasciatus* has not yet been introduced into Vancouver, or the climate here has favored the other species. *A. circumscriptus* is the more abundant of the two species present. *A. silvaticus* is less numerous, occurring only in localized colonies.

The color forms of our *A. circumscriptus* and *A. silvaticus* conform to the descriptions in Chichester and Getz (1973), except that the local *A. circumscriptus* frequently share with *A. silvaticus* an abundance of white pigment flecks in the ventralmost rows of tubercles. The middle third of the epiphallus of *A. circumscriptus* is speckled with black, an apparently consistent character for separating it locally from *A. silvaticus*. We have observed only the black form of *A. circumscriptus* here.

Our observations show that previous local references to *A. circumscriptus* in British Columbia were correct. It was first recorded in British Columbia at Agassiz by R. Glendenning in 1937 (Pilsbry, 1948). It was probably present earlier, however, as Glendenning (1941) observed that it was already causing considerable damage by 1940.

Control measures against *A. circumscriptus* were necessary on carrots and beetroots at Agassiz in 1945 (Glendenning, 1945). Glen-

denning (1947) ranked this species with *D. reticulatum* as major pests in the lower Fraser Valley, and King (1949) believed it was the main pest species in 1948, when it attacked lettuce, sweet peas, peas and other crops. By 1949 it was also a pest on Vancouver Island (Glendenning and King, 1949). In 1955 it caused heavy losses of corn, beans, and potatoes near Chilliwack in the Fraser Valley (Fulton, 1955; Forbes *et al.*, 1956). In 1960 it damaged ornamentals, clover and truck crops, especially lettuce (Anonymous, 1961a).

The life history of the *A. fasciatus* complex in the field is not well known (Runham and Hunter, 1970). Chichester and Getz (1973) gave an account for *A. fasciatus* but not for *A. circumscriptus* or *A. silvaticus*. Rollo (1974) described the life cycle of *A. fasciatus* in Ontario. *A. circumscriptus* appears to be an annual species in Vancouver. Adults are present throughout the year, but young are found mainly in fall and spring. *A. silvaticus* overwinters successfully, but the remainder of its life cycle is still unknown.

Arion hortensis Féruissac

Although Carl and Guiguet (1958) suggested that *A. hortensis* might be present in British Columbia because it was already established in Washington, there has been no actual record of this species in British Columbia. *A. hortensis* is relatively uncommon in North America (Chichester and Getz, 1969, 1973), forming localized colonies mainly in the Pacific Northwest (Getz and Chichester, 1971). In Britain, however, *A. hortensis* is ranked with *D. reticulatum* as one of the most destructive slugs (Ellis, 1926; Miles *et al.*, 1931; Quick, 1949; Anonymous, 1959; Dunn, 1963; Stephenson, 1968). There is some cause for concern, therefore, in our finding that *A. hortensis* is very numerous throughout Vancouver and the adjacent districts of Burnaby and Richmond.

Some of its local populations in fact exceed those of all other species. In most places, however, *A. hortensis* appears to be about as numerous as *A. circumscriptus*. Because of its subterranean habit, populations are easily underestimated. After rain on June 3, 1975, 15 individuals were found within a 650 cm² area in a garden at 2585 W. 2nd Ave., Vancouver,

in which none could be found in drier weather.

Specimens found in gardens tend to be almost black dorsally with wide lateral bands reaching almost to the foot fringe. Those encountered in uncultivated areas are light brown in color, with narrower lateral bands. At Guelph, Ontario, both color forms were encountered in mixed deciduous woods and in marshy areas, indicating that the species is extending its range in Canada even where there is more severe weather than in the Pacific Northwest.

In the autumn of 1974, most of the recorded *A. hortensis* were adults, but by May, 1975, the majority were immature individuals. Eggs were observed in the field in early May. Thus, the species appears to be an annual one, breeding in fall and spring. Quick (1949, 1960), Hunter (1968), Stephenson (1968), and Chichester and Getz (1973) give some details of the life cycle.

Arion intermedius (Normand)

Distribution records of *A. intermedius* are summarized for the West by Hanna (1966) and for the East by Dundee (1974). The species was previously recorded only from California in western North America.

We found *A. intermedius* in two widely separated localities near Vancouver. On the U.B.C. Campus it was found near or in greenhouses, but it was also actively breeding outdoors, as its eggs were found under boards on October 18 and November 26, 1974. One specimen was also collected on the roadside of a rural area of Richmond in May, 1975. Both collection sites were short-grass habitats.

This slug is easily recognized by its small size, hedgehog appearance, and lemon-yellow slime. Some of our specimens had faint traces of dark lateral bands, whereas others lacked bands. Stephenson (1968) classed *A. intermedius* as an agricultural pest in Britain. It is typically a woodland and ecotonal animal (Chichester and Getz, 1973), however, and is not yet considered to be of agricultural importance in North America (Anonymous, 1961). Quick (1949, 1960), and Chichester and Getz (1973) gave details of its biology.

Arion subfuscus (Draparnaud)

A. subfuscus was reported from the Pacific

Northwest by R. T. Paine (Getz and Chichester, 1971). Except for one interception at Penticton in a shipment from Holland (Anonymous, 1962), the species does not appear to have been previously recorded from British Columbia. In Europe, *A. subfuscus* lives in mixed and coniferous forests, under dead wood and the bark of dead trees (Likharev and Rammelmeier, 1962; Quick, 1960), feeding mainly on fungus (Chichester and Getz, 1973). In north-eastern North America this slug readily enters woodland (Chichester and Getz, 1968), indicating an ability to become established throughout the forested areas of that region (Chichester and Getz, 1969; Getz and Chichester, 1971). In contrast, there has been no indication that *A. subfuscus* has been able to establish itself in forested regions of the Northwest (Getz and Chichester, 1971). We have now found *A. subfuscus* in the natural wooded areas surrounding the University of British Columbia. Specimens were discovered under the bark of cedar logs in coniferous woodland, and many individuals were also found under logs in a deciduous-coniferous area. Hundreds of eggs were discovered October 23, 1974, under logs in the coniferous area. Adults were found in the autumn of 1974 and in the spring of 1975.

Miss Susan Elliott (pers. comm.) collected *A. subfuscus* from a cultivated area at 58th Avenue and Cartier Street in Vancouver in May, 1975. This slug probably was first established here in the suburban gardens, being introduced later into adjacent woods when gardeners dumped garden refuse and compost in such areas. Such dumping offers a major means of dispersal for introduced species within the city of Vancouver.

The typical dorsal coloration of *A. subfuscus* is orange- to mahogany-brown, slightly darker in the mid-dorsal region. The sides are lighter, and the foot fringe may be white or yellow with distinct striations. Lateral bands may be present or absent. Tentacles range from light brown to black. Slime is always yellow to bright orange.

A. subfuscus is regarded as a pest in European U.S.S.R. (Likharev and Rammelmeier, 1962), and in Britain (Miles *et al.*, 1931). It has

not become a serious agricultural pest in North America (Anonymous, 1961b). However, Chichester and Getz (1969) stressed that it might have some impact on natural communities. Chichester and Getz (1973) should be consulted for details of biology.

Ariolimax columbianus (Gould)

A. columbianus is a native slug ranging from Alaska to California. In British Columbia it occurs west of the Cascade Range (Mead, 1942; Pilsbry, 1948). Hanham (1914) observed damage to a garden by *A. columbianus*, but it is usually restricted to forests and woodlands, rarely damaging gardens unless they are on recently cleared land (Spencer, 1961).

Dr. J. P. Kimmins (pers. comm.) believes that this species is a major herbivore in west-coast forests, where it eats the herb layer, especially bracken fern. One of his students, using radiotracers, estimated its maximum feeding rate as 53.01 ± 8.65 mg dry weight of leaves/slug/day (Fahlman, 1972). Introduced species which are invading uncultivated habitats may be having comparable effects. In 1961, Spencer reported that *A. columbianus* was the dominant species of slug in the natural settings of Stanley Park, Vancouver. However, we now find that *A. ater* is most abundant there.

In most localities, both the spotted and the uncolored forms of *A. columbianus* are common. Black individuals were found at Long Beach, Vancouver Island. Some of these individuals had a coalesced spotted pattern, but others were dark with overlying darker maculations. At Capilano Park, North Vancouver, several uniformly straw-yellow individuals were discovered. In California, there is a comparable color variety that has distinctive genitalia (Mead, 1942, 1943; Pilsbry, 1948), but the Capilano specimens were typical *A. columbianus* in all respects.

Mead (1942) observed dark necrotic areas on some individuals of *A. columbianus* which he suggested were fungus infections. Dr. H. R. MacCarthy (pers. comm.) discovered that such spots continued to develop when field-collected slugs were reared in isolation, thus reinforcing Mead's suggestion.

Adults of *A. columbianus* are found throughout the year, but young are mainly encountered in spring. Eggs were found as early as October by J. Spence in 1974 (pers. comm.), and Taylor (1889) observed that they were common under bark or logs during the winter on Vancouver Island. Details of the biology can be found in Mead (1942; 1943), Pilsbry (1948), and Westfall (1960).

Deroceras caruanae (Pollonera)

The only previous North American records of *D. caruanae* have been from California (Hanna, 1966) and Quebec (Getz and Chichester, 1971; Dundee, 1974). We found the slug in several parts of the campus of the University of British Columbia. Adults were present in the autumn and the spring.

This species closely resembles *Deroceras laeve* (Müller) externally, except that it is larger with better-defined spots on the mantle. Internally the black mesentery lining the body cavity and the unusual genitalia make it easy to recognize (Pilsbry, 1948; Ellis, 1967). Lange (1944) observed that it invades gardens in California in association with *D. reticulatum*, and Burch (1960) listed it as an economically important slug. Quick (1949, 1960) gives some details of its biology.

Deroceras laeve (Müller)

D. laeve is a native species found throughout North America (Pilsbry, 1948). It appears to be less common around Vancouver than in Ontario, although it is widely distributed in marshes, fields, woodlands and gardens. Isolated individuals are usually encountered, but large populations develop in greenhouses at the University of British Columbia, so that control measures must be routinely applied.

D. laeve has not been considered of economic importance in British Columbia, but elsewhere it has damaged seedling plants and tomato fruits that ripen near the ground (Fox and Landis, 1973). It may also do considerable damage in greenhouses (Chichester and Getz, 1973). Details of the biology of this slug may be found in Quick (1949, 1960), Getz (1959), Chichester and Getz (1973), and Rollo (1974).

Deroceras reticulatum (Müller)

Older literature referred to *Deroceras reticulatum* (Müller) as *Agriolimax agrestis* (L.), a species with a more limited distribution (Quick, 1960; Chichester and Getz, 1973). Since both species have been found in North America (Grimm, 1971), dissection is necessary for proper identification. Ellis (1967) gives characters and figures for separating *D. reticulatum*, *D. agrestis*, *D. laeve*, and *D. caruanae*.

No *D. agrestis* has been encountered in Vancouver. *D. reticulatum* is the most abundant single species and also the most economically important slug in British Columbia. Taylor (1889) first recorded this species in British Columbia at Victoria. He observed that it was present around 1886 and that it was a "dreadful pest" in gardens by 1891 (Taylor, 1892). In 1921, Glendenning (1923) observed much damage to corn in the Fraser Valley which was probably due to *D. reticulatum*.

Many reports of slug damage do not specify which species is involved. Most of our local reports of slug damage can be attributed at least partially to *D. reticulatum*, however, as it is as dominant here as in western Washington, where Howitt and Cole (1962) estimated that it comprised 60% of the slug population.

In the appropriate environment, slugs can be very destructive. Lovett and Black (1920) estimated that slugs (mostly *D. reticulatum*) caused more damage to truck crops in the Pacific Northwest than any single species of garden insect. In certain areas of New Brunswick in 1936, slugs caused more loss to the potato crop than the combined activities of all potato insects (Anonymous, 1937). Severe damage to field corn occurred in Ohio in 1968 and 1969 (Musick, 1972), and H. Gerber (pers. comm.) notes that appreciable acreage of corn in British Columbia has also been lost to slugs, especially where there are weeds. Up to 50% damage to potatoes (Anonymous, 1943), 25% damage to lettuce (Anonymous, 1948) and 10% damage to tomatoes (Nielson and Handford, 1955) have been reported here. On Vancouver Island, vetch plantings have been almost totally destroyed (Anonymous, 1947). Up to 75% damage to sweet corn, bush beans and

strawberries occurred in Washington (Hanna, 1966; Anonymous, 1968), and clover can be destroyed within a single growing season in the Pacific Northwest (Howitt, 1961).

Adult *D. reticulatum* can be found throughout the year in the Vancouver area, but most eggs are laid in the spring and autumn. Adults which we brought into the laboratory in the spring often died after laying eggs, and they probably also die after depositing spring eggs in the field. More details of the biology of this species are given in Lovett and Black (1920), Hawley (1922), Carrick (1938, 1942), Stephenson (1968), Judge (1972a), and Rollo (1974).

Limax maximus Linnaeus

The first record of *L. maximus* in western North America was from San Diego (Orcutt, 1890). Henderson (1929) includes a record from Salem, Oregon. Pilsbry (1948) does not list *L. maximus* from British Columbia, but it was already a pest in the Fraser Valley in 1947 (Glendenning, 1947). In 1960 it caused damage in gardens in the Vernon district (Arnott and Arrand, 1961). Spencer (1961) found it in a Vancouver garden, but it was much less abundant than *A. ater*.

L. maximus now appears to be as widely distributed as *A. ater* in the Vancouver area. Pilsbry (1948) and Chichester and Getz (1973) stated that it was not found in woods or anywhere far from human habitation in North America. However, we have found it in small numbers in forests at Cultus Lake park and in wooded areas and fields not closely associated with dwellings around Vancouver. Adults and immature specimens were found in the autumn of 1974 and the spring of 1975. There appears to be some reduction in the adult population by June.

Nightly observations in a garden revealed that particular individuals ate the same kind of food repeatedly, some taking only compost, and others green plants. Over a two-month period one individual was observed to eat only dog faeces, whereas others were feeding on green plants. White (1918) found that individuals of this species only changed their diet slowly unless starved, and Gelperin (1974) believes that

learning is involved. If so, repellents may be effective in protecting garden plants.

L. maximus is extremely variable in color. The mantle may be mottled or spotted, and the body may be spotted or striped. More rarely an individual is uniformly dark brown. The photograph which Wilkinson (1964) refers to as *A. ater* is probably a unicolored *L. maximus*. Pilsbry (1948), and Quick (1960) give more details of the biology of this species.

Prophysaon andersoni (Cooper)

P. andersoni is a native species which ranges from California to Alaska (Hand and Ingram, 1950). In late summer it frequently becomes a garden pest in British Columbia (Glendenning, 1952), and it is also a pest in Oregon and California (Lovett and Black, 1920; Runham and Hunter, 1970).

This species is common on the University of British Columbia campus. In spring, only immature specimens were encountered, whereas in late summer and fall, all individuals were large. Although it may become a garden pest, it is more abundant in forests and woodlands.

MISCELLANEOUS OBSERVATIONS

British Columbia appears to be a particularly favorable region for slugs, so that several other species could become established here. In fact, *Limax flavus* Linnaeus was recorded earlier from North Vancouver by W. M. Draycott (Hanna, 1966). However, we found no specimens during our survey, nor any later reference to this slug in British Columbia. It is common in California (Hanna, 1966) and is now present in Oregon (Crowell, 1967).

Glendenning (1952) and Wilkinson (1964) observed that *Milax gagates* (Draparnaud) was widely distributed but mainly confined to greenhouses. We found no specimen of this species in the Vancouver area. It is very destructive in California (Lange, 1944; Hanna, 1966) and in Oregon (Lovett and Black, 1920), and should be considered a potential threat to the Vancouver area.

Another slug which could become economically important if introduced is *Lehmannia valentiana* (Férussac). This species is very destructive in California where it may be as abundant as *D. reticulatum* (Gregg, 1944).

Establishment of these species around Vancouver may be limited because of our cooler winters. For example, Howe (1972) found that *L. valentiana* was killed by winter in Manitoba and so was limited to greenhouses there.

We examined the Canadian Insect Pest Review and its successor, the Canadian Agricultural Insect Pest Review, for records of slugs in British Columbia for the period 1930-1972. The records show that in general slug damage has been reported very locally and sporadically. This sporadic occurrence is the main reason there has been slow progress in slug control (Judge, 1972b). Damage has been widely distributed in British Columbia, ranging from Vancouver Island and the Fraser Valley to the Okanagan Valley and Prince George. Outbreaks have occurred in wet seasons, especially in consecutive wet years. In consecutive dry years, damage has been restricted to irrigated, low lying, or poorly managed areas. Damage suddenly increased after the introduction of *A. circumscriptus*, and again with the appearance of *A. ater*. Spencer (1961) stated that introduced slugs were approaching outbreak proportions in Vancouver, and damage reports from previously untroubled areas attested to the dispersal of the pests inland.

The official reports, combined with a list from Banham and Arrand (1970), show that at least 26 crops have been attacked in British Columbia. The more important of these are corn, potatoes, lettuce, cabbage, beans, peas, strawberries, tomatoes and clover. In addition, the extent of damage to horticultural crops may exceed field- or truck-crop damage (Runham and Hunter, 1970).

It appears that an introduced species can become a pest within ten years, so that any new introduction is potentially dangerous. Crop damage by slugs can be expected to increase in severity in British Columbia as new species become established, and the recently established species continue to disperse.

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

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ABSTRACT

Twelve species of postlarval mollusks were found among fouling organisms collected from a navigation buoy. Length data for the three most abundant species, Placopecten magellanicus, Anomia aculeata,¹ and Mytilus edulis, were analyzed in an attempt to explain normal and log-normal frequency distribution patterns. Molluscan community relationships on the buoy were closely observed and reported. The ocean bottom under the buoy was sampled by dredge, and the population composition of mollusks on the bottom did not include the postlarval forms found on the buoy.

INTRODUCTION

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

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

Immediately upon launching, buoys become attractive bases for colonization by marine organisms. The organisms which settle, survive, and grow are, for the most part, species which are able to attach themselves securely. When the buoy is returned for cleaning and servicing, the entire community of organisms can be conveniently observed and sampled. The outside buoy surfaces are subjected to strong tidal currents and wave action, which restrict at-

tachment to those organisms with the most tenacious holdfasts. The inside of the stabilizer tube (Fig. 1) offers a more sheltered environment with considerable, but gentler, water exchange as the buoy surges up and down. Here are found the densest populations, and here the struggle for space is readily observed (Merrill, 1965).

METHODS

The collection was taken from the Nantucket Shoals Lightship (NSLS) buoy. The buoy was

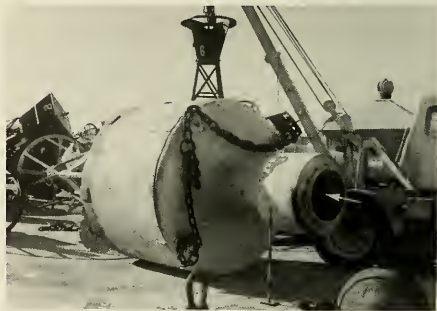


FIG. 1. Typical navigation buoy. Arrow indicates the sheltered, inner portion of the stabilizer tube.

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

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

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

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

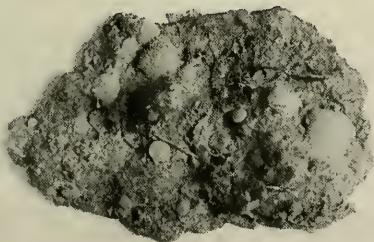


FIG. 2. A piece of iron rust removed from within the stabilizer tube of a buoy. The material dried slowly and a number of organisms can be seen adhering in their original positions.

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

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

Several of the smallest scallops from the buoy measured as little as 0.5 mm. The prodissoconch measured about half this size, so these smallest specimens had approximately doubled in size since settling. To our knowledge, these are the smallest metamorphosed sea scallops ever collected⁵.

After death, the ligamental structure in the hinge of the scallop continues to hold the valves together, but gaping. In this condition, sea scallop valves tend to tangle in filamentous bryozoa or amongst the byssal threads of the

TABLE 2

	Number of specimens	
	Live	Dead
Gastropoda		
<i>Colus pygmaea</i> Gould	1	5
<i>Nassarius trivittatus</i> Say ¹	8	3
<i>Buccinum undatum</i> Linnaeus	62	60
<i>Lunatia heros</i> Say	74	64
<i>Crepidula plana</i> Say ²	78	0
Pelecypoda		
<i>Placopecten magellanicus</i> Gmelin ³	6	1
<i>Arctica islandica</i> Linnaeus ⁴	8	125
<i>Ensis directus</i> Conrad ⁴	0	5
<i>Astarte castanea</i> Say	2	0
<i>Venercardia borealis</i> Conrad	5	0
<i>Modiolus modiolus</i> Linnaeus	1	1
<i>Anomia simplex</i> d'Orbigny	1	0
<i>Spisula solidissima</i> Dillwyn ⁴	9	1

¹ This species had deposited numerous egg cases on the interior of practically every dead valve of the mahogany clam (*Arctica islandica*).

² Found attached inside large dead shells, usually *Lunatia heros*.

³ The heights of these in millimeters were 59.9, 85.2, 117.8, 131.7, 157.4, 164.7; one upper valve, 28.2.

⁴ The animal lives in the substratum, consequently not adequately collected by the type of dredge used.

⁵ We have since taken from buoys scallops as small as 0.3 mm, the prodissoconchs having barely a fringe of dissoconch growth.

mussels. There were 233 dead specimens of scallops in the total population, the mode at about 2.0 mm. Size-frequencies for the dead and live scallops (Table 1) show similar curves which suggests that valves do not remain long in the buoy after death. The pint sample contained 214 dead mussels (Fig. 3, dotted line), many of them of smaller size. In fact at about 1.2 mm, more dead than live mussels were counted. Some of these were found trapped in aggregates of mussels, while many were found partly or completely buried in the light layer of fine silt and debris that builds up in the buoys. The great mortality in the smallest mussels occurred over a period of time, judging from the various degrees of shell decomposition observed. The top and bottom valves of *A. aculeata*¹ soon separate after death and shell remains are quickly flushed from the buoy; hence, dead specimens are rarely found.

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

¹Abbott in the second edition of *American Seashells* (1974, p. 452) follows Winckworth, 1922, and others, in calling this species *squamula* Linné, 1758.

²Temperature records for the time and locality involved in this study are available in published form (Day, 1958a; 1959b).

In Milford Harbor, Connecticut, spawning of *M. edulis* is restricted to those months when the temperature is approaching and above 60°F² (Engle and Loosanoff, 1944). In "Marine Fouling and Its Prevention" (Woods Hole Oceanographic Institution, Contribution No. 580, 1952), early to late June is indicated as the beginning of the breeding season for *Mytilus* at Woods Hole, Massachusetts. *Mytilus* larvae, then, must have been in the water after the buoy was placed on station, and, because of the low temperatures that prevailed, there could have been no further sets in the spring before the buoy was taken off station. No spawning information is available for *A. aculeata*, but the size-frequency distribution suggests that the spat of this species settled about the same time as the other two species.

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

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

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

	Average	Maximum
<i>Placopecten magellanicus</i>	2.9 mm	13.2 mm
<i>Mytilus edulis</i>	3.9 mm	24.5 mm
<i>Hiatella arctica</i>	3.7 mm	9.5 mm
<i>Anomia aculeata</i>	4.5 mm	13.2 mm

The averages represent shell growth for 6 to 7 months after setting, and during the coldest months of the year. The maximum sizes attained are an indication of the amount of growth that can be achieved under the existing conditions.

The location of the NSLS buoy is such that pelagic bivalve larvae could be transported from many coastal areas, and this could effectively extend the setting season. The currents that sweep over Nantucket Shoals undoubtedly carry planktonic larvae originally spawned in many different estuaries and bays of the Massachusetts coast, as well as from a large area of the Gulf of Maine. It seems most reasonable to suggest that, for *Mytilus* at least, the peak of setting may have occurred for several weeks af-

ter the buoy was on station. Initial settlers would have had less competition from their own kind, as well as a warmer and longer period in which to grow.

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

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

The sea scallop size-frequency is well fitted by a log-normal transformation, as can be seen

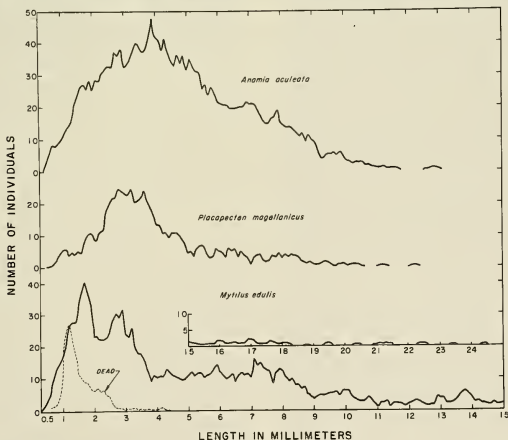


FIG. 3. Size-frequency distribution of the three common mollusk species found on the Nantucket Shoals Lightship buoy (1-pt subsample).

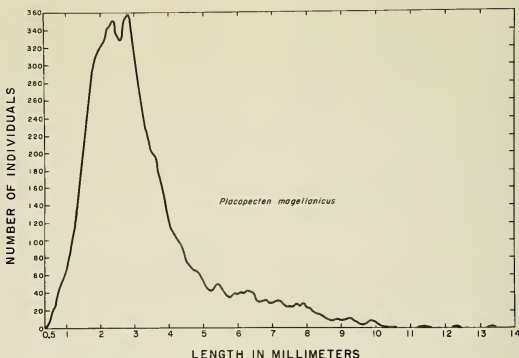


FIG. 4. Size-frequency distribution of the sea scallops found on the Nantucket Shoals Lightship buoy.

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

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

RESULTS

Three species of pelecypods - the sea scallop, *Placopecten magellanicus*, the jingle shell, *Anomia aculeata*, and the common, blue mussel, *Mytilus edulis* - dominated the community found on the buoy. Because the two latter species were so numerous, a 1-pt subsample (of the 12-pt total sample) was taken and all specimens were counted and measured. The length-frequency distributions obtained of the

three most common mollusks are shown in Figure 3. As a check on the validity of this subsample, all molluscan species in the total sample, except the numerous *A. aculeata* and *M. edulis*, were also counted and measured.

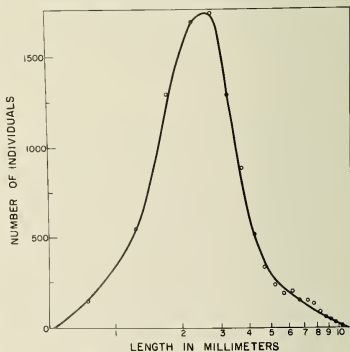


FIG. 5. Size-frequency distribution of the sea scallops found on the Nantucket Shoals Lightship buoy plotted on semilogarithmic paper to produce the symmetry of a log-normal curve.

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

Species	Size (mm)											Total		Range in size mm
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Live	Dead	
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	
GASTROPODA														
<i>Mitrella lunata</i> Say		4	13	12	12							41	3	1.4-4.6
<i>Lacuna neritoides</i> Gould	7	6										13	1	0.3-1.8
<i>Spiratella lesueuri</i> D'Orbigny		2										2		1.7
<i>Anachis awara</i> Say		1										1		1.4
Unidentified	2											2		0.3
PELECYPODA														
<i>Placopecten magellanicus</i> Gmelin	148	1,845	3,433	2,174	868	425	371	275	154	86	27	9,806		0.5-13.2
<i>P. magellanicus</i> (dead)		118	84	23	4	1	2	1						2.0-6.9
<i>Anomia aculeata</i> Gmelin	396	2,400	3,900	4,608	4,452	3,516	2,472	2,160	1,500	732	468	26,604	108*	0.5-13.0
<i>Mytilus edulis</i> Linnaeus														0.4-24.3
<i>M. edulis</i> (dead)	204	1,800	396	60	24	48	12	12	12					0.4-8.3
<i>Hiatella arctica</i> Linnaeus		4	14	14	6	5	3	1		1		48	2	1.1-9.3
<i>Anadara ovalis</i> Bruguiere			1									1		2.5
<i>Tellina agilis</i> Stimpson	1											1		0.9
<i>Periploma papyratum</i> Say		1										1		1.1
												55,120	2,915	

*Calculated from 1/12 aliquot of total sample.

Figure 4 shows the frequency distribution of *P. magellanicus* found in the total sample.

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

The mussel produces a stout and intricately woven byssus, and the jingle shell a short thickened byssal plug, both of which are capable of holding shell remains securely to a substrate after drying. The thin byssal threads of scallops become brittle upon drying and break easily. Therefore, the size-frequency data presented in Figure 3 for the mussel and jingle shell are possibly more representative of the total sample than for the scallop. Proportionally, there were fewer small *Placopecten* in the pint subsample than in the total sample, and the mode was about 0.5 mm higher. Apparently, some of the smaller scallops settled to the bottom of the original scrapings before the

aliquot was obtained. However, aside from these minor differences, the scallop size-frequency distribution in the aliquot (Fig. 3) is similar to that in the total sample (Fig. 4).

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

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

DISCUSSION

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

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

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

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

SUMMARY

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

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

3. The population structure and the interrelationships of species in the mollusk community were closely observed. Methods of attachment and distributional patterns, par-

ticularly patterns of preference in utilizing surface area, are discussed in some detail.

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

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

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

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DISTRIBUTIONAL AND ANATOMICAL OBSERVATIONS OF *BERTHELLA TUPALA* (OPISTHOBRANCHIA: NOTASPIDEA)

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ABSTRACT

Berthella tupala occurs on the Caribbean coast of Panama, in addition to Florida, Puerto Rico, and Brazil. Scanning electron micrographs illustrate the morphology of the internal shell and radular teeth, and the development of the jaw platelets.

DISTRIBUTION

The occurrence of *Berthella tupala* Marcus, 1957, has been reported only rarely, but from greatly separated areas of the Caribbean zoogeographic province. It is known from São Paulo and Rio de Janeiro, Brazil (Marcus, 1957); Puerto Rico (Marcus and Marcus, 1970); and the southern tip of Florida, U.S.A. (Marcus and Marcus, 1967). On August 28, 1974, I found one specimen of *B. tupala* under a rock on the Galeta reef flat, Panama Canal Zone (9° 24' N; 79° 52' W). This is the first record of this species from the Caribbean coast of Central America, and represents a range extension of over 1500 km from the closest previously published locality.

ANATOMY

Externally, the 5-mm specimen matched the coloration pattern described by the Marcuses: yellowish, with a central, white T-shaped marking, and additional white specks scattered over the notum.

Shell. The strongly calcified shell was quite prominent, covering almost the entire main body of the slug internally. The nuclear whorl is clearly visible, but lacks the sculpture pattern of growth rings and longitudinal lines that are prominent on the rest of the shell (Fig. 1). Irregularities of the sculpturing can be seen to increase in the newer portions of the shell; figure 63 of Marcus (1957) is probably a drawing of these more peripheral regions.

Radula. There are three different shapes of teeth in each radular half-row. The outermost

laterals are erect, with a smaller accessory cusp (Marcus, 1957). Central laterals from the middle of the half-row are simple hooks with a long, thin base (Fig. 2). Marcus and Marcus (1967, 1970) have reported that the innermost tooth of each half-row has a basal denticle. Close examination of scanning electron micrographs of the center of the radula (Figs. 3 and 4) of our Panama specimen shows that at least the first three inner lateral teeth have a basal denticle, not just the innermost one.

Jaws. Marcus and Marcus (1967) state that the jaw platelets of *B. tupala* have 0-5 denticles on either side of the tip; the specimen I collected in Panama had no denticles. However, of special note, are the developmental stages of the platelets visible in different parts of the jaw. The base and about one-third of the tip above the lateral flanges form first (Fig. 5). In this earliest stage, the tip is not yet free, and terminates in two antero-lateral points separated by a deep concavity. Further growth results in a lengthening of the tip, and a relative straightening of the distal margin (Fig. 6). The final shape of the platelet (Fig. 7) is brought about by additional lengthening in the central portion of the tip, creating the convex, unattached distal tip.

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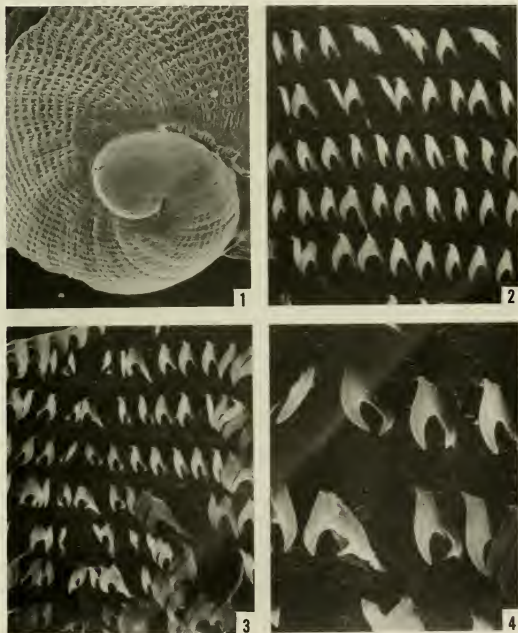
the field, and to Mrs. Emily Reid for help with preparing the illustrations. My research in Panama was supported by a fellowship from the Smithsonian Tropical Research Institute.

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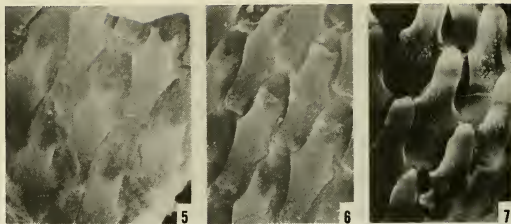
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FIGS. 1-4. Scanning electron micrographs of the shell and radular teeth of *Berthella tupala*. FIG. 1. Embryonic whorl of shell, 78X. FIG. 2. Teeth from middle of half-row, 470X. FIG. 3. Innermost lateral teeth, 470X. FIG. 4. Accessory denticle on innermost lateral teeth, 1565X.



FIGS. 5-7. Three areas from jaw platelets of *Berthella tupala*, showing developmental stages; all scanning electron micrographs, 720X.

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