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INDEX TO THE NAUTILUS

An index to The Nautilus, both author and subject matter, will appear every five years. The first index to cover the new format will be issued separately at the completion of volume 90 in early 1977. It will cover volumes 86 through 90 (1972-76). An accumulative index is tentatively planned in 1986 to cover volumes 61 through 100.

RECENT PUBLICATIONS

Boss, K. J. and M. K. Jacobson. 1973. Monograph of *Ceratodiscus* (Archaeogastropoda; Helicinidae). Occasional Papers on Mollusks, Harvard Univ., vol. 3, no. 45, pp. 253-279, 4 pls. Three species of this operculate land snail from the Greater Antilles are well treated. $1.40.

Boss, K. J. and M. K. Jacobson. Sept. 1973. Monograph of the Genus *Alcadia* in Cuba (Mollusca: Prosobranchia: Helicinidae). Bull. Mus. Comp. Zool., Harvard, vol. 145, no. 7, pp. 311-358, 6 pls. The genus is fully treated, with a new subgenus *Glyptalcadia* and a new subspecies, *A. bermudezi jatibonica* from Las Villas, Cuba.

Johnson, Richard I. 1973. Distribution of Hydrobiidae, A Family of Fresh and Brackish Water Gastropods, in Peninsular Florida. Occ. Papers on Moll., Harvard Univ., vol. 3, no. 46, pp. 281-303. The late Tertiary topographical history of Florida is interpreted from present-day hydrobiid mollusks, refuting some of F. G. Thompson's 1968 interpretations. $1.20.

Stern, Edward M. 1973. The *Ashmunella rhyssa* (Dall) Complex (Gastropoda: Polygyridae): Sierra Blanca — Sacramento Mountains, New Mexico. Science Series No. 5, Univ. of Texas at El Paso, VII & 57 pp., 18 text figs., 1 pl. $2.00.

Ruhoff, Florence A. 1973. Bibliography and Zoological Taxa of Paul Bartsch [1871-1960], with a Biographical Sketch by Harald A. Rehder. Smithsonian Contributions to Zoology, no. 143, pp. v + 166. Excellently done and extremely useful. $2.85 postpaid, Smithsonian Institution Press, Wash. D. C.

Kaicher, Sally D. Oct. 1973. Card Catalogue of World-wide Shells. Marginellidae, pack no. 1, 97 cards. A useful and novel set of 3x5-inch cards, each bearing good black-and-white photographs, identification, marine province and short notes on colors and habitats. $3.00 per pack (postpaid), foreign $4.00 (airmail postpaid). Sally D. Kaicher, 5633B 18th Way South, St. Petersburg, Fla. 33712.

THE RELIGIOUS USE OF *TURBINELLA PYRUM* (LINNAEUS), THE INDIAN CHANK

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ABSTRACT

The Indian chank, Turbinella pyrum *(Linnaeus), has played an important role in Indian religion and art for centuries. Hundreds of years before the birth of Christ, chanks were in use in the Indus Valley civilizations. Chank sections and bangles served as ornaments and jewelry in many parts of India in the early Christian era. The earliest utilization of chanks as amulets and religious objects dates back nearly two millenia. Sinistral ("left-handed") specimens are very rare and have received the greatest veneration. Various Hindu gods have been associated with the chank; the most prominent of these is unquestionably Vishnu (or his incarnation Krishna), who is so often affiliated with the chank that it has become a reliable symbol of him. References to chanks, especially those modified as trumpets, are numerous in Hindu legends, and sacred writings such as the* Bhagavad Gita. *Some authors have suggested that Hindu influence may be responsible for similar reverence of large gastropod shells by the Aztecs.*

It is well-known that shellfish and seashells have long been significant items to the peoples of the Indian subcontinent. The early Hindus grouped crabs and mollusks under the name *kambustha* and used the cleaned shells as ornaments and amulets. Some shells, such as cowries, have served as money in parts of India (as well as throughout the Indo-Pacific region) for centuries in the past. Such uses as these have occurred in many cultures and have not necessarily been restricted to one or a few species.

The Indian chank, *Turbinella pyrum* (Linnaeus) 1758, is an example of an unusual instance in which one molluscan species has acquired a very special religious significance. The chank attained its prominence as a symbol of the Hindu god Vishnu, who is often portrayed holding a sinistral chank in one of his four hands. It is recognized particularly as an emblem of Krishna, the most important avatar of Vishnu; but the chank is sometimes associated with other Hindu gods. The basis for the chank's religious significance can be traced to many Hindu legends, as will be shown below. Some preliminary remarks on the classification,

FIG. 1. *Map of the Indian subcontinent.*

natural history, and ornamental uses of the species will be discussed first.

The controversy over the proper nomenclature for the Indian chank has been reviewed recently

(Vokes, 1964) and is summarized here. The chank was first named by Linnaeus (1758), who coined the binomial *Voluta pyrum* for the species. Lightfoot (1786) listed the name *Voluta ponderosa* for a sinistral ("left-handed") specimen of the Indian chank, but the name is unnecessary and invalid, for it refers to the same species described by Linnaeus. Later students discovered that this species had been incorrectly placed in the genus *Voluta*. The genus name *Xancus* first appeared in reference to the Indian chank in Roding's Bolten Museum Catalogue (1798), but this reference was rather obscure until the early part of the twentieth century. Therefore, Lamarck's (1799) name *Turbinella* became widely known and was applied to the Indian chank by most authorities (e.g. Hornell, 1916) for more than a century. More recently, the name *Xancus* returned to use, due to a ruling on priority by the International Commission on Zoological Nomenclature (Opinion 96, 1926); but a later Opinion of the Commission (Opinion 489, 1957) reversed the 1926 ruling, formally suppressing the name *Xancus* and requiring use of the name *Turbinella*. *Turbinella pyrum* is a member of the family Vasidae.

Turbinella pyrum occurs commonly in the Bay of Bengal off the Indian coast and in the vicinity of the Andaman Islands, and in the waters surrounding Ceylon, particularly the Gulf of Mannar (Hornell, 1913, 1916, 1951). The Andaman Islands form is often regarded as a distinct subspecies, *Turbinella pyrum fusus* Sowerby 1825; it is characterized by its high spire and angular shoulder. Other subspecies have been described (see, for example, Hornell, 1916) but most of these have not achieved universal acceptance. Like the majority of gastropods, the shell of *Turbinella*
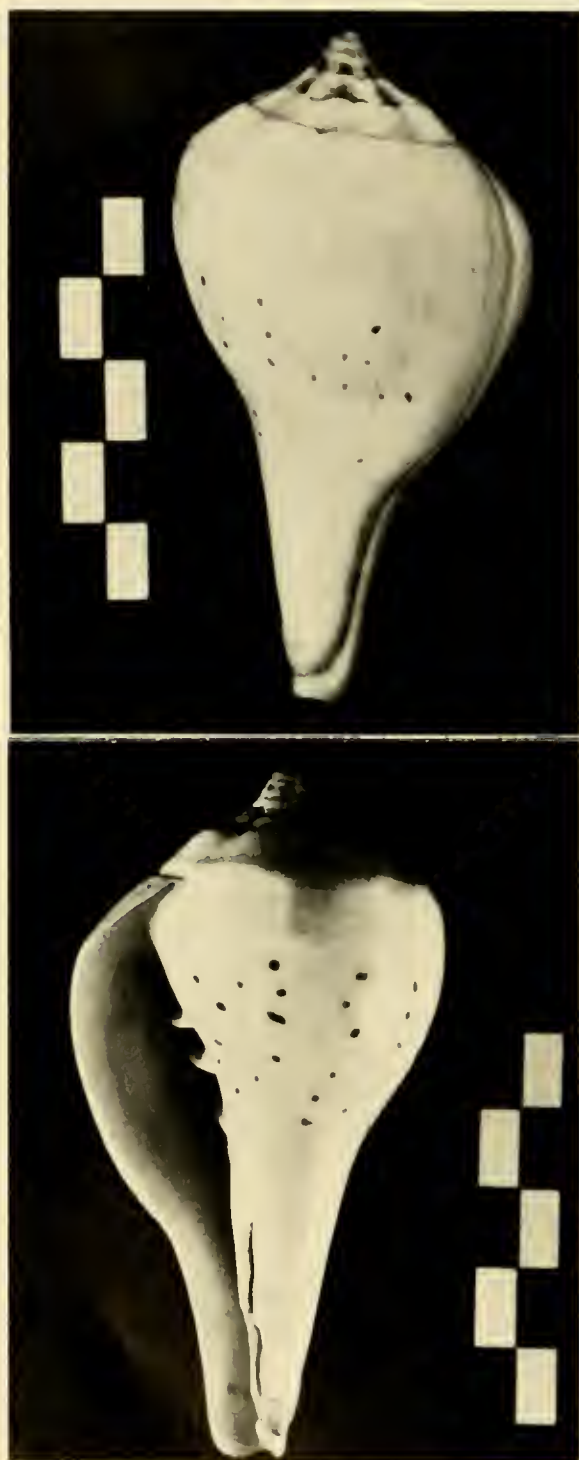
FIG. 2. *A rare sinistral specimen (MCZ no. 249020) of the Sacred Indian Chank,* Turbinella pyrum *(Linnaeus) (=* "Voluta ponderosa" *Lightfoot, no. 4023 in the Portland Catalogue). This prized specimen, once in the collection of the Duchess of Portland, is from the Trincomali Coast of India. It was purchased for the Museum of Comparative Zoology about fifteen years ago, as part of the collection of Mrs. Fiske Warren. (Scale is in centimeters.)*

pyrum is typically dextral ("right-handed") but, as noted above, rare sinistral specimens have been recorded. It is the latter that have achieved the highest veneration.

The cleaned shell of the Indian chank is heavy and porcelainlike, a factor which contributes to its popularity and utility in jewelry and ornamental work. It is usually white or cream-colored, or rarely pinkish. In life, the shell is covered with a thick, light-brown periostracum, which may function to some degree to protect the shell from boring sponges. The animals are gregarious and are frequently found in large numbers on sand in relatively shallow water, up to ten fathoms deep. They feed chiefly on tube worms (Hornell, 1951). An interesting account of the breeding and larval development of *Turbinella pyrum* is presented by Hornell (1951, pp. 24-25).

The use of the chank as an ornamental or religious object, although prevalent today, was perhaps more popular in the past. Bangles cut from the shell were widespread in India in ancient times, and have been the center of a small industry in more recent times. Chanks have been found in the excavations of the Indus Valley civilizations, which date back to centuries before the birth of Christ. They may have been collected from the Persian Gulf at that time. Chank sections were used in inlay patterns (e.g., petals, rosettes, crosses) in northwestern India over two thousand years ago, but examples are quite rare (Agrawala, 1965).

Important bangle workshops were located from Tinnevelly in the south to Kathiawar and Gujarat in the northwest, during the reign of the Pandyan kings in the early Christian era. *"Maduraikkanchi"*, a Tamil poem of the second or third century A. D., describes the *parawas,* men who dived for pearl oysters and chanks. In fact, the *parawas* are still active today (N. Hein, personal communication). Another Tamil poem, attributed to the reign of the Pandyan King Nadunj Cheliyan II (second century A. D. ?), mentions sectioning chanks for use as bangles (Hornell, 1913).

In north-central India, as early as the first or second century A. D., there is evidence indicating that the religious significance of the chank was already established. Terracotta seals from Rajghat, near Benares, associate Vishnu with religious emblems including the wheel, spear and chank.

The chank again appears in slightly later seals and seal impressions from the early Gupta Period (fourth century A. D.) at Basarh and Rajghat. Inscriptions on some seals from Basarh and Bhita reveal associations of the chank with the god Siva and the goddess Laksmi, consort of Vishnu (Banerjea, 1941). Chanks also were "extensively used in wars by ancient Indians" (Bhattacharyya, 1958, p. 438), supposedly to inspire warriors and to frighten away the enemy. Indeed, the veneration of the chank by Hindus has evolved in large part from legends of its use as a war trumpet by the god Krishna.

In more recent times, chank fisheries in India and Ceylon have gathered as many as two or three million chank shells per annum. Additional subrecent shells are excavated from the silt beds of the Jaffna Lagoons in Ceylon. Chanks have been sent to Calcutta and Dacca to be sectioned for use as bangles by Hindu women of all castes. In this century, chank bangles have been most popular in Bengal and surrounding states (Hornell, 1913, 1951). Not very long ago, the chank apparently

FIG. 3. *A normal (dextral) specimen of* Turbinella pyrum *(MCZ no. 235923). (Scale is in centimeters.)*

achieved status as a good-luck charm in the Tamil districts of Madras. Whole shells and circular, hollowed sections worn as bracelets were used as amulets by some people, to (in the words of Hornell, 1913, p. 410) "protect them against the baneful influence of the evil eye." Hornell (1913) also r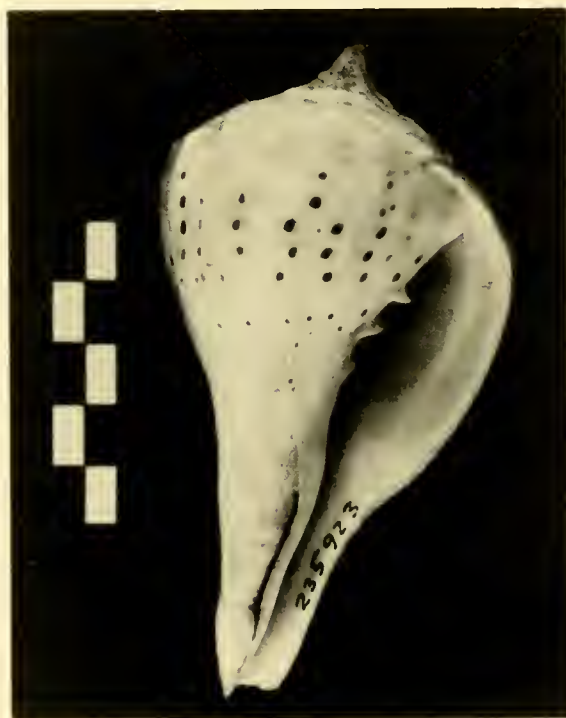eported their use as ornaments on the forehead of draught bulls in southern India. As religious objects chanks, which may be modified as trumpets, are often seen in Hindu temples; and they have been used in recent times in place of bells to initiate worship of the god Siva (N. Hein, personal communication).

Chanks, especially sinistral specimens, have been of importance not only to Hindus, but also to Buddhists. According to Hornell (1951), sinistral shells have been mounted in silver in some Tibetan lamaseries; and the value of "left-handed" chanks was once considered to be their weight in gold. The chank has been associated with the Buddhist deities Sagaramati and Gandhahasti (Bhattacharyya, 1958).

In the Hindu pantheon, Vishnu (or his incarnation Krishna) is the deity most often affiliated with the chank - so often, in fact, that the chank has become a reliable symbol of Vishnu. Other Hindu gods, however, are occasionally shown in connection with a chank. For example, Siva is sometimes depicted with a chank in his hand (Jackson, 1916); Kubera, the corpulent god of wealth, may be portrayed with his foot resting on a chank (Rubel, 1968).

The association of the chank with Krishna derives from the sacred Hindu poem *Bhagavad Gita* ("The Song of the Blessed One"), which forms a part of the great Hindu epic *Mahabharata*. Although the *Bhagavad Gita* was evidently not included in the original epic, and may have been written at a later date (Edgerton, 1964), it has for centuries been considered an integral part of the *Mahabharata*; it is unquestionably one of the most highly regarded of all Hindu sacred scriptures. The *Bhagavad Gita* itself is a dialogue (between Krishna and Arjuna, a warrior) in which major Hindu doctrines are expounded; while the main theme of the entire *Mahabharata* concerns a battle. Frequent references to the impending battle appear throughout the *Bhagavad Gita*, and it is in these that the chank is of paramount importance. The Sanskrit term *śankha*, usually translated simply as "conch",

is almost certainly a reference to the Indian chank.

In Chapter 1 of the *Bhagavad Gita*, each warrior preparing for battle can be recognized by his personal conch, which is distinctive in color, size, and sound (Walker, 1968). In Chapter 1, verse 12 (Edgerton, 1964, 1:12), we read "The aged grandsire of the Kurus . . . blew his conch-shell, in full valor." Conch trumpets were sounded before the battle, and Arjuna and Krishna blew their conchs (Edgerton, 1:13-14). King Yudhisthira blew his conch, named *Anatavijaya;* it was a long, slender yellow shell, with a mellow tone. Nakula's conch, *Sughosa,* was large, heavy, and gray, and it produced a neighing sound. Sahadeva possessed a long, slender, pink chank called *Manipuspaka* ("little jewel-flower"), which emitted a mooing sound (Edgerton, 1:16). Arjuna's chank was named *Devadatta,* "god-given" (Edgerton, 1:15). The most important conch of all belonged to Krishna. It was a small, slender, sweet-sounding shell, called *Panchajanya* (Walker, 1968).

According to legend, Krishna obtained his sacred shell in a confrontation with the demon Panchajana. In one version of the myth (Munshi, 1963-1965) Panchajana, an evil member of a seagoing tribe, wore a beautiful pink conch over his shoulder. Krishna noticed the demon's shell and remarked " 'I will take this conch. I have never seen such a thing of beauty, nor heard such wonderful tones. I shall call it *Panchajanya,* the gift of Panchajana' " (Munshi, 2, p. 60). In another interpretation of the same legend (Walker, 1968), Panchajana lived in a shell at the bottom of the sea. Krishna pursued the demon and slew him, and used his shell for a trumpet.

A different legend describes the chank as one of fourteen jewels (*chaturdasa-ratnam*) which emerged from the "churning of the ocean", a major event in the epic confrontation between the gods and the demons. The chank was taken by Vishnu, but it was soon stolen from him by the shell demon, *Śankāsura.* Vishnu slew the demon, however, and recovered the conch, dedicating it to his own service. Thus chanks are blown in temple worship in modern time (Walker, 1968).

Numerous other allusions to chanks in Hindu lore clearly associate them with Krishna. In the *Krishnavatara,* Krishna blew his chank trumpet to challenge the Rakshasa demons to battle; but the

sound served to summon his friends, while scaring the demons to flight (Munshi, 3 pp. 189-200). Another tale relates Krishna's meeting with the King of Karavirapura. The deity arrived in a chariot, blowing his chank trumpet to greet the king (Munshi, 2, pp. 175-182). The Leelas of Krishna, stories adapted from the *Bhagavata Purana,* tell of a wrestling match, between Krishna and a demon, which is initiated by trumpet blasts, perhaps chank trumpets. In a later episode, the arrival of Krishna at the court of his intended bride is accompanied by a flourish of trumpets (Sarma, 1948); this passage, too, probably refers to the chank.

It may be significant that in the Aztec culture, similar reverence was centered around large snail shells, including *Turbinella angulata* (Lightfoot, 1786), a close relative of the Indian chank (Jackson, 1961; Vokes, 1963). Jackson emphasized similarities between Indian mythology involving the chank and Aztec moon worship involving large snail shells. Hindu influence on early Middle American civilizations is considered a distinct possibility by these authors.

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SPECIES DIVERSITY OF TERRESTRIAL SNAILS
IN THE GREAT SMOKY MOUNTAINS

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ABSTRACT

A comparison was made of species diversity (Shannon index and number of species) of larger terrestrial snails and gradients of moisture, temperature, and diversity of dominant tree, shrub and herbaceous plants in the Great Smoky Mountains. Estimates were also made of habitat breadth of the snails. There was a positive correlation between snail diversity and the moisture regime and diversity of dominant tree species. There was no correlation between snail diversity and temperature, or shrub and herbaceous vegetation diversity. Comments are also made concerning the habitat breadths of the more common species.

INTRODUCTION

A series of terrestrial snail collections was made as a special class project by the University of Illinois Field Ecology Course to the Great Smoky Mountains, Tennessee and North Carolina, 28-31 March, 1972, to compare species diversity in various communities of the region with selected environmental gradients. Although the data are not extensive, they do show indications as to the relationship between snail diversity and given environmental factors. They are presented here primarily to stimulate more intensive studies of species diversity of snails in the various communities within the Smoky Mountains.

AREA OF STUDY

Nine sites within eight of the community types defined by Whittaker (1956) were sampled. Except where noted, special effort was made to sample within a representative site in each community type. The following communities were sampled (see Whittaker, 1956, for detailed descriptions of the community types):

Red spruce—Mt. LeConte, on Bullhead Trail, approximately 1,640 meters elevation.

Grass bald—The upper half of Andrew's Bald, 1,775 meters.

Beech gap—Approximately 1.5 km. north of Indian Gap, 1,580 meters.

High hemlock—On the south side of U. S. Route 411, at 1,200 meters. This site was typical of Whittaker's eastern hemlock type at its upper limits. The tree canopy was composed almost entirely of hemlock; shrub stratrum was a complete cover of rhododendron. An herbaceous stratum was essentially absent.

Low hemlock—Along the one-way road leading from Cherokee Orchard to Gatlinburg, at approximately 745 meters. This site was characteristic of Whittaker's description of the eastern hemlock type as it segregates from the Cove forest. The tree stratum was composed primarily of hemlock, but several deciduous species were also present.

Pitch pine-table mountain pine heath—Mt. LeConte, along the Bullhead Trail at 1,100 meters. The site had essentially an equal mixture of pitch and table mountain pine. The rest of the vegetation corresponded to that as described by Whittaker for the higher elevation pine heaths in the Smoky Mountains.

Chestnut oak-chestnut—Mt. LeConte, a long Bullhead Trail at 850 meters. The site sampled was in an area in which American chestnut originally made up the major portion of the tree canopy. The site is now occupied by a mixture of young oak and other deciduous trees.

Virginia pine—Adjacent to the Cades Cove Campgrounds, 550 meters.

Cove forest—Along the road in Greenbrier Cove, 2 km. beyond the turnoff to the Trillum Gap Trail to Mt. LeConte, at 760 meters.

METHODS

A timed-interval search was used to sample all communities. The twelve individuals involved in the project each searched intensively for snails for ten minutes at each site, resulting in a total of two hours of searching. The search was conducted so as to cover as much total area as possible. All situations in which snails could be found were searched; these included under the leaf litter, under logs, fallen limbs, and rocks, and in crevices at the base of trees. All live snails and dead shells were collected. The sampling of smaller species was not complete, so only larger species were included in the analyses; *Retinella* and other such small snails were excluded.

Although there is bias in any collecting method, the one used eliminated some obvious sources. That the same twelve individuals sampled all nine sites reduced bias from different collecting idiosyncrasies; the same microhabitats received equal coverage in each community. The inclusion of dead snails in the analysis would tend to reduce the bias resulting from suppression of snail activity (and thus accessibility to collection) because of lower temperatures in the early spring in those communities at higher elevatons; there would be more adequate representation of the species present in those communities.

Spot checks by the author of most of the same community types on 12-13 April and 24-25 June, 1972 indicated the original data were representative of the abundance and diversity of species in the various communities.

The species diversity of snails within each community was measured by the Shannon index, H' (Shannon and Weaver, 1963). The formula and tables of Lloyd, *et al.* (1968) were used in the calculations. Between-community species diversity indices were also calculated. The former are used to evaluate the influence of various environmental factors on the species diversity of snails; the latter are used to estimate relative habitat breadth of the species.

RESULTS

Within-community species diversity—Table 1 summarizes the species diversity values within each community and the correlation with the various environmental gradients. The environmental gradients have been summarized from Whittaker (1956,

1966). There was a positive correlation between species diversity of snails and the moisture regime in the nine communities (r_s = .87, P < .01; Spearman Rank Correlation, Siegel, 1956). Likewise, there was a positive correlation between snail diversity and the number of dominant tree species present in each community (r_s = .80, P =< .01). There was no correlation between snail diversity and temperature, shrub diversity, or herbaceous vegetation diversity.

The major deviation from the correlation between the amount of moisture in the community and snail diversity was in the Virginia pine community. This community was judged to be the third driest community studied, but ranked fourth highest in snail species diversity. The Virginia pine community had one of the higher number of dominant tree species (third highest) which may be at least partly responsible for the greater snail diversity.

The major deviation from the correlation between number of dominant tree species and species diversity of snails is the high-elevation hemlock. This community ranked third lowest in the number of dominant tree species, but third highest in snail diversity. The high-elevation hemlock, however, ranked as one of the more moist communities studied (third highest) which may be responsible for the greater snail diversity.

Habitat breadth—Between-community diversity indices which have been used as an index of habitat breadth are summarized in Table 2.

The immature Polygyridae had the widest range of habitats. This would be expected since several species were undoubtedly grouped into this category; we, therefore, are not dealing with one "habitat" but several and, thus, a wider apparent habitat.

Pallifera sp. (probably only one species involved) also had a wide habitat range, but the numbers involved are rather low. The early seasonal aspect undoubtedly biased the results regarding this species. The observations made in May and June of 1972 did indicate, however, that the species was common in most of the habitats studied.

Two or three species may have been involved in the *Stenotrema* sp. category. Thus, the comments concerning habitat breadth of the immature Polygyrids also apply to this grouping.

TABLE 1. *Correlation of species diversity of terrestrial land snails and environmental gradients in the Great Smoky Mountains National Park.*

Community-Type	Number Species[1]	Number Individuals	H'[2]	Moisture[3]	Temperature[3]	Vegetation Diversity[3]		
						Trees	Shrubs	Herbs
Spruce	10	47	2.9944	9	3	8	6	6
Cove Forest	11	44	2.9715	8	8	9	7	9
Hemlock (High)	9	17	2.8163	7	4	3	2	1
Virginia Pine	7	18	2.4806	3	9	7	9	4
Hemlock (Low)	7	75	1.9724	6	6	6	3	3
Oak-Chestnut	5	35	1.9039	5	7	4	8	8
Pitch-Table Mt. Pine	3	3	1.5849	2	5	5	5	2
Beech Gap	3	81	0.3320	4	2	2	1	5
Grass Bald	1	8	0	1	1	1	4	7

[1] Includes two groupings (one genus and one family) considered as "species"
[2] To log base 2
[3] Ranked from low to high (1-9)

Of the more abundant species, *Ventridens elliotti, V. demissus, V. ligera,* and *Mesomphix andrewsae* obviously have relatively wide habitat ranges while *Vitrinizonites latissimus* and *Haplotrema concavum* have more narrow habitats. The other species either had very low habitat breadths or were collected in too few numbers (i.e., *Mesodon christyi*) to place much significance on the relatively high between-community diversity indices.

Vitrinizonites latissimus was the most abundant species and occurred in five communities. The reason for the low H' appears to be related to its association with graminoid vegetation. Observations of the specific sites in which this species was found indicated that it occurred primarily where some type of grass or sedge was present. Graminoid vegetation was most abundant in the grass balds and the beech gap. *V. latissimus* is abundant in these two communities; the species is much less abundant and is spotty in its occurrence in the other communities studied.

DISCUSSIONS AND CONCLUSIONS

The data obtained in this study indicate moisture and/or number of dominant species of trees are primary factors influencing species diversity of terrestrial snails within communities in the Smoky Mountains. This differs somewhat from the trends in species diversity of insects in the Smoky Mountains observed by Whittaker (1952). He found insect diversity to be greatest in the intermediate moisture conditions, with lesser diversity at both moist and dry extremes.

Terrestrial snails (especially the families collected in this study) are relatively susceptible to desiccation. Those species with less tolerance to desiccation would tend to be restricted to the more moist communities. There would, therefore, be a gradual "filtering" process with the less tolerant species dropping out, as one progresses toward the drier communities. The density of snails may not show such a relationship, however, since those species adapted to dry conditions could develop high population densities in such sites. Except for the Virginia pine community these relationships are borne out by the data (Table 1).

The beech gap community is of special interest in that more individuals were collected here than in any other community, but the diversity index was next to the lowest of the nine communities.

TABLE 2. *Habitat breadth of terrestrial snails in the Great Smoky Mountains National Park.*

Species	Total Individuals	Total Communities	H'[1]
Polygyridae (immature)	18	6	2.2109
Pallifera	6	4	1.9182
Mesomphix andrewsae	33	5	1.7712
Stenotrema sp.	17	4	1.7575
Ventridens ligera	19	4	1.6164
V. elliotti	77	4	1.5040
V. demissus	16	3	1.4198
Mesodon christyi	5	3	1.3710
M. perigraptus	2	2	1.0000
Vitrinizonites latissimus	93	5	0.9256
Haplotrema concavum	13	3	0.7733
Mesodon downieanus	5	2	0.7219
Mesomphix subplanus	1	1	0
Triodopsis tridentata	1	1	0
Mesodon andrewsae	3	1	0
Ventridens sp. (immature)	2	1	0
Mesodon ferrissi	3	1	0
M. clauses	1	1	0
Mesomphix sp. (immature)	2	1	0
Mesodon rugeli	1	1	0
Mesomphix sp. (adult)	1	1	0
M. vulgatus	2	1	0
Ventridens intertextus	7	1	0

[1] To log base 2.

Almost all the specimens from this community (77 of the 81 collected) were *Vitrinizonites latissimus*. The beech gap has trees and a relatively deep leaf litter which moderate the physical environment (especially the surface soil moisture) in addition to the presence of a dense stand of grass. The only other community with significant grass is the grass bald. Trees and shrubs are very sparse in this site, however, so that there is not a cover of leaf litter to modify the surface soil moisture regime. A very low moisture availability in the grass bald may be responsible for the low populaton density of *V. latissimus* in this site.

Since trees furnish most of the organic matter to forest soils (Lutz and Chandler, 1946), there would be a positive correlation between tree species diversity and diversity of nutritional and physical properties of the soil. This microhabitat diversity in turn would have a direct influence on the diversity of terrestrial snails (Burch, 1956) and may partially account for the correlation between tree diversity and snail diversity in the communities studied.

Much more data would be necessary to evaluate the habitat breadth of all the species of the region. The results of the present study do·

indicate, however, that *Mesophix andrewsae* has broader habitat tolerances than most of the other species. *Vitrinizonites latissimus* displays more narrow habitat requirements. This apparently results from an association with graminoid vegetation. Such vegetation occurs in abundance only in a few habitats. That these sites are also relatively xeric indicates that the primary factor influencing the distribution of this species is not moisture.

Owing to the rather small amount of total collecting effort involved in the current study, more extensive analyses and extrapolations do not appear warranted. I think this preliminary study does indicate, however, the utility of making a more intensive study of this type. With comprehensive sampling of these and other community types in the region, one should be able to arrive at more definitive conclusions regarding the factors influencing the diversity and habitat breadth of terrestrial snails.

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A NEW SPECIES OF HAWAIIAN *GYRINEUM* (CYMATIIDAE)

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ABSTRACT

Gyrineum louisae *is described as a new species from Hawaii. The unusual sculp-
ture of the protoconch is described and figured. The protoconchs of* Gyrineum
gyrinum *(Linné),* Gyrineum natator *(Röding),* Gyrineum bituberculare *(Lamarck),
and* Gyrineum concinnum *(Dunker) are figured for comparison. Various taxonomic
characters of the genus are discussed.*

INTRODUCTION

In the June 1963 issue of the Hawaiian Shell
News, Dr. C. M. Burgess illustrated a species ta-
ken during the *Pele* expedition and suggested
that it was "similar to a *Bursa.*" The figured
specimen is actually a new species of *Gyrineum.*
Since that time no other specimens have been
reported. Recently the figured specimen was
brought to me for examination by Dr. Alison
Kay of the University of Hawaii during her visit
to the Academy of Natural Sciences of Philadel-
phia. The morphology of the shell and the shape
and proportion of the protoconch are typical of
the genus (figs. 1-3 and 6). Microscopic examina-
tion of the protoconch reveals a remarkable can-
cellate sculpture which is unique to *Gyrineum
louisae.* The regular, fine sculpture on the whorls
of *Gyrineum louisae* are clearly distinct from any
other species in the genus.

HISTORICAL DISCUSSION OF
THE GENUS *GYRINEUM*

A great deal of confusion has existed con-
cerning the proper use of *Gyrineum* Link, 1807.
Many authors, including Wenz (1961, p. 1073),
have considered this to be a name properly ap-
plied to a bursid genus. This misuse still persists
in recent literature, as well as in the systematic
arrangement of various museum collections.

Dall (1904, p. 115) discussed Link's genus and
pointed out that there is a mixture of species
included in the original description which "seems
to have been based wholly on the presence of
symmetrical lateral varices, and included species

like *M. gyrinus* Linné, which have no posterior
canal." He also stated that "Montfort 1810, saw
more clearly and put the ranelliform tritons by
themselves under the name of *Apollon . . .* with
Murex gyrinus (Linné) Gmelin as type." Dall
confirmed the validity of *Gyrineum* as a cymatiid
genus, designating *Murex gyrinus* Linne, 1758, as
the type, and listing *Apollon* as a synonym of
Gyrineum. In spite of the wide-spread circulation
of Dall's paper, many authors mistakenly contin-
ued to use the name *Gyrineum* for a bursid
genus and the name *Apollon* for the cymatiid
genus which should properly be called *Gyrineum.*

Cernohorsky (1967, p. 322) agreed with Dall
and pointed out that the type for *Apollon*
Montfort, 1810, is *A. gyrinus* (=*Murex gyrinus*
Linné). Therefore *Apollon* is synonymous with
Gyrineum Link, 1807. He also stated that
Rovereto's designation (1899, p. 106) of
Gyrineum spinosum (Dillwyn, 1817) as the type
species for *Gyrineum* is invalid because *spinosum*
was not originally included in Link's genus.
Gyrineum spinosum (= *G. echinatum* Link,
1807) belongs to the bursid genus *Bufonaria*
Schumacher, 1817. Link's list included *G.
echinatum* Link, *G. rana* (Linné) Link, *G.
bufonium, G. natator, M. gyrinus* and *G.
verrucosum,* a mixture of *Bursa* and *Gyrineum.*

It does seem unfortunate that the rules of tax-
onomy cause us to recognize *Gyrineum* and to
synonymize *Apollon* simply because Link in-
cluded a species which, in fact, is not typical of
the genus he described. This is especially true
when we realize the consequential confusion
which has existed for almost 167 years concern-

ing the misuse of *Gyrineum* as a bursid genus. As recently as August 1973, Kilias (p. 13) persists in the use of *Apollon* for *Gyrineum*. It is also unfortunate when we realize how much more clearly Montfort understood the relationship of the species he included in *Apollon*.

Species of *Bursa* and *Gyrineum* are easy to confuse because of the similarity of shell morphology, especially since both have more or less laterally aligned varices. However the presence of the open posterior anal canal in the Bursidae and the absence of it in the Cymatiidae as a distinguishing characteristic is widely accepted and applies very well in this instance.

Genus Gyrineum Link, 1807

Gyrineum Link, 1807, Beschreibung der Naturalien Sammlung der Universitat zu Rostock, p. 123. Type species, *Murex gyrinus* Linné, 1758, subsequent designation W. H. Dall, 1904.

Apollon Montfort, 1810, Conchyliologie Systématique, et Classification Méthodique des Coquilles: p. 570-571.

Description — Shells range in length from 20 to 45 mm. The genus is typified by laterally aligned varices which on some species actually connect to form a single continuous varix on each side. This gives the whorls a distinct bilaterally compressed appearance. They are sculptured by spiral cords and axial ribs which form fine to coarse beads or nodules where they cross. The aperture is oval to round with dentition usually present on the inner edge of the outer lip. The anterior siphonal canal is short. The radula is taenioglossate and is differentiated from other Cymatiidae by the flat character of the base of the rachidian which contrasts with the arched base typical of the rachidian of most Cymatiidae. The opercula of all species examined are terminal in pattern, with the exception of occasional damaged specimens which have regenerated with a nucleus. This condition has been observed in other genera of the Cymatiidae. The protoconchs of the various species are very similar (figs. 6-10) with the exception of *G. louisae* which has a fine regular cancellate sculpture. Jaws were present in all species examined.

Gyrineum louisae
new species, Lewis
Figs. 1-3

Description — Shell white, 19 mm. in length and 12 mm. in width at the periphery. There are 6 whorls producing a spire of 57°. The outer lip is thickened at the final varix. The 9 varices do not align but are slightly offset (fig. 3). There are 13 spiral cords crossed by 16 axial ribs between the varices which form a very fine beaded pattern. The axial ribs do not extend to the varices but the spiral cords cross the varices forming 13 distinct fine ridges on the varix at the outer lip. The siphonal canal is very short, measuring only 1½ mm. from the base of the outer lip to the tip of the canal. There is a glossy raised peristome on the inner edge of the outer lip which continues to the upper edge of the glazed parietal wall. The protoconch is covered by a fine network of axial ribs and spiral cords (fig. 6) but is similar in shape to other species in the genus (figs. 7-10). The operculum and animal are unknown.

The distribution is unknown except for the type locality where the holotype was taken on the *Pele* expedition at 180 fathoms, off Pokai Bay, Oahu, Hawaii. The holotype is deposited in the B. P. Bishop Museum, Honolulu.

I take great pleasure in naming this species after my wife Louise in small repayment for her continued patience during my work with the Cymatiidae. It is hoped that there will be no confusion with the little used name *Bursa louisa* M. Smith, 1948, which is a synonym for *Bursa caelata* (Broderip 1833) from the Panamic region.

Differentiating features — *Gyrineum louisae* is most similar to *Gyrineum natator* but differs by being smaller, lacking pigmentation by having 13 spiral cords instead of 8. The protoconch of *natator* is smooth.

Gyrineum louisae differs from *Gyrineum gyrinum,* the type of the genus, by being smaller, lacking pigmentation and the color bands of *gyrinum,* having finer sculpture with 13 spiral cords instead of 8. The protoconch of *gyrinum* lacks the sculpture of *louisae.*

Although most species of *Gyrineum* are pigmented, *Gyrineum pusillum* (Broderip, 1832) is also white, and species such as *hirasei* Kuroda
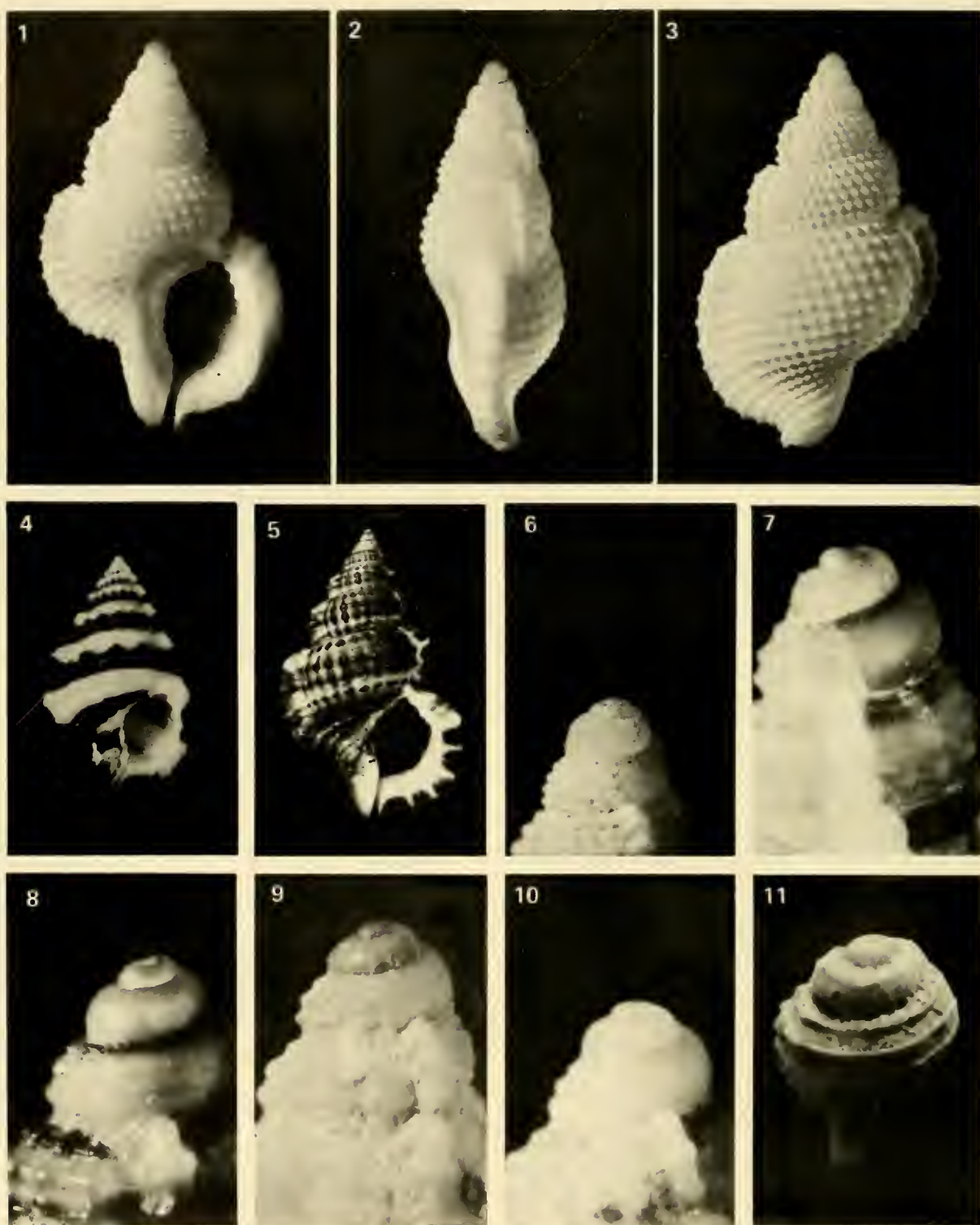
FIGS. 1-11, *Explanation on opposite page.*

and Habe, 1964 and *bituberculare* Lamarck, 1816 can be very pale.

FOSSIL LITERATURE

An investigation was made in order to determine whether or not this species had been named in the fossil literature. Special attention was given to the various species from Java and Timor described and discussed by K. Martin. A partial list of these papers is included in the cited literature. No fossil species was discovered which can be considered to be this species.

ACKNOWLEDGEMENTS

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FIG. 1-3. Gyrineum louisae *new species, Lewis, Holotype, 180 fathoms off Pokai Bay, Oahu, Hawaii 19mm. x 12 mm.*

FIG. 4, Gyrineum gyrinum (Linné), *North side of Kyangel Isl. Palau district, West Carolines 30 mm. x 20 mm.*

FIG. 5, Gyrineum natator (Röding), *India 38.5 mm. x 24 mm.*

FIG. 6, Protoconch of Gyrineum louisae *Lewis, Holotype, 180 fathoms off Pokai Bay, Oahu, Hawaii x 17.*

FIG. 7, Protoconch of Gyrineum bituberculare (Lamarck), *Tayabas Bay, Philippines, x 17.*

FIG. 8, Protoconch of Gyrineum natator (Röding), *Bay of Bengal, India, x 17.*

FIG. 9, Protoconch of Gyrineum gyrinum (Linné), *West Carolines, x 17.*

FIG. 10, Protoconch of Gyrineum concinnum (Dunker−, *Obhur, Saudi Arabia, x 17.*

FIG. 11, Larval shell of Gyrineum natator (Röding), *Bay of Bengal, India, with periostracal formation showing spiral ridges somewhat similar to the spiral cords formed on the protoconch of* Gyrineum louisae *Lewis. (In the Cymatiidae, the shell sculpture of cords and ribs usually corresponds to periostracal formation.)*

GROWTH STUDIES ON THE GENUS *CERITHIUM* (GASTROPODA: PROSOBRANCHIA) WITH NOTES ON ECOLOGY AND MICROHABITATS

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ABSTRACT

The growth rates and general ecology of four species of Cerithium *were studied in Florida. Comparative ecological observations on worldwide species of the genus are made. All* Cerithium *species are shallow water subtidal or intertidal dwellers and most are associated with marine grasses and algae. Some species occur in large populations. They appear to be selective algal-detritus feeders and have style-bearing stomachs with complex ciliary sorting mechanisms.*

Species in Florida spawn from winter through spring, grow from juveniles to adult stages in a few months, and have life spans of about one year. Predation on Cerithium *species occurs by carnivorous mollusks, crabs, starfish and bony fish. Smaller* Cerithium *species tend to be intertidal.*

INTRODUCTION

The genus *Cerithium* is common in a variety of shallow-water, tropical and subtropical habitats. There are few accounts of the ecology of this genus beyond some scattered remarks in various papers dealing with anatomy and systematics. Few studies have been made on the ecology of littoral gastropods in the tropics. The growth rates of marine tropical and subtropical benthic mollusks are little known (Lewis *et al.*, 1969) while those living in temperate and cold climates have been more thoroughly investigated. Literature concerning growth in intertidal marine organisms has been reviewed by Moore (1958), Newell (1965, 1970), and Wilbur and Owen (1964). Lewis *et al.* (1969) have surveyed the literature concerning the factors which are known to influence growth rates (gonadal maturation, age, temperature, food supply, and environmental factors). The environmental factors have also been discussed by Vohra (1970). Houbrick (1970; 1974, in press) recently defined the mode of reproduction in *Cerithium* species from the Western Atlantic.

The account which follows is primarily concerned with four species of *Cerithium* common in Florida, *C. muscarum* Say, 1832 (Fig. 4, D), *C. lutosum* Menke 1828 (formerly *C. variabile*[1]) (Fig. 4, B) *C. eburneun.*

Bruguiére 1792 (Fig. 4, C) and *C. atratum* (Born, 1778) [=*C. floridanum* Mörch[2]]. A literature survey and observations on other worldwide species of *Cerithium* and *Rhinoclavis* are also included.

MATERIALS AND METHODS

This study is based mainly upon material collected in Florida. Observations were made in the field and laboratory from September 1968, through May 1971. Supplementary field work was done at the Eniwetok Marine Biological Laboratory, Marshall Islands, in August 1970, and at Carrie Bow Cay, British Honduras, in May 1972. In Florida, monthly samples and observations, when possible, were made from a total of four field stations, while other areas in the state were visited less regularly. The sites selected for ecological and growth studies in Florida represent several environmentally different habitats and are located in different marine zoogeographical provinces. The data collected on the populations of species studied at these sites does not necessarily apply to other populations of the same species in other parts of their ranges.

The four main stations in Florida were located at Port Everglades (lat. 26°6'N, long. 80°4'W), Bear Cut (lat. 25°44'N, long. 80°8'W), Dunedin (lat. 28°2'N,

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[1] *C. variabile* C. B. Adams 1845 is a synonym of *C. lutosum.* This will be documented in a later paper.

[2] *C. floridanum* Mörch, 1876 is a synonym of *C. atratum.*

long, 82°45′ W), and Mullet Key (lat. 27°35′N, long. 82°44′W). The first two stations are located on the lower east coast of Florida where the environment and fauna are largely tropical and Caribbean in nature, while the latter two are located along the central Gulf coast of the state, where the marine fauna and environment are subtropical and largely Carolinian in composition. More detailed descriptions of the four stations may be found in the body of this paper.

Quantitative monthly data on temperature, salinity, and tides were taken. Monthly measurements of the growth of populations of *C. muscarum, C. lutosum, C. atratum,* and *C. eburneum* were made.

For growth studies, samples from the four field stations were collected with a mesh push-net in grass beds, sand, and mud habitats. Material was passed through a screen of 0.25-cm mesh and the samples removed. Algae and marine grasses were washed in fresh water to collect any young snails in the populations. Collecting was limited to about one hour at each station. Measurements of the monthly samples were made in the laboratory. The length of the shells was determined to the nearest 0.1 mm with vernier calipers. In most cases, 50 or more were measured. Snails with badly eroded apexes were not measured. Length was determined as the distance from the apex of the shell to the base of the aperture, and width by measuring the thickness of the last whorl. Difficulty was encountered in width measurements because of the random presence or absence of varices on the body whorl. For this reason, length measurements were relied on in making size frequency plots. Size-frequency analysis was made on monthly measurements and the mean, mode, standard deviation, and range were computed. The addition of new whorls and increases in shell length were taken as indications of new growth. To determine population densities of species with obvious high densities, random samples were taken by dropping a 10-cm square metal frame over the area to be sampled. All animals appearing within the frame were counted and Stein's two-stage sampling technique (Steel and Torrie, 1960) was used to compute average densities. Living animals were maintained at a temperature of 25°C in aquaria of seawater with a salinity of 34°/∞. The snails were fed on local algae, marine grasses, and detritus from Tampa Bay. Observations and dissections of living animals were conducted to determine food preferences and stomach contents.

Associations, kinds of predators, and behavior were also noted and are herein recorded. However, these observations were not of a quantitative nature and may not be significant.

Various sites in Florida, the Caribbean and the Pacific, were also studied to collect comparative data on other species of *Cerithium.*

ECOLOGY OF *CERITHIUM MUSCARUM*

Habitat

Cerithium muscarum, throughout its range, is found associated with marine grasses such as *Thalassia testudinum, Ruppia maritima, Halodule wrightii* and *Syringodium* sp.

Cerithium muscarum is a common inhabitant of bays and other estuarine areas, but is also found in the open sea in areas shallow enough to support extensive beds of grass such as occur on the Gulf coast of Florida.

A population of *C. muscarum* was studied
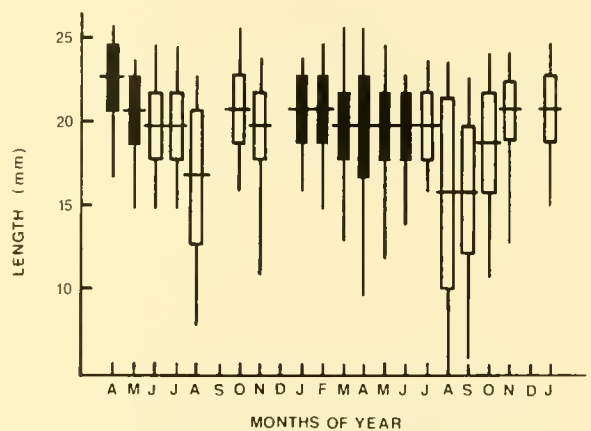
Fig. 1.   Cerithium muscarum. *Growth of population expressed as a measure of shell length. Vertical lines represent range, horizontal lines the mean, and bars, the standard deviation. Solid bars represent months of oviposition.*

intensively at the north end of Mullet Key in the entrance of Tampa Bay, Florida. This is a shallow estuarine habit with mangroves constituting the predominant shore line vegetation. The general ecology of Tampa Bay has been treated by Dragovich and Kelly (1964). There is little wave action at Mullet Key and the mean tidal range is about 60 cm. Average water temperature at this station was 25.3°C, ranging from extremes of 14°C in January 1970, to 33°C in

June 1969. Mean salinity was 34.6°/oo with a range from 31°/oo in February 1969, to a high reading of 37°/oo in August 1970. Salinity levels appear to be relatively stable, although heavy rains may lower them appreciable for short periods. Some wave action occurs when winds are strong causing considerable amounts of debris and detritus to be deposited in the intertidal zone and on the beaches. The water is generally clear during the winter and spring, but is turbid in summer and fall.

Cerithium muscarum is found living in the beds of *Thalassia* and *Ruppia* about 16m offshore, just at and below the low tide mark. Occasional minus tides expose the whole area. The substratum is sand but quantities of detritus and debris collect about the roots and in between the blades of the *Thalassia* and *Ruppia. Cerithium muscarum* is found browsing upon the epiphytic algae on *Thalassia* leaves and also partially burrowing in or crawling on the detritus and sand. Its distribution is limited to the *Thalassia* and associated detritus.

This species is also common in Hillsborough Bay, Florida, a more brackish environment, where it is found in beds of *Ruppia* near submerged oyster bars. I also observed it in beds of *Thalassia* in Biscayne Bay, Florida, and the Florida Keys. Tabb, Dubrow and Manning (1962) found it in the shallow brackish waters of Florida Bay.

Behavior

Cerithium muscarum is a continual browser with a monotaxic type of locomotion. Captive specimens exhibit shadow responses by quick withdrawal into their shells. When the water is stirred by wave action, *C. muscarum* buries itself in the sand at the bases of the *Thalassia* plants. During low tides, slight clustering of individuals occurs.

Food and Feeding

Cerithium muscarum feeds and deposits fecal pellets intermittently. In the aquarium it eats the sand and surface deposits on the bottom as well as epiphytic algae on *Thalassia* blades. Decaying *Thalassia* leaves are also consumed. Stomach contents consist of sand grains, detritus, and green algae such as *Cladophora* and *Chaetomorpha.* Fecal pellets contain the same type of material as is found in the stomach, only many of the algal cells are evacuolated.

Associations and Predators

In some habitats, the potamidid snail, *Batillaria*

minima, is associated with *C. muscarum* but it occupies a higher tidal zone. No mixing between the two species occurs. Frequently, young *Crepidula fornicata* are found on the siphonal canal of the shell of *C. muscarum.* Seventy-two per cent of the Mullet Key population harbor *Crepidula fornicata* on their shells. The digenetic trematode, *Mesostephanus appendiculatoides,* found in birds, uses *C. muscarum* as its first intermediate host (Hutton and Sogandares-Bernal., 1960). In *Thalassia* communities of the Florida Keys and Biscayne Bay, *C. muscarum* is occasionally found with *C. eburneum.*

Cerithium muscarum is attacked and eaten by crabs of the genera *Callinectes, Menippe,* and *Libinia.* Numbers of shells with broken apertures indicate that predation by crabs is common. I also observed the carnivorous snails, *Melongena corona, Busycon contrarium, Fasiolaria tulipa,* and *Pleuroploca gigantea* preying upon *C. muscarum.* Shells with drilled holes indicate that naticid snails *(Polinices, Natica, Sinum)* as well as muricid snails *(Murex, Eupleura)* may also be predators. Stingrays and horseshoe crab, *Limulus,* are abundant in the study area and are also suspected predators.

Growth

Size frequency analysis (Table 1) indicates that the monthly mean shell length of the Mullet Key population of *C. muscarum* fluctuated between 23-16 mm (Fig. 1). Oviposition takes place from January through July and development is direct with no pelagic stages (Houbrick, 1970). Although a few young snails were found in the population during the spring, young snails (5-10mm) were most common in August and September. Growth rates were rapid. The mean shell length of the population, 16 mm in August, had reached 21 mm by October. Thus, the new generation took only three months to reach an adult size. The largest individuals taken were 26 mm in length and were found in early spring.

In addition to increase in shell length, another indication of growth is a thin-lipped shell aperture, formed during the addition of new whorls. This was most evident during the fall and early winter (September-December). Monthly statistics on this population were maintained, and a summary is given in figure 1.

C. muscarum was most abundant during the winter when the density of the population averaged 25 snails/m^2. By late spring, the population size began to

decrease and during the summer was the lowest prior to the hatching of new snails. The new generation appeared in late August. In the fall, new adult individuals were easily differentiated from the previous generation on the basis of their shells, which were erosion-free, more colorful, and free of marine foulers. Snails over a year old had eroded shells, covered with oysters, barnacles, brozoans, etc. On the basis of the number of new individuals present in the population by November, and the lack of older snails, *C. muscarum* probably has a life span of about one year.

ECOLOGY OF *CERITHIUM LUTOSUM*

Habitat

Cerithium lutosum exhibits great ecological diversity in terms of substratum preference. I collected it on substrata ranging from fine, muddy sand to limestone slabs and beachrock. Occasionally, it occurs in beds of *Thalassia*, but it is almost always associated with some type of algae. *Cerithium lutosum* (occurring in both estuarine and high-salinity environments) is euryhaline by comparison with most other species of *Cerithium*.

Detailed studies on this species were carried out at Port Everglades, Florida. This station is located in southeastern Florida between Ft. Lauderdale and Hollywood. It is a deep-water port on the Intracoastal Waterway, which opens to the ocean by a narrow inlet. In the vicinity of the port, the Intracoastal Waterway branches into several smaller canals, one of which is known locally as "Whiskey Creek". This was the site of the study and is a shallow, brackish tidal canal about 11 m wide extending for a length of about 2 mi. At its center it is about 2 m deep at high tide and slopes gradually upwards to the banks. Tidal fluctuations are about 1 m and generate a current between tides. The average bottom water temperature, recorded monthly, throughout this study was 28.4°C, ranging from 20°C in February 1969, to 35°C in September 1969. Mean salinity was 27.5°/°° ranging from a low of 13°/°° in October 1969, to a high reading of 35°/°° in December 1969. Salinity is variable and may drop rapidly after periods of heavy rainfall. Because there is no wave action, the bottom and intertidal zone are stable, but detritus is distributed and redeposited by tidal action. The canal bottom is sandy with occasional areas of muddy sediment. The sand is composed of broken shell and

is coarse. The water, although darkly stained by tannic acid from the mangroves, is seldom turbid or muddy. The canal is bordered on one side with *Rhizophora mangle*, the red mangrove, and with open beach sand on the other side. Portions of the bottom are covered with algae, primarily *Gracilaria folifera*, *Hypnea musciformis* and *Chaetomorpha gracilis*. A vascular plant, *Halophila balionis*, is also present as well as *Halodule wrightii*.

Cerithium lutosum occurs in great numbers (average density of 3,400/m²), occupying a zone 2 m wide along the shallow banks of the canal from the high-tide mark to just below the low-tide level. The highest concentration of snails (15,000/m²) is just above the low-water mark to mid-tide level. Much detritus is deposited in this area during tidal changes. *Cerithium lutosum* is closely associated with the green alga, *Chaetomorpha gracilis*. This alga covers the substratum and the shells of the snails. I also
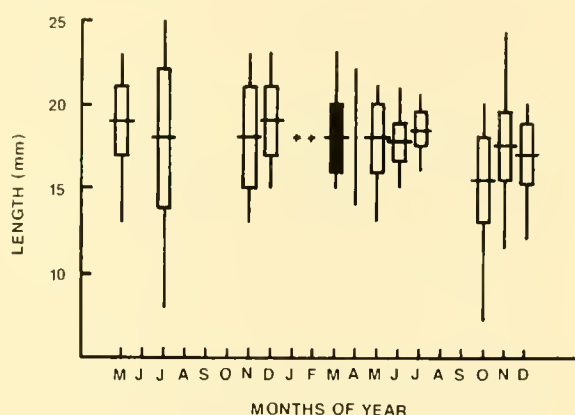
Fig. 2.   Cerithium lutosum. *Growth of population expressed as a measure of shell length. Vertical lines represent range, horizontal lines the mean, and bars, the standard deviation. Solid bars represent months of oviposition. Asterisks represent months of oviposition when other measurements were not made.*

observed *Cerithium lutosum* on intertidal beach rock along Bear Cut, Key Biscayne, Florida, where it is likewise abundant (average density of 1,700/m²), clinging to the rocks or partially buried in mats of the filamentous green alga, *Enteromorpha*. The highest concentrations at Bear Cut were just above the low-tide mark (6,500/m²). This species was also abundant on intertidal coral rock at Pigeon Key, Florida. In the Laguna de Terminos, Campeche,

Mexico I found it in the brackish lagoon, intertidally, on most algal-covered rocks. At Portete, Costa Rica, and on Carrie Bow Cay, British Honduras, I observed it in shallow water *Thalassia* communities. Jackson (1972) found large populations of *C. variabile* (now *C. lutosum*) in *Thalassia* in Jamaica.

Behavior

Cerithium lutosum moves frequently with tidal changes. It was found crawling on the substratum and also partially burrowing in the sand. When tidal currents are strong the population orients itself with the anteriors of the shells facing the current and then buries itself almost completely. The snails emerge when conditions are more stable. Their mode of locomotion is monotaxic, direct. *Cerithium lutosum* is frequently exposed to the sun at low tide and is able to tolerate desiccation for this period. It is capable of surviving water temperatures in excess of 41°C (Jackson, 1972). Light clustering of individuals occur during low tide, but not to the extent observed by Moulton (1962) in some Australian species. In the laboratory, the snails appear to be photopositive but are repelled by strong light and will also quickly withdraw into their shells in response to a shadow.

Food and Feeding

Observations in the laboratory indicate that *C. lutosum* is a relatively continuous feeder. It constantly rasps the substratum, engulfing algae and detritus, pausing occasionally, and intermittently deposits strings of fecal pellets. Stomach contents revealed a variety of material such as diatoms, Foraminifera, sand grains, blue-green and green algae, especially *Enteromorpha* and *Chaetomorpha*, and much detritus. It is difficult to determine what is selectively digested in the complex sorting system of the stomach. The above-mentioned stomach contents are also found in the fecal pellets.

Associations and Predators

In all habitats and locations studied, the potamidid snail, *Batillaria minima*, which closely resembles *C. lutosum*, is found just above the tidal zone level occupied by *C. lutosum* and upwards to the high tide mark. At the Port Everglades site there is a zone of mixing between the two species about 10 cm wide, but they generally tend to remain separate. They both feed on algae and detritus.

Predators that eat *C. lutosum* are the blue crab, *Callinectes sapidus*, hermit crabs of the genus *Pagurus*, and the snail *Melongena corona*. Raeihle (1968) observed the snail, *Mitra floridana* eating the young of *C. lutosum*. Jackson (1972) recorded predation of *C. lutosum* in Jamaica by the naticid snails *Polinices* and *Natica*. Predation by rays is suspected because they have been noticed frequently in the study areas. Other suspected predators are the horseshoe crab, *Limulus*, the spider crab, *Libinia*, bony fishes and wading birds.

Growth

C. lutosum has direct development (Houbrick, 1970; 1973, in press), and size-frequency data (Fig. 2) indicate that adult size is reached in about one year. Size-frequency analysis of the Port Everglades population shows that the monthly mean shell length varies between 7-11 mm throughout the year. The largest snails were 16 mm in length and were found in March. Frequent oviposition occurred from fall through early spring, with minor egg-laying, activity seen at other times of the year (Fig. 2). Most of the young snails were found from April through September, indicating that development and growth of the new generation occurs during the summer months. The mean length of the snails during this period was 8 mm. Average growth in length was most rapid in the fall (October-November). Size-frequency data indicate that young snails reach adult size in a few months. It was not possible to determine the life span of *C. lutosum* with accuracy because attempts to raise newly-hatched snails to adulthood were unsuccessful. However, it appears that snails in the Port Everglades population live about one year. Fluctuations in the size of the population (in numbers of individuals) occur during late summer and early fall when both generations are found together.

ECOLOGY OF *CERITHIUM EBURNEUM*
Habitat

Cerithium eburneum occurs in the shallow sandy areas associated with *Thalassia*. This species was studied at Bear Cut, Key Biscayne, Florida. Bear Cut is an inlet at the north shore of Key Biscayne leading into Biscayne Bay. The general ecology of this region has been treated in detail by McNulty (1962) and an ecological bibliography of the area has been compiled by Morrill and Olson (1955). In the shallow water

along the north shore of Key Biscayne, the plants *Thalassia, Valonia* and *Padina* are common. These shallow areas and their associated biota extend up to the sublittoral zone. Tidal fluctuations are about 1 m and flushing currents of considerable strength may be generated by changing tides. During the sampling periods the average bottom water temperature was 26.7°C, ranging from 22°C in December 1970, to 33°C in August 1969. The average salinity was 37°/∘∘ with a low of 34°/∘∘ in August 1970, and a high of 40°/∘∘ in December 1969. The water is usually clear, but can become turbid due to strong winds and rough seas.

The population of *C. eburneum* occurred sub-tidally, just beyond the low tide mark (MLT), but was never observed completely exposed. The snails were dispersed on a sandy substratum near beds of *Thalassia* at a density of about $4/m^2$. Populations observed in the Florida Keys and British Honduras occupy the same kind of habitat.

Behavior

Cerithium eburneum is an active snail and crawls on the surface of algal-covered stones and shells between the grass beds as well as on the blades of *Thalassia*. The snails were normally on the surface of the substratum but some burrowing was occasionally observed. This snail lived well in captivity. Its mode of locomotion is monotaxic, direct.

Food and Feeding

Cerithium eburneum was fed in captivity on local algae and detritus. It was frequently observed eating complex algal mats, detritus, and the epiphytic algae on *Thalassia* leaves. Examination of stomach contents revealed detritus, fine sand grains, diatoms, blue-green algae such as *Anacystis aeryginosa* and *Mirocoleus lyngbyaceus,* and the green algae *Enteromorpha* and *Chaetomorpha*. Fecal pellets also contained the above material and were heavily invested with mucus.

Associations and Predators

Cerithium eburneum is occasionally found with *C muscarum.* In the Bear Cut population, the former often has its shell covered with filamentous green algae. The young of *Crepidula fornicata* are frequently attached to the siphonal canal of *C. eburneum* (36% of the Bear Cut population).

The prosobranch snails, *Cymatium nicobaricum* and *Fascioloria tulipa* were observed eating *C.*

eburneum. Many drilled shells were found indicating predation by naticid or muricid snails. Crabs such as *Callinectes sapidus* and *Calappa flammea* were also observed eating *C. eburneum.* Randall (1967) found *C. eburneum* in the stomachs of the blenny, *Labrisomus nuchipinnis,* the puffer, *Diodon holocanthus,* and the porcupine fish, *Diodon hystrix.* Predation by rays is also suspected.

Growth

Cerithium eburneum has an indirect development (Houbrick, 1970), but due to difficulties in raising the pelagic larvae, it is unknown how long the planktonic stage is maintained. Judging from the small larval shells, and the well-developed velum and cilia, the planktonic stage may be lengthy. Fretter and Graham (1962) have indicated that in species such as *Cerithium,* where the adult shell has a tall spire, there is a fairly long pelagic phase.
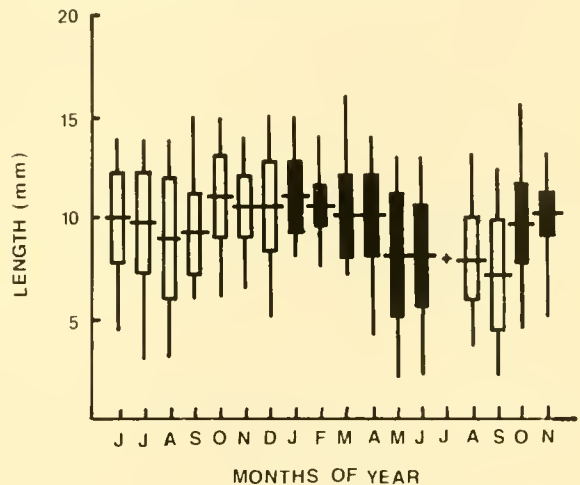

Fig. 3.   Cerithium eburneum. *Growth of population expressed as a measure of shell length. Vertical lines represent range, horizontal lines the mean, and bars, the standard deviation. Solid bars represent months of oviposition. Asterisk represents months of oviposition when other measurements were not made.*

Young snails 7-8 mm in length were first found in the population at midsummer and continued to appear through October. Although this was 4 months after oviposition, the young that had metamorphosed and settled out of the plankton to a benthic substratum may have been so small that they were overlooked until they attained a larger size. Therefore, the young snails that I collected may have settled several months earlier. This would indicate

TABLE 1. *Environmental distribution of* Cerithium *and* Rhinoclavis *species.*

Environments: 1. Sandy bottom 2. Rocky shore 3. Grass beds 4. Sand and rubble 5. Reef edges and fronts. Qualitive Abundance: R=rare, P=present, C=common, A=abundant.

Species	Predominant Plant Associations	Intertidal Zone			Subtidal Zone	Locale	Author
		MHW	MTL	MLW			
C. lutosum	Chaetomorpha Gracilaria Hypnea Halophila Enteromorpha Thalassia	1,2,R	1,2,A	1,2,A	1,P	Florida Jamaica	This study Jackson, 1972
C. muscarum	Thalassia Halodule Syringodium	-	-	3,R	3,A	Florida	This study Jackson, 1972
C. litteratum	Hypnea Ceramium Dictyota Halmeda	-	-	-	2,C;3,P; 4,C	Puerto Rico Florida	Warmke & Almodovar, 1963; Arnow et al., This study
C. eburneum	Laurencia Dictyota Padina Thalassia	-	-	3,P	3,C	Puerto Rico	Warmke & Almodovar, 1963; Arnow et. al., 1963; This study
C. guinaicum		-	-		4,C	Florida	This study
C. atratum	Enteromorpha Gracilaria	-	-	4,P	4,A;1,C	Florida	This study
C. nodulosum	Porolithon Lithophyllum Polysiphonia	-	-	5,P	5,C 5,P	Eniwetok Seychelles	This study Taylor, 1968

Species	Predominant Plant Associations	Intertidal Zone MHW	MTL	MLW	Subtidal Zone	Local	Author
C. columna	-	-	-	-	4,C 3,P;4,P	Eniwetok Seychelles	This study; Taylor, 1968
C. morum	Gracilaria Thalassia Enteromorpha	2,A; 3,P 2,A 2,A	-	-	-	Seychelles Eniwetok Aldabra	Taylor, 1968; This study Taylor, 1971
C. piperitum	-	-	-	-	4,P	Seychelles	Taylor, 1968
C. echinatum	-	-	-	-	4,R 4,A	Hawaii Seychelles	This study; Taylor, 1968
C. sejunctum	Jania	2,A	2,P	-	-	Eniwetok	This study
C. alveolus	Jania	-	2,A	-	-	Eniwetok	This study
C. articulatum	-	-	-	-	3,P;5,C	Seychelles	Taylor, 1968
C. rostratum	Enhalus Thalassia Syringodium Halophila Cymodocea	-	-	-	3,4	Aldabra	Price, 1971
Rhinoclavis asper	-	-	-	-	1,C 3,C;4,C	Eniwetok Seychelles	This study; Taylor, 1968
R. fasciatus	-	-	-	-	1,C	Eniwetok	This study
R. pharos	-	-	-	-	1,P	Eniwetok	This study
R. sinensis	-	-	-	-	4,C;5,P	Eniwetok Hawaii	This study

that a possible pelagic period of 2-3 months. After the larvae settled, growth was rapid; the young snails observed in October had reached an adult size by the end of November. If one allows a month between settling and the first observation of young snails, it would take about 2 months for newly settled snails to reach a mature size. New growth, indicated by the presence of fresh whorls and thin apertural lips, occurred from July through November. Growth statistics for the entire sampling period are summarized in figure 3. Population size, in numbers, was lowest during the summer months, indicating that after the spawning period many of the adults died. The new generation showed up in late summer and by early winter the population size had considerably increased. It is thus probable that the life span of this population of *C. eburneum* is about 1 year (Fig. 3).

ECOLOGY OF *CERITHIUM ATRATUM*

Habitat

This species lives in habitats of considerable ecological diversity. It has been collected in shallow, sandy bottoms and dredged from deeper waters in the open sea. It may be found on limestone substratum, areas of rubble, sand, or in *Thalassia.*

The collecting site at which *C. atratum* was studied is located at Dunedin, Florida, along St. Joseph Sound. The population was found on the north side of the causeway that runs to Honeymoon Island. Tides here range about 1 m and the causeway shore is subject to frequent wave action. Average water temperature was 26.7°C, ranging from 17°C in January 1969, to 42°C in June 1969. Mean salinity was 34.6°/oo with a low of 31°/oo in June 1969, and a high of 38°/oo in July 1969. As in all shallow water environments, salinity is subject to sudden change by runoff from heavy rains. The bottom of the shallow portions of St. Joseph Sound is covered with *Thalassia.* Along the causeway, the bottom is irregular, consisting of rubble dredged up when the causeway was built. The rocks are covered with various filamentous algae and *Gracilaria* and *Enteromorpha* are common. Winds, waves and tidal action deposit considerable amounts of debris and detritus throughout the intertidal zone, and the waters are frequently turbid.

Cerithium atratum occurs subtidally in great numbers (150/m²) just below the low-tide mark in a band 2 m wide bordering the causeway. It is usually found buried in the calcareous sand around the bases of rocks and rubble. This species was rarely seen crawling on the substratum except during calm periods. It does not occur beyond the rubble area.

Another population observed at Point of Rocks, Sarasota, Florida, was browsing upon the algal-covered rocks on a rocky subtidal shelf. In Sarasota Bay, I found *C. atratum* crawling subtidally on open sandy flats at low tide.

Behavior

Cerithium atratum is easy to maintain in the laboratory. In the lab, it is a relatively inactive animal, is usually burrowing, and moves mostly in the dark or when disturbed. Its mode of locomotion is monotaxic, direct. In the field, it burrowed and was rarely found at the surface of the substratum. Clustering on the surface was not observed, but many individuals were often found together in the sand at the bases of rocks. The animal exhibits a rapid shadow response by quickly withdrawing into its shell. Dr. Steiger (pers. commun.) claims that this species is migratory, but no migration was observed in the Dunedin population or at any other sites during the study period.

Food and Feeding

In the aquarium, *Cerithium atratum* feeds intermittently. After periods of starvation it is able to detect the presence of fresh algae and detritus placed in the aquarium and will immediately emerge from the sand and begin feeding. Feeding also occurs during the night. Stomach contents reveal many coarse sand grains, detritus, crustacean appendages, diatoms, blue-green algae and other debris. *Enteromorpha* and unidentified evaculated algal cells were also found. In captivity, *C. atratum* fed upon the detritus on the bottom of the aquarium, on decaying *Thalassia* and the alga, *Enteromorpha.*

Associations and Predators

The potamidid snail, *Batillaria minima*, is found just above the upper limits of the distribution of *C. atratum* and extends upwards to the splash zone. No mixing between the two species was seen, (although they appear to play the same trophic role in their respective zones). *Cerithium atratum* is frequently covered with *Enteromorpha*, bryozoans, barnacles, and young oysters. It is often parasitized by annulated rediae which give rise to fork-tailed strigeata-like cercariae.

Predators include the carnivorous snails, *Pleuroploca gigantea, Fasciolaria hunteria, Busycon contrarium* and *Melongena corona*. The crab, *Menippe,* was also seen eating *C. atratum.* Off-shore, *C. atratum* is frequently found in the stomach of the starfish *Astropecten articulatus* (W. Lyons, pers. commun.).

Growth

Although samples of this population were collected monthly over a period of two and one half years, no significant changes in the mean length of individuals in the population occurred. Oviposition occurs from March through July and development is indirect. A few young snails were found in November, December, and January of 1970, but despite thorough screening of the sediments, no other juveniles were encountered. Consequently, it is not possible to estimate the growth rate of this population.

ECOLOGY OF OTHER SPECIES

Other, less detailed, observations were made on *Cerithium* species in Florida, the Caribbean, and in the Pacific.

In Florida and the Caribbean, populations of *Cerithium litteratum* (Born) occur just at the low tide mark and subtidally. They are usually associated with algal-covered rocks and rubble found near the shore line and in shallow water patch reefs. I observed a large subtidal population of *C. litteratum* on an algal-covered rocky bottom off of Boca Raton, Florida. Stomach contents of members of this population contained detritus and the algae *Enteromorpha* and *Chaetomorpha.*

Dead snails with drilled shells were common at Boca Raton indicating predation of boring gastropods. Randall (1967) found *C. litteratum* in the stomach of the puffer fish, *Diodon holacanthus.*

Cerithium guinaicum Philippi, 1849, [=C. *auricoma* Schwengel][1] occurs subtidally (1-3 m) in southern Florida and throughout the Caribbean under rocks and in the sandy pockets associated with reef flat rubble, I found large populations in reef habitats both at Sand Key, Florida and along the barrier reef off British Honduras. Captive specimens avoid bright light. Stomach contents contain detritus, *Foraminifera* and carbonate sediments. Many drilled shells were seen.

[1] *C. auricoma* Schwengel, 1940 is a synonym of *C. guinaicum.*

In the Pacific, at Eniwetok Atoll, Marshall Islands I observed members of the genus *Cerithium* and the closely related genus *Rhinoclavis* in the shallow water on reef flats and lagoons. Wiens (1962) has discussed the general ecology of atolls and the Marshall Island group. At Eniwetok, different species of *Cerithium* are separated by microhabitat, bottom types and tidal zonation. *Cerithium morus* Lamarck occupies the higher tidal zones, where it is found under rocks and on beach rock. On the windward limestone benches, *C. alveolus* Hombron & Jaquinot is found associated with the alga, *Jania* at about the midtide mark, *Cerithium columna* Sowerby and *Rhinoclavis sinensis*
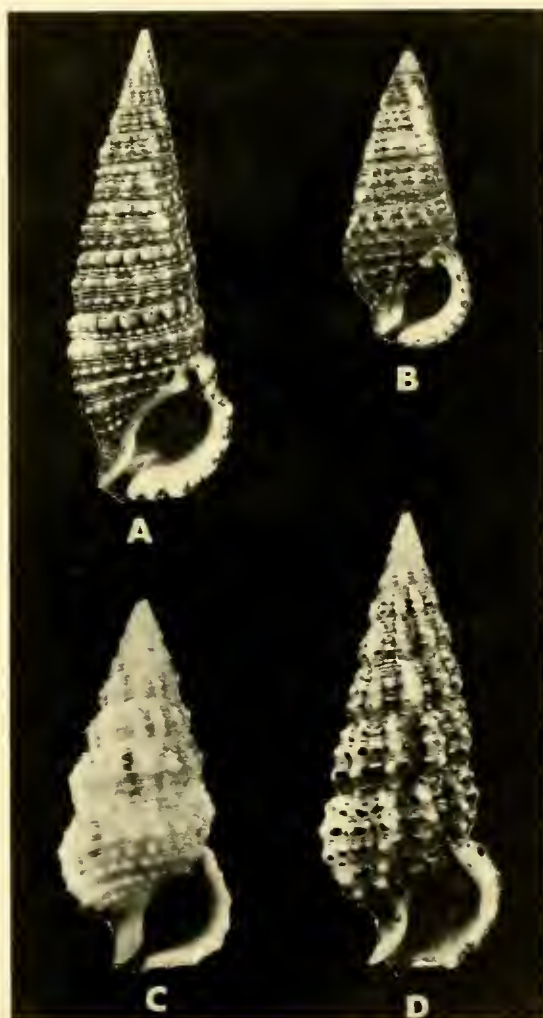

Fig. 4. A., Cerithium atratum *(Born)* [*formerly* C. floridanum *Mörch*] B., Cerithium lutosum *Menke (formerly* C. variabile *C. B. Adams);* C., Cerithium eburneum *Bruguière;* D., Cerithium muscarum *Say.*

(Gmelin) are most common on the patch reefs and in the rubble at the edges of coral reefs. *Cerithium nodulosum* Bruguière is found on rocky substratum just shoreward of the windward reef edges. *Rhinoclavis fasciatus* (Bruguière) and *R. asper* (Linnaeus) are found in sandy bottoms of leeward lagoons.

Taylor and Lewis (1970) found four species of *Cerithium* in the marine grass beds of Mahé, Seychelles. All were algal-detritus feeders. *Cerithium rostratum* Sowerby lives in grass beds in the leaves. *Cerithium morus* is present in large numbers in the sediment surface of the grass beds, in contrast to its habitat on Eniwetok. *Rhinoclavis asper* is found buried beneath the sediment on windward reefs.

The stomach contents of these Indo-Pacific species consisted primarily of detritus, carbonate sediments and algae. *Cladophora* and *Chaetomorpha* were found in the stomach of *C. morus* while the blue-green alga, *Lyngbia* and the red alga, *Polysiphonia*, were common in the stomach of *C. nodulosum*. Taylor and Lewis (1970) observed *C. rostratum* engulfing the epiphytic alga, *Enhalus* on Seychelles.

I observed the carniverous snail, *Cymatium nicobaricum*, eating *Cerithium columna* at Eniwetok. The same predator eats *Rhinoclavis sinensis* in Hawaii (Houbrick and Fretter, 1969). The snail, *Pleuroploca trapezium*, preys upon *C. echinatum* (Lamarck) in Seychelles (Taylor and Lewis, 1968). *Morula granulata*, a muricid snail, reportedly eats Hawaiian species of *Cerithium* (Kohn, 1970).

DISCUSSION

The environmental distributions of members of the genus *Cerithium* are summarized in Table 1. Most species are tropical or subtropical, and temperature is undoubtedly the primary limiting factor in their distribution. It is difficult to derive any coherent ecological conclusions because only four species and their respective stations were examined in detail and the geographic ranges of these four species are extensive. Moreover, some species, such as *C. lutosum*, occur in a variety of habitats and under differing environmental regimes. Substrate preferences of cerithiids appear to vary between soft and hard bottom types. Most species occur on sandy bottoms or hard bottoms with algal mats.

In terms of vertical distribution, the species most frequently exposed during low tides in the Western Atlantic are *Cerithium lutosum* and *C. muscarum.*

Cerithium lutosum, the smallest member of the genus in the western Atlantic, occupies the highest tidal level, close to shore, while *C. eburneum, C. atratum* and *C. litteratum* occur subtidally. *C. guinaicum* lives in the deepest zones. *C. atratum, C. litteratum* and *C. guinaicum* are the largest of the western Atlantic species.

In the Pacific, *C. morus, C. alveolus* and *C. sejunctum,* all small species, occupy the intertidal zone; *C. morus* lives in the highest tidal zone; *C. columna* and *C. echinatum* are found subtidally; the largest species, *C. nodulosum,* occurs in deeper, subtidal zones. Thus a pattern emerges in which species which are found intertidally are smaller than those occuring subtidally. Jackson (1972) noted the same phenomenon in Jamaica and suggested that epifaunal mollusks from high stress environments tend to be much smaller than their more stenotypic relatives. Atapattu (1972) found that *Cerithium* species in Ceylon were more abundant in sheltered places along the coast.

In Florida *C. muscarum* and *C. lutosum* are more euryhaline than other species although *C. atratum* is in the brackish waters of the Intercoastal Waterway at St. Lucie, Florida. Parker (1959) found *C. lutosum* in the hypersaline waters of the Laguna Madre, Texas.

Many species of *Cerithium* are loosely associated with beds of marine grasses such as *Thalassia* and *Ruppia.* A summary of the plant and algal associations with *Cerithium* species throughout the world is given in Table 4.

All species of *Cerithium* that I examined are style-bearing algal-detritus feeders. In Florida, the Caribbean, and the Pacific, I observed several species occuring together in the same general habitat. Kohn (1971) has suggested that co-occurring congeners that feed selectively on detritus tend to specialize to different micro-habitats. This is probably true of *Cerithium* species because the stomach of all examined species are complex structures, highly specialized for the sorting and transport of small particles and detrital material, indicating that partical selection is taking place. Driscoll (1972) found that the stomachs of the potamidids, *Batillaria zonalis* and *Cerithidea californica,* were specialized to selectively transport and digest a continuous supply of detritus by means of complex ridges, grooves and ciliary currents. *Batillaria* and *Cerithidea* species are related style-bearing mesogastropods of the super-family Cerithiacae. The role of detritus in the nutrition of

marine detritus feeders has been discussed by Newell (1965) who suggested that animals living on detritus feed by abstracting proteins from the bodies of microorganisms, such as bacteria that coat the silt and organic debris, and reject the organic carbon compounds with the feces. Odum (1971) pointed out that detritus feeders obtain some of their energy directly from plant material, most of it secondarily from microorganisms, and some tertiarily through carnivores, such as protozoa and small invertebrates. I was unable to distinguish what the sympatric species of *Cerithium* selectively ate and consequently their exact ecological niches in the trophic scheme remain unknown. It is probable that competition is avoided and ecological niches determined by particle selection in the complex sorting mechanisms of the stomach. But as Odum (1971) stated, apportioning the energy sources utilized by detritus feeders at the individual and species level presents a difficult technical problem which has not been solved.

I observed many *Cerithium* species engulfing algae as well as detritus, especially the small epiphytic algae associated with blades of marine grasses. Feeding occurs continuously as in most mollusks possessing a style (Graham, 1939). A review of style-bearing gastropods and their feeding occurs in Driscoll (1972). The abundance of detritus and algae in shallow water habitats probably reduces competition for food among sympatric members of the genus *Cerithium.*

The reproductive biology of the genus *Cerithium* has already been discussed (Houbrick, 1970; 1971; 1973, in press).

Cerithium muscarum, C. lutosum, C. eburneum, and *C. atratum* exhibit a definite seasonal reproductive activity. Oviposition occurs in these species from winter through spring. Young snails appear in the populations during the summer and early autumn.

I was unsuccessful in attempts to rear newly hatched snails to adulthood, but size frequency data along with qualitative observations indicate that it takes about one year to attain maturity. Raeihle (1968) was successful in rearing larvae of *C. lutosum* from the Florida Keys to adulthood. She found that the larval shells were less than 1 mm in length 5 weeks after hatching; at 12 weeks they had reached 1.3 mm and by 13 months they were 8-11 mm in length and were reproductively mature, having spawned 13 months after the time of hatching. These findings are compatible with my size-frequency data

which indicate a life-span of one year.

It is more difficult to determine the growth rates of *Cerithium* species with pelagic life histories than those with direct life histories because the time spent in the plankton before settling is unknown, and one is never sure if the juveniles found in a population are products of the spawn of that particular population.

The results of this study indicate that the Florida populations of *C. lutosum, C. muscarum* and possibly *C. eburneum* grow from juvenile stages to adult stages in a few months, and that their life spans last approximately one year; however, spawning and growth may vary in other populations of *Cerithium* species depending upon their geographic distribution. Lewis *et al.* (1969) found different rates of growth for the same species of mollusks, depending upon their latitudinal distribution in the Caribbean. They also mentioned that microclimatic differences are equally as important as latitudinal ones. The annual cycles of the species studied indicate that the majority of the adult populations die after spawning. Vohra (1970) observed the same phenomenon in *Cerithidea cingulata.*

Horizontal movement, migration and seasonal recruitment from other areas were not observed in the populations of *C. lutosum* and *C. muscarum;* despite the fact that these species have a direct development, it is possible that eggs on marine grasses may drift from one locality to another. In species with indirect development, recruitment from other populations is probable. More detailed studies may reveal subtle tidal or season migrations in *Cerithium* species. Mark and recapture experiments with *Cerithium stercusmuscarum* indicate a migratory pattern due to positive phototaxis to the rising sun (Burch and Burch, 1970). Vohra (1965, 1970) found that the potamidids, *Pyrazus ebeninus* and *Cerithidea cingulata,* migrated with tides and seasons, respectively. Horizontal and vertical migrations may be correlated with drainage and presence of detrital food as well as with spawning behavior. A discussion of these factors may be found in Vohra (1970).

I observed segregation between older (larger) and younger (smaller) individuals of *C. lutosum.* Older specimens were found further upshore while the younger ones occurred just subtidally. A similar segregation pattern was also noticed by Vohra (1970) in *Pyrazus ebeninus.*

Some clustering of *Cerithium lutosum, C. morum, C. alveolus* and *C. sejunctum* occurs at low tides.

Moulton (1962) believed that this phenomenon is an adaptation of *Cerithium* to drying conditions and high temperatures on tropical beaches and postulated that clustering is a homeostatic mechanism. He suggested that *Cerithium* possesses a hydrostatic mechanism which helps to determine whether the animals shall be clustered or dispersed. Fischer (1966) added the idea that adhesion to a preferable substratum may also be a factor in aggregation.

The potamidid snail, *Batillaria minima* was found closely associated with most of the *Cerithium* species in Florida. *Batillaria* appears to fulfill the same trophic function as *Cerithium* only at a higher level in the tidal zone. Its close association and resemblance to *Cerithium lutosum* has led to confusion between the two species (Abbott, 1954), and to erroneous reports of egg laying, etc. At Port Everglades, Bear Cut, and Pigeon Key, Florida, I observed the two species overlapping in a minor degree in their vertical distribution. During periods of high seas they are frequently mixed together.

Considering the great numbers of snails observed in the study areas, it is surprising that more predators of *Cerithium* were not seen. Most of the predators listed in this study were observed infrequently and only account for minimal mortality. Fish may prove to be the main predators of the species with very large populations. A more quantitative study of predation is needed in order to elucidate the exact position of *Cerithium* species in the trophic structure of the shallow-water communities they inhabit.

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BOOK REVIEW

AMERICAN MALACOLOGISTS. *(editor) R. Tucker Abbott. First Edition, iv + 494 pages. American Malacologists, 6314 Waterway Drive, Falls Church, Virginia 22044. Hardbound, $12.50.*

This is the first attempt to bring together the biographical sketches of all American malacologists, both past and present. Its scope is wide, as it covers both the professional and amateur students interested in any phase of the mollusca.

These personal sketches cover a wide spectrum of facts, not only the vital statistics, but in addition, the interests, travels, publications and other data of much historical value. Many of the deceased persons covered in the book built up important shell collections. A large number of these collections have been given or sold to museums. Their present location is of considerable value to historians and research workers as a source of much informative data.

A feature of considerable importance, in addition to the biographies of 539 past workers, is a list of 420 persons about whom little is known other than their names. These people have had a particular interest in mollusks, and most of them at one time or another reached the printed page either as authors or collectors. Dr. Abbott hopes that interested persons may be able to add new data or give references where such information may be found. Completion of this section will be a major contribution to the history of our science.

Analyses have been made of all living malacologists as to their geographic location, their individual fields of research and endeavor, and their main occupation if they are not professional malacologists. Among our reference books, this will be one of the most frequently consulted.

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ON A SINISTRAL SPECIMEN OF *LIGUUS VIRGINEUS*
(WITH ADDITIONAL REMARKS ON THE GENUS *LIGUUS*)

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Sinistral specimens of *Liguus virgineus* (Linnaeus) from Hispaniola are exceedingly rare. Pilsbry (1899: 163-164) listed five records known up to that time, citing illustrations for three of them. However, the figures published by Küster & Pfeiffer (pl. 14, fig. 9, 10) are copies of those of Chemnitz (1788, pl. 173, figs. 1682-1683) so that up to the present, sinistral specimens have been figured only by Favanne (1780, pl. 65, fig. G4) and Chemnitz (1788).

The specimen here illustrated, therefore, is of interest. The shell was presented to The American Museum by Mr. Burton Anderson of Dania, Florida, who found it, together with another such specimen, in a shipment of *L. virgineus* from Haiti. No other data are available.

The present specimen measures 33 mm in height, 18.5 mm in width, aperture height 12 mm. The color bands are as follows: a yellow band below the suture, a purplish-black band, a slate blue one, and a rose one at the periphery. There is a faint yellow band encircling the base.

A word might be added here about the rarity of this type of teratology in the genus *Liguus*. Pilsbry (1946: 39) guessed that it occurs among *L. fasciatus* (Müller) in Florida in the order of one in 10,000 and cited the testimony of Mr. R. F. Deckert who knew of only 9 sinistral shells. W. J. Clench (personal communication) stated that he has examined perhaps 60,000 specimens of *Liguus* without having encountered a single sinistral specimen.

Dautzenberg (1914: 51) commented on the relative abundance of reported sinistral shells among *Helix pomatia* Linnaeus and *H. aspersa* Müller as compared to other pulmonate species. He concluded that this is probably due to the fact that the former were collected -- even bred -- in vast numbers for culinary purposes and thus many more shells came to the attention of collectors. This would also partly explain the scarcity of similar shells in the genus *Liguus*.

Two other minor comments can be made. Dautzenberg (1914) presented a list of all species in which dextral and sinistral teratological specimens were reported, but strangely included *Liguus poeyanus* (Pfeiffer) (=*vittatus* Swainson) of Cuba, a species which like *Amphidromus* from southeastern Asia, appears ambidextrously in most populations. Zilch (1960: 518) erroneously included Cozumel Island as lying within the range of *Liguus (Oxystrombus)*. This subgenus is limited to southern Florida, Cuba, and the Isle of Pines -- which Zilch transcribes in the Portuguese fashion as 'Isla dos Pinhos.'

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FIGS. 1 and 2. Liguus virgineus *from Haiti. Le)... a specimen of the dextral or normal form, 32 mm. in height. Right. Sinistral specimen, 33 mm. in height. (Photos courtesy of The American Museum of Natural History).*

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THE CHROMOSOME NUMBER OF *EUGLANDINA ROSEA* (STYLOMMATOPHORA: OLEACINIDAE)

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ABSTRACT

No chromosome numbers have been reported for members of the Stylommatophoran family Oleacinidae. Examination of chromosome spreads for Euglandina rosea *(Férussac) revealed a haploid number of n=29. It has been suggested that higher chromosome numbers may be correlated with phylogenetically more advanced or morphologically specialized Euthyneuran snails. The high chromosome number obtained here substantiates this, even in the light of the extremely conservative nature of chromosome numbers.*

Chromosome numbers are known for less than 0.5% of the species of recent mollusks, and none has been reported for members of the Stylommatophoran family Oleacinidae. Several individuals of *Euglandina rosea* (Férussac) were collected in January, 1973, from under moist debris along the Mississippi River levee, Port Allen, West Baton Rouge Parish, Louisiana. The snails were injected directly through the shell near the apical whorl with .15cc of Velban (1mg/ml concentration) and returned to their container. They were sacrificed approximately 16 hours later and the ovotestis removed. Meiotic chromosome squashes were prepared using an acetic-orcein squash technique as described by McPhail and Jones (1966).

Six spreads of *E. rosea* were examined and revealed a haploid number of n=29 (Fig. 1). Morphologically, with regard to the modified radular teeth, and ecologically, as evident by its carnivorous diet, *E. rosea* might be considered a
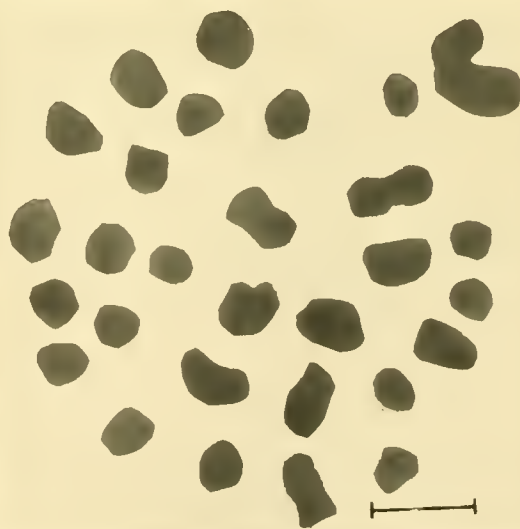

FIG. 1. *Meiotic chromosomes of* Euglandina rosea. *Scale line = 5 micra.*

specialized species. Burch (1965), Patterson (1969 and 1971) and others have suggested that higher chromosome numbers may be correlated with phylogenetically more advanced or morphologically specialized Euthyneuran snails. Conversely, lower chromosome numbers are found in the more "primitive" groups. The infraorder Holopoda contains some relatively morphologically specialized groups of land snails, including the active, rapacious members of the family Oleacinidae. Haploid chromosome numbers for the Holopoda range from n=21 to n=31. The high haploid chromosome number (n=29) of *E. rosea* seems to substantiate the above contention.

The chromosome number for *E. rosea* is similar to those found for other species in the suborder Sigmurethra, which is thought to be the most advanced Stylommatophoran group with a mean chromosome number of 28.6 and a mode of 29 (Patterson, 1971). Ranier (1967) stated that, in general, relationships suggested by cytological studies have correlated well with the modern classification of the Stylommatophora. However, because of (1) the extremely conservative nature of chromosome numbers, even at the subordinal level as noted above, and (2) the number of exceptions, as pointed out by Ranier (1967) in the Helicidae, a broad statement may not yet be justified. Nevertheless, when used in conjunction with other techniques, cytotaxonomy represents a valuable tool that may be used by the systematist in an attempt to confirm or question phylogenetic relationships previously based solely upon morphological and/or anatomical features.

ACKNOWLEDGMENT

Special thanks are given Dr. J. B. Burch for his comments concerning this paper.

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BOOK REVIEW

SEASHELL PARADE. *By A. Gordon Melvin. 369 pp., 74 pls., 1 in color. Charles E. Tuttle, Co., Rutland, Vt. 05701. Hardback, $11.50.*

For shell collectors who enjoy reading about shells and learning more about their usefulness and interest to man, this book will supply many pleasant hours. The 76 short chapters consist of illustrated vignettes, many of which had been published in *Hobbies Magazine*. A novel chapter at the end covers the biographies of some malacologists. The author requests readers to send in data on living malacologists, but this project is now superseded by the rather extensive biographies recently published in the national register, *"American Malacologists."*

An excellent chapter gives a panoramic treatment of some of the shell books likely to be of most interest to shellers. Curiously, however, the author has evidently forgotten that the writer of the famous children's book, *Captain January,* was Mrs. Laura E. Howe Richards, and not California's Julia Ellen Rogers, author of *The Shell Book.*

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Marine Molluscan Genera of Western North America

An Illustrated Key

A. Myra Keen & Eugene Coan

SECOND EDITION. First published in 1963, this Key has become the standard reference work and handbook in its field. This second edition has been completely revised and reset, the page size has been reduced to make the book more portable, and the illustrations have been provided with additional information to aid the novice in making easy identification. The text of the Keys takes account of the most recent nomenclatural changes and introductions of genera to the region, and an entirely new section has been added to identify the species used for each illustration in the Keys. The Systematic Lists, Notes on Ranges and Habitats, Glossary, and Bibliography have been greatly expanded and revised; and the Systematic Lists now include the many non-shelled genera to be found on the Pacific Coast. $8.75

Stanford University Press

A NEW SPECIES OF *VOLUTOCORBIS* FROM SOUTH AFRICA

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Some years ago Mrs. Helen Boswell, of Valhalla, Transvaal, South Africa, sent specimens of an apparently new species of *Volutocorbis* to the junior author, who prepared a preliminary description. Somewhat later Mrs. Boswell sent further specimens of the same species to the senior author. In view of this we have decided to prepare this paper jointly.

In addition to expressing our appreciation to Mrs. Boswell for her continuing cooperation, we also wish to thank Mr. Michael Meyer, of Durban North, Natal, and Mr. Kenneth J. Fuller, of Lambton, Germiston, Transvaal, both of whom have sent us material of the new species. A fine specimen, which has been made the holotype, was sent us recently by Mr. Richard N. Kilburn, of the Natal Museum, Pietermaritzburg, to whom we express our thanks.

After this paper was completed two further specimens were loaned to us by Mr. William E. Old, Jr. of the American Museum of Natural History. These specimens, found attached to *Xenophora pallidula* Reeve, were received from Mr. C. P. Fernandes of Lourenço Marques, Mozambique. They represent an extension of range, and so have been included in this paper. Our grateful thanks to Mr. Old for allowing us to examine this material.

Volutocorbis semirugata
Rehder and Weaver, *new species*
Figs. 1-8

Diagnosis — Shell of medium size, 33.0 to 55.3 mm (1¼ to 2¼ inches) in length, rather shiny, axial ribs absent on body whorl or if present found only below angulate shoulder as low broad, rather obscure folds, especially in early portion of whorl. Outer lip very much thickened and reflected, posteriorly ascendant on penultimate whorl, sometimes obscurely denticulate, especially in gerontic specimens. Resembles *V. gilchristi* (Sowerby, 1902) but is larger, with weaker sculpture on last whorl, and with sloping shoulder, not canaliculate subsuturally.

Range — From off central Natal, South Africa, between Durban and the mouth of the

FIGS. 1-8. Volutocorbis semirugata *Rehder and Weaver, new species: Figs. 1, 5, holotype, Natal Museum Moll. 9939, 45.1 mm. in length. FIGS. 2, 6, paratype #1, USNM* 709349, 54.3 mm. in length. FIGS. 3, 7, paratype #3, Boswell Colln., 47.9 mm. in length. FIGS. 4, 8, paratype #7, Boswell Colln., 38 mm. in length.

Tugela River, to off Lourenço Marques, Mozambique, in 100 to 280 fathoms.

Description — Shell of medium size, 33.0 to 55.3 mm (1¼ to 2¼ inches) in length, elongately ovate. Ground color pale yellow to straw color or light grayish yellowish brown, sometimes bluish gray on the body whorl; fresh specimens with interrupted (occasionally continuous) axial streaks of reddish brown or with spiral bands of interrupted blotches of reddish brown. Protoconch mammillate, with 2¼ smooth, rounded, pale straw-color whorls, initial whorl slightly tilted. Early postnuclear whorls with low, rather distant axial ribs that show a small node below the suture, and a somewhat larger one on the shoulder, with an obscure one below, or rarely above. The subsutural series may increase in strength for one or more whorls and then decrease, or the series may rapidly become obscure, ridgelike, and in the last whorl disappear; the shoulder knobs are strongest on the antepenultimate and penultimate whorls but become weaker on the last whorl, being present either as one or two unequal low ridges or a series of low nodes. The lower half of the body whorl is strongly marked by spiral grooves, which towards the base form angulate ridges. Aperture long, narrow, slightly arcuate, the anterior canal rather narrow and at a slight angle to the axis of the aperture. Outer lip broad, posteriorly ascending halfway up on the penultimate whorl, generally thickened internally and externally, where it forms a stout varix; noticeably denticulate at inner edge. Parietal lip meeting in a broad angle with the columellar lip which is usually made slightly arcuate by reason of the columellar pad bearing the numerous plaits; plaits on columellar pad normally 9 to 11 of varying strength, separated from basal fold by a pronounced groove. A rather broad, white callus, thick on the columellar area, extends from the inner lip over half of the ventral surface of the body whorl.

Material — Holotype: SE of the Bluff, Durban, in 120 fathoms; collected by G. Scott, August 1872. Natal Museum, Mollusca No. 9939.

Paratypes (see table of measurements below): Nos. 1, 6, 10, 13: 10-20 miles off mouth of Tugela River, in 120-150 fathoms; Nos. 3, 4, 7: 15-20 miles off Durban, in 280 fathoms; Nos. 2, 5, 8, 9: off southern Zululand, in deep water; Nos. 11, 12: 10 miles NE of Inhaca Island, Lourenço Marques, Mozambique, in 100 fathoms.

Measurements (mm)

		length	width	no. whorls
	Holotype (Natal Museum Moll. 9939)	45.1	19.5	6¼
	Paratypes			
#1	(USNM 709349)	54.3	23.6	6½
#2	(Fuller Colln.)	49.6	25.3	(apex worn)
#3	(Boswell Colln.)	47.9	21.6	6½
#4	(USNM 709350)	43.7	19.2	6¼
#5	(Visagie Colln.)	38.5	17.1	6⅛
#6	(Boswell Colln.)	36.8	17.3	6¼
#7	(Boswell Colln.)	38.0	17.4	6⅛
#8	(Meyer Colln.)	35.3	16.5	
#9	(Meyer Colln.)	33.0	15.5	
#10	(Boswell Colln.)	55.9	22.3	7
#11	(AMNH 177285)	41.6	19.8	6¼
#12	(Fernandes Colln.)	41.1	18.1	
#13	(Boswell Colln.)	on *Xenophora pallidula* Reeve		

Remarks — *Volutocorbis semirugata* is distinguished from all previously described species by the axial sculpture of the early postnuclear whorls disappearing on the last half of the body whorl leaving it smooth except on the angulate shoulder, and on the base where it is marked by spiral sculpture

One specimen, paratype No. 10, is a rather thin shell, very pale yellow without spots, and is a typically elongate with the outer lip only moderately thickened.

ON THE GENUS *VOLUTOCORBIS* WITH DESCRIPTIONS
OF TWO NEW SPECIES FROM SOUTH AFRICA

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In the last few years I have received new material of the genus *Volutocorbis* from Mrs. Helen Boswell of Valhalla, Transvaal, South Africa, and from Mr. Kenneth J. Fuller of Lambton, Germiston, Transvaal. Among them are specimens of three new species, two described in this paper, and one described in a previous paper in this issue of *The Nautilus* (vol. 88, no. 2). In a loan of several interesting species of marine mollusks from the Natal coast, sent to me by Richard N. Kilburn of the Natal Museum, Pietermaritzburg, were specimens of two of the new species described in these papers. To all these correspondents I give my grateful thanks.

Darragh (1971) has questioned the propriety of regarding this genus as distinct from *Athleta* Conrad, 1853, and *Volutospina* Newton, 1906. In this respect he follows the conclusions reached by Cossmann (1909, p. 210), who suggests that *Volutocorbis*, *Volutospina* and *Neoathleta* Bellardi, 1890, should be considered junior synonyms of *Athleta* Conrad, 1853, because he felt that in sculptural characters and general shape there were species that represented transitional stages between these groups that he had at one time considered of sectional rank. In support of this viewpoint he cited the work of Burnett Smith (1906) on the races of *Volutilithes petrosus* Conrad, 1853.

Both Cossmann and Darragh with justice depreciate the importance of the size and number of whorls of the protoconch as a basic character in classifying the Volutidae. Cossmann complained that Dall overemphasized the generic significance of the nuclear whorls while ignoring the characters of the columellar folds (Cossmann, 1907, p. 191). Earlier, Cossmann (1899, p. 101) in discussing his classification of the Volutidae had stressed the necessity of utilizing all characters found in the shells.

In the process of reviewing the problem of the proper allocation of the group *Volutocorbis* I decided to use this occasion to reorganize and arrange the Cenozoic members of the family Volutidae present in the National Museum of Natural History. I had, therefore, the opportunity of examining hundreds of specimens from both Europe and the United States, which I attempted to arrange according to what I considered a logical classification. Particular attention was paid to the representatives of the subfamily Athletinae. Needless to say, the conclusions arrived at, and which I outline in the following paragraphs, are in a sense prelim-
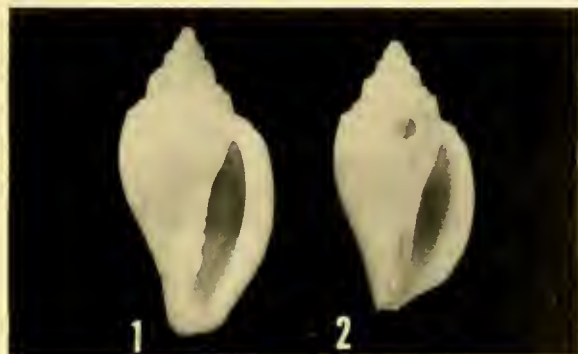
FIGS. 1-4 Volutocorbis nana *Rehder, new species: FIGS. 1, 3, holotype, USNM 709351,* 23.5 mm. in length. FIGS. 2, 4, paratype, Fuller Colln., 20.6 mm. in length.

inary, and should be considered as suggested guideposts in future, more detailed phylogenetic studies similar to the excellent one published by Fischer, Rodda, and Dietrich (1964). It is to be hoped, however, that these studies will involve related species and genera from other faunal areas, on both sides of the Atlantic.

Darragh in his study makes only occasional references to the columellar plaits found in members of the groups under discussion, emphasizing primarily the characters of the protoconch and external sculpture. I believe that the folds on the columellar can be utilized in arriving at a satisfactory classification provided one considers their basic characters and is not led astray by minor details.

I consider *Athleta* Conrad, 1853, whose type-species is *Voluta rarispina* Lamarck, 1811, of the Miocene of France, to be distinct from the *Volutospina* — *Volutocorbis* complex. The columellar folds are stouter, with two lowermost ones equal or subequal in strength, the upper one of the two frequently the stronger. On opening the shell behind the aperture three ascendant plaits are seen on the columella, the upper one usually less prominent than the other two. The early postnuclear whorls may be cancellate or with axial ribs crossed by spiral grooves. The protoconch is turbinate or mammillate with several smooth whorls. Synonyms are *Eoathleta* Gardner, 1945, and *Volutovetus* Pilsbry and Olsson, 1954. Based on the figure and description *Bendeluta* Eames, 1957, may also for the time being be placed in the synonymy of *Athleta*.

The genera *Volutocorbis* Dall, 1890 (type-species *V. limopsis* (Conrad)) and *Volutospina* Newton, 1906 (type-species *V. spinosa* (Linné)) are very closely related. Both groups have the columellar folds rather steeply ascending with the most anterior one the strongest and the posterior varying greatly in number and sometimes on a more or less prominent columellar pad. In sculpture and shape one can find among the European Eocene species an almost complete gradation from *V. spinosa* (Linné, 1767) through

luctator Solander in Brander, 1766 — *scalaris* Sowerby, 1843 — *ambigua* Solander in Brander, 1766 — *suturalis* Nyst, 1836 — *crenulifer* Bayan, 1870, to *digitalina* Lamarck, 1811, a species close to the type species of *Volutocorbis*. It is therefore difficult to determine the limits of these groups, and therefore for the present I consider *Volutocorbis* Dall as the generic name to be used, with *Volutospina* Newton as a junior synonym. As Darragh points out some of the recent South African species I have described resemble closely the Miocene species *V. suturalis* Nyst, 1836.

Notoplejona Marwick, 1926, seems to be a genus rather variable in sculpture, judging from the literature and the two specimens I have been able to examine in the collection here. The nature of the columellar folds and the characters of the sculpture lead me to place it near *Volutocorbis* but as a distinct subgenus because of the strong parietal callus and broad anterior siphonal notch.

I have been unable to examine a specimen of *Voluta affinis* Brocchi, 1814, the type-species of *Neoathleta* Bellardi, 1890, but the figure given by Brocchi shows a species that seems to belong in *Volutospina* (i.e. *Volutocorbis*). Cossmann states that *affinis* is congeneric with *Voluta cithara* Lamarck, 1811, the type-species of *Volutopupa* Dall, 1890, which, judging from the figure of *affinis*, seems unlikely. Until the protoconch of *V. affinis* can be examined and described, I am inclined to add *Neoathleta* to the synonyms of *Volutocorbis* Dall, 1890. Unfortunately, the date of publication of *Neoathleta* Bellardi is 6 April 1890, while that of *Volutocorbis* Dall is August 1890, so that *Neoathleta* would replace *Volutocorbis* as a generic name, if my surmise on the allocation of *affinis* is correct. However, because of the present uncertainty as to the nature of the protoconch of the species, I am continuing to use *Volutocorbis*, and consider *Neoathleta* to be a *genus inquirendus* for the present.

Dall, in 1890, proposed the name *Volutopupa* as a section of *Volutilithes* for a group of species with a high, many-whorled, relatively large protoconch, citing as type

Voluta cithara Lamarck. This name, as stated above, Cossmann placed in the synonymy of *Neoathleta* Bellardi, and included in the group a number of Paris Basin species, some of which undoubtedly do not belong here. The only one that is definitely congeneric with *V. cithara* is *lyra* Lamarck, and *V. lineolata* Deshayes also is probably a *Volutopupa*. I have examined the protoconch of *V. bulbula* Lamarck, 1803, and find that it possesses a small, conical protoconch with few whorls, and thus should be placed in *Volutocorbis*. *Volutopupa* can be retained as a subgenus of *Volutocorbis* for those species with a relatively large, elevated-conical, multispiral protoconch, and a rather thin shell with a more less inflated last whorl.

The Australian species, that Darragh places in *Athleta (Ternivoluta)*, and of which I have been able to examine several lots of *antiscalaris levior* (McCoy, 1866) and *anticingulata* McCoy form *indivisa* McCoy, 1866, I would place in the "*Volutospina* section" of *Volutocorbis*.

Ternivoluta Martens, 1897, is definitely worthy of subgeneric rank under *Volutocorbis* because of its large, paucispiral, deviated protoconch. The Australian Eocene to Miocene species that Darragh placed in *Ternivoluta* belong in *Volutocorbis* since they possess a protoconch typical of this group and the posterior columellar folds are not placed on a columellar pad that is generally found in *Ternivoluta*.

Volutocorbis nana Rehder, *new species*
Figs. 1-4

Diagnosis — Shell small, with strong axial ribs and obscure spiral sculpture, a thick outer lip, and four to five folds on the columellar wall. Closest to *V. gilchristi* (Sowerby, 1902), which is strongly subsuturally channeled, with stronger spiral sculpture, and more pronounced columellar folds.

Range — Off southern Zululand, Natal, South Africa, in 160-180 fathoms.

Description — Shell small, 20.6 to 23.5 mm (3/4 to 7/8 inches) in length, ovate, rather stout, color of dead shells dull ivory white.

Protoconch depressed-mammillate, of about 1½ smooth whorls, early postnuclear whorls marked by rather sharp axial riblets, 20 in second postnuclear whorl, marked by two increasingly prominent nodes, one subsutural and the other stronger; the narrow platform-like subsutural ramp and the strong nodes at the shoulder give the early postnuclear whorls a stepped appearance; in the penultimate and ultimate whorls the subsutural ramp becomes gradually more inclined and the subsutural row of nodes less angulate. The last whorl with 16 and 18 axial ribs in the two specimens seen, showing obscure minor nodes below the shoulder, marking the presence of obscure spiral ridges, which continue anteriorly to the neck where they become rather strong cords; in the mid-portion of the last whorl they are visible only as very faint nodes on the ribs. Aperture narrow; outer lip gently arcuate, broad, thickened internally, and varicose, possibly obscurely denticulate in fresh specimens; inner lip weakly angled at juncture of parietal and columellar portions, the latter with 7 or 8 low rounded folds of varying strength, the anteriormost one the largest. Parietal callus thin, obscure.

Material — Holotype: off coast of southern Zululand, Natal, in 160-180 fathoms, attached to *Xenophora pallidula* Reeve, USNM 709351. Paratype: same locality as holotype; also attached to *Xenophora pallidula* Reeve; Fuller Collection.

Measurements (mm)—

	length	width	no. whorls
Holotype	23.5	12.5	6¼
Paratype	20.6	11.0	6

Remarks — This species is distinct because of its small size (the holotype has the same number of whorls as the holotype of *V. semirugata* Rehder and Weaver, 1974, measuring 45.1 mm, almost twice as long), relatively strong axial riblets, without obvious spiral sculpture on the upper parts of the whorls, and the thickened, varicose outer lip.

Volutocorbis mozambicana Rehder, 1972

1972. *Volutocorbis mozambicana* Rehder. The Veliger, vol. 15, p. 12, figs. 3-5, 7-9.

I have recently received a specimen of this species trawled off Durban, which extends the previously known range of this species southward for 650 miles.

Through the kindness of Mr. Richard N. Kilburn 1 have been able to examine the holotype of *Volutocorbis glabrata* Kilburn, 1971. This species is somewhat larger, with a relatively shorter spire, and a last whorl which is smooth rather than strongly sculptured as in *mozambicana;* the whorls lack the subsutural shelf seen in the latter species.

Volutocorbis kilburni Rehder, *new species*
Figs. 5-8

Diagnosis — Shell smooth except for very faint, obscure, irregular spiral threads, and with a pronounced and narrowly canaliculate suture. Outer lip moderately thickened and recurved, narrowly varicose externally.

Range — From off Ilha Bazaruto, Inhambane, Mozambique, to off Durban, Natal, South Africa in 180 to 280 fathoms.

Description — Shell of medium size, 33 to 39.2 mm (1¼ to 1½ inches) in length, ovately obconical with evenly convex whorls separated by a deeply impressed suture. Color dark grayish yellow (Kelly and Judd, 1965; color No. 91), the body whorl with distant reddish brown spots below the suture, occasionally prolonged into streaks, and with obscure pale maculations over the whole whorl, these becoming darker and more or less arranged in spiral bands towards the apertural outer lip; the bands mark the varix of the outer lip with rectangular maculations. Protoconch conical-mammillate, consisting of

2¼ smooth convex whorls with impressed suture. Early postnuclear whorls with flattened subsutural shelf which gradually becomes convex as the suture deepens and becomes canaliculate. Postnuclear whorls rather high and weakly convex, resulting in a rather narrowly conical spire; whorls smooth, without sculpture, except for very weak, obscure spiral ridges and irregular growth ridges. Aperture narrowly elongate, outer lip gently arcuate, thickened and reflected, smooth; inner lip rather straight, only slightly angled at juncture of parietal and columellar portions; columellar lip with a thickened callus on which are situated 9 to 12 folds, the 7 to 10 upper or posterior ones separated from the two anterior ones by a more pronounced gap; of the latter two the posterior one is large, the anterior one low and broad. Siphonal canal rather broad and open. Parietal callus very thin.

Material — Holotype: 15 miles off Durban, Natal, in 280 fathoms; USNM 709352. Paratype No. 1: 10-15 miles off Durban, Natal, in 280 fathoms; Boswell Collection. Paratype No. 2: off Ilha Bazaruto, Inhambane, Mozambique, in 180 fathoms; ex A. Visage; Natal Museum Moll. No. 9769.

Measurements (mm) —

	length	width	no. whorls
Holotype (USNM 709352)	39.2	18.3	6¼
Paratype #1 (Boswell Colln.)	38.1	18.5	6¼
Paratype #2 (Natal Museum Moll. 9769)	33.0	15.1	6⅛

FIGS. 5-8. Volutocorbis kilburni *Rehder, new species: FIGS. 5, 7, holotype, USNM 709352,* 39.2 mm. in length. FIGS. 6, 8, *paratype, Boswell Colln., 38.1 mm. in length.*

Remarks — This distinctive species is not close to any known forms of *Volutocorbis.* Paratype No. 2, from off Mozambique, is an immature specimen with a thin, not fully formed outer lip.

This species is named for Mr. Richard N. Kilburn of the Natal Museum, Pietermaritzburg, Natal, in appreciation of his important contributions to our knowledge of the molluscan fauna of this part of the South African coast.

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BOOK REVIEW

INTERTIDAL MOLLUSKS OF IQUIQUE, CHILE. By Marincovich, Louie. Los Angeles County Natural History Museum, Science Bull. 16, 49 pp., 102 figs. Feb. 20, 1973. Available from Los Angeles County Museum Bookshop, $2.35 (postpaid, including tax).

Although the west coast of South America was early explored and the first mollusks from there were described as long ago as 1782, the fauna has remained rather sketchily represented in most collections. Literature is scanty and scattered. The present work results from two collecting trips, comprising a total of six months of intertidal collecting. Some 87 molluscan species and one brachiopod are discussed, all being well illustrated by photographs and by line drawings of radulae (except for five forms that are specifically unidentified). One new genus, *Salitra*, is proposed in the family Columbellidae. The type species, *S. radwini*, also is new. Ten other new species are described, in the genera *Nucula*, *Lyonsia*, *Tricolia*, *Eatoniella*, *Eatonina*, *Fartulum*, *Aesopus*, and *Iselica*.

The systematic account is well documented, and the utility of the paper is increased by discussion of biogeography and by a review of pertinent literature. The author is to be commended for this useful work.

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THE DISTRIBUTION and ECOLOGY of
COMMON MARINE and ESTUARINE PELECYPODS
in the DELAWARE BAY AREA[3]

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ABSTRACT

Samplings from 1967 to 1973 of the marine-estuarine pelecypods of the Delaware Bay region indicates that about half of the 44 common species are true estuarine while the other half are evenly distributed between euryhaline and stenohaline marines, with only a single oligohaline species, Rangia cuneata. *The latter case is a northern range extension for this southern species.*

INTRODUCTION

This research was undertaken to determine the distribution and ecology of common marine and estuarine pelecypods in the Delaware Bay area. Increased attention to pollution problems has renewed interest in benthic ecology. As a result, a series of local surveys have been conducted dealing with different taxonomic groups (Watling and Maurer 1972 a, b, Watling et al, 1973). This paper represents a part of those surveys.

Lowden (1965) provided an annotated checklist of marine molluscs which covered Delaware Bay and New Jersey ocean beaches and enclosed bays. Watling and Maurer (1974) prepared a guidebook for the Delaware Bay region fauna which included a taxonomic key for the marine and estuarine molluscs. Moreover, some studies on pelecypods collected among oyster beds were also reported (Maurer and Watling 1973 a, b).

METHODS

This report is based on samples collected from 1967 to 1973 with a wide variety of sampling gear; epibenthic dredge, oyster dredge, hard clam dredge, hydraulic surf clam dredge, Van Veen bottom grab (0.1 m^2), Petersen bottom grabs (0.1 m^2 1/15 m^2). Several areas on Coast and Geodetic Survey

[3] Contribution No. 84, College of Marine Studies.

Maps 1218 and 411 which received intensive sampling are: 1) quantitative samples off Cape Henlopen, 13 transects from the capes to Woodland Beach, Cape Henlopen flat, Rehoboth, Indian River, and Little Assawoman Bays, eight miles east of Rehoboth, 2) qualitative samples include the above sites together with heavy sampling in Delaware's oyster beds. 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, dissolved oxygen) were collected for many of the samples together with samples of the sediment. The sediment samples were dried and sieved through a graded sieve series to determine sediment particle size.

RESULTS AND DISCUSSION

A list of the species discussed in this paper together with a summary of their ecology is presented in telescopic form. Salinity values, spawning and substrate data are derived from our data in the Delaware Bay region and from other sources (Chanley 1958, Loosanoff *et al.* 1966, Chanley and Andrews 1971). Notations for burrowing behavior are drawn from Stanley (1970). Carriker (1967) developed a scheme of geographic divisions, salinity

ranges, types and distribution of organisms in estuaries. His scheme is adopted to facilitate comparison with other estuaries.

Among 44 species, 20 species are designated as true estuarine, 11 as euryhaline marine, 12 as stenohaline marine, and one as oligohaline. These designations represent the maximum distribution of these species rather than exceptional or marginal occurrences.

OLIGOHALINE

Rangia cuneata is the only local oligohaline species. It was reported from upper Chesapeake Bay and Elk River, Maryland (Pfitzenmeyer and Drobeck 1964). Subsequently, Gallagher and Wells (1969) indicated that it should be expected in upper Delaware Bay. Dead shells were collected near the eastern end of the Chesapeake-Delaware Canal by the Field Station. Recently several specimens were sampled from Delaware waters (J. Lindsay and Ron Smith, personal communication). This represents a northern range extension for this species. One specimen (29 mm in length) was collected August 20, 1971 in 1.0 m of water from sand bottom off Oakwood Beach, New Jersey. A second specimen was collected August 15, 1972 in 1.8 m of water from a mud and detritus bottom 200 m north of Appoquinimink Creek. Although not normally considered as oligohaline species, *Mya arenaria* and *Macoma balthica* have been reported from salinities as low as 5 ‰ in European and American estuaries (Segerstrale 1957, Bird 1970). These species must occur in the bay in great abundance between the St. Jones River and Woodland Beach because the volume of their shell debris is large. Other local species *(Modiolus demissus* and *Brachiodontes recurvus)* also extend their range into areas where salinity becomes lower than 5 ‰ , but they more properly belong to true estuarine species.

TRUE ESTUARINE

Amygdalum papyria, Mysella planulata, and *Modiolus demissus* are found attached by byssal threads to oysters. In the rivers, *M. demissus* and *A. papyria* are most commonly attached to marsh vegetation or partly buried in soft sediment. The ribbed mussel, *M. demissus,* is more common intertidally on roots of *Spartina alterniflora* than subtidally (Lent 1967), while *A. papyria* is always far less abundant than *M. demissus* and occurs subtidally. The ribbed mussel is uncommon in the bay except at Woodland Beach. Here the proximity of the marshes as a source of brood stock favors heavy setting on any firm substrate. Kunkel (personal communication) informs us that the hooked mussel, *Brachiodontes recurvus* was at one time frequently collected above the Cohansey River, but is now very rare. The reason for its decline is unknown, but it was coincident with the mid-1960's drought.

Two bivalves show an affinity for a specific substrate. *Petricola pholadiformis* and *Barnea truncata* are characteristic of sections of the Murderkill, St. Jones, and Leipsic rivers with substrates of hard clay and packed marsh debris.

Infaunal species such as *Macoma balthica, M. tenta, Mya arenaria, Ensis directus, Solen viridis, Tagelus plebeius,* and *T. divisus* mainly occur in mud, fine sand, and shelly-mud bottoms. High density $(200/0.1 \ m^2)$ populations of juvenile razor clams, *Ensis directus,* were found in sandy shoal areas bordering the ship channel, particularly from the mouth of the bay to the Miah Maul shoal. The above species together with *Solemya velum* (50 individuals per $1/15 \ m^2$) is also very abundant in the fine sands of Rehoboth and Indian River Bays. The soft clam, *Mya arenaria,* occurs in mud (> 50% silt-clay) bottoms of the smaller bays.

The oyster, *Crassostrea virginica,* is a dominant member of the estuarine community and locally ranges from the Cape May Flat to north of Arnolds Point. Maximum development of natural seed beds extends from Woodland Beach to Port Mahon on the Delaware side of the Bay and from Egg Island Point to north of Arnolds Point on the New Jersey side. In addition to its commercial significance, the oyster forms the nucleus of a community that contains many species (Maurer and Watling 1973 a, b).

Anomia simplex was formerly reported in

abundance in New Jersey oyster beds where the salinity is above 20 ‰ (Kunkel, personal communication). Our experience with *A. simplex* is primarily restricted to Rehoboth and Indian River Bays where it is found attached to algae, rocks, and shells.

Two small (< 2 cm) bivalves, *Gemma gemma* and *Mulinia lateralis*, are locally very common, but their maximum distributions are dissimilar. *Mulinia lateralis* is found in muddy and sandy substrates and is one of the most abundant pelecypods in Delaware Bay. Great numbers (8-10,000/0.1m^2) of *M. lateralis* shells in channels and troughs near the mouth of the bay attest to its abundance. *Gemma gemma* inhabit a silty (20% silt-clay) or muddy-sand substrate and occur in the bay in relatively small numbers. It is, however, extremely abundant in Rehoboth and Indian River Bays, where counts of subtidal populations were as high as 280,000/m^2. Both species are ecologically significant, because a number of fish, invertebrates, and birds feed on these bivalves (Sellmer 1967, Calabrese 1969).

The hard clam, *Mercenaria mercenaria*, is commonly collected in fine sand with some clay. In Delaware Bay it ranges from Woodland Beach to the ocean, although it is most abundant in the lower Bay from south of Port Mahon to Broadkill Beach (Keck et al. 1972). Further, the hard clam occurs in commercial numbers in Rehoboth and Indian River Bays. Coincident with the occurrence of the hard clam in the smaller bays is that of *Pitar morrhuana*, which is commonly collected but in considerably lower numbers. Both species are on the borderline between true estuarine species and euryhaline marine species because they frequently occur near high salinity inlets or in the ocean.

EURYHALINE MARINE

Two species which occur in oceanic salinity but also extend into the estuary are the wood borers, *Bankia gouldi* and *Teredo navalis*. Evidence of their work can be found in wooden pilings along Delmarva and Delaware Bay beaches. *Teredo navalis* has a wide tolerance to salinity and *B. gouldi* occurs in

Chesapeake Bay in water with a mean salinity of 9.3 ‰ and a range of 3.3‰— 15.6 ‰ (Scheltema and Truitt 1954, Nair and Saraswathy 1971). Among other euryhaline marine species *Siliqua costata* and *Tellina agilis* are considered rapid burrowers and *Corbula contracta*, *Lyonsia hyalina*, *Anadara ovalis*, *A. transversa*, and *Noetia ponderosa* are considered slow burrowers (Stanley 1970). *Tellina agilis* is a dominant species in fine sand (0.25 mm median sediment size) near the mouth of the Bay. A codominant species occurring with *T. agilis* is *Nucula proxima* which is common in sediments with high (> 50%) silt-clay content (Maurer et al. 1973). *Tellina agilis* is also common on the Cape Henlopen flats. This tellinid may also occur with *L. hyalina*, which is most common in sediment with 20-40% silt-clay. The ark shells, *Anadara transversa* and *A. ovalis*, occur in the ocean but are more frequently collected in algae beds of the smaller bays. In contrast, *Noetia ponderosa* is more common in the ocean.

STENOHALINE MARINE

Tellina versicolor, *Donax fossor*, and *Spisula solidissima* occur very near open shore beaches. In fact, *Donax fossor* may be considered an intertidal species. These species are primarily restricted to clean sand with shell and gravel. The surf clam, *Spisula solidissima*, is an important offshore commercial species (Yancey and Welch 1968). Laboratory observations showed that *S. solidissima* was unable to survive the diurnal tidal fluctuation in the Broadkill River (14-28 ‰).

Species such as *Pandora gouldiana*, *Astarte undata*, *Venericardia borealis*, *Cerastoderma pinnulatum*, *Abra aequalis*, and *Arctica islandica* occur in deeper water (> 12 m) in coarse sand. However, *P. gouldiana* is collected from the Cape Henlopen flat. Fragments of *Cyrtopleura costata* shells commonly wash ashore on Delaware's Atlantic coast but we have not collected any alive. None of these species is abundant with the exception of *A. islandica*. It probably occurs in commercial numbers, but has not been vigorously marketed.

Yoldia limatula also is common in the ocean, but it has the same affinity for sediment with high silt-clay content as *N. proxima*. Both species occur together locally. *Nucula proxima* is more dominant in shallow and semi-enclosed water than *Yoldia limatula*. *Mytilus edulis* is found attached to rocks, wrecks, and jetties near the mouths of bays and in the ocean. It occasionally occurs in such numbers to form small lenticular reefs in rivers (e.g. Broadkill) along the lower Bay.

The Bay scallop, *Argopecten irradians* is occasionally obtained in Rehoboth and Indian River Bay. This species is not abundant, but when it occurs it is associated with algae in the smaller bays. We have found it only occasionally in the ocean, but it may be more common there.

COMMUNITY STUDIES

In an earlier study, the habitat zone, substrate, form, and feeding type of molluscan communities of Beaufort, North Carolina, were described (Bird 1970). With the caveats of different sampling design, methods, and treatment of pelecypod molluscs alone, comparison of Bird's data with ours show the following similarities and differences. From estuary mouth to the head he named three communities: *Tellina, Mulinia — Syndosmya [Abra], Retusa; Syndosmya [Abra] — Aligena;* and *Macoma balthica.* Only the *Macoma* community was sharply delineated. The association of the estuary mouth graded into the shallow open-ocean community of the area, the *Tellina — Spisula* community.

There was no attempt here to define pelecypod communities *per se.* Instead, particular suites of species were recognized based on salinity distribution. Following Carriker's (1967) outline for biota and salinity divisions, pelecypods *(Spisula, Donax, Astarte, Venericardia)* occurring in local stenohaline marine conditions would probably agree with Bird's (1970) open ocean community *(Spisula — Tellina).* Pelecypods *(Tellina, Lyonsia, Anadara, Corbula)* locally recognized as euryhaline marine species may be equated with Bird's *Tellina, Mulinia — Syndosmya [Abra] Retusa* community.

Those species *(Macoma, Modiolus, Mulinia, Brachiodontes)* which are true estuarine forms may fit Bird's *Macoma* community.

Two other comparisons can be made. The range of salinity of species distribution reported by Bird (1970) is narrower than salinity ranges for similar species in this study. This tends to telescope molluscan assemblages towards the mouth of the estuary. As a result, differences between his results and ours are more superficial than significant. The important fact remains that the relative sequence of pelecypod assemblages is very similar in both areas. He commented that community boundaries were gradational even between open ocean and estuary-mouth communities. Gradual shifting of relative abundance of the most abundant species rather than wholesale change in species composition characterized community flux. We agree with Bird's (1970) findings in that in some cases it was difficult to distinguish among true estuarine, euryhaline marine, and stenohaline marine species. Controlling mechanisms to explain these differences remain to be studied.

In summary, there are approximately 44 common species of marine-estuarine pelecypods in the Delaware Bay region. As might be expected about 50% are true estuarine species. The other 50% are evenly distributed between euryhaline and stenohaline marine species with a single bonafide oligohaline species *(Rangia cuneata).* The latter is a northern range extension. The designation of stenohaline marine and oligohaline species is easier to determine than euryhaline marine or true estuarine forms.

SUMMARY OF ECOLOGY

Salinities in parentheses represent values from published literature, while those not in parentheses represent our data. The substrate is classified by median sediment size, in mm: fine sand, 0.063-0.25; medium sand, 0.25-0.50; coarse sand, 0.50-2.00.

Rangia cuneata (Gray): Salinity, 0-10 ‰, (0-20 ‰), oligohaline; spawning months, April through June; substrate, silt-clay and fine sand; mode, infaunal suspension feeder, slow burrower.

Brachiodontes recurvus (Rafinesque): Salinity, 8-15 ‰ , (0-20 ‰), true estuarine; spawning months, April through December; substrate, rocks and oysters; mode, epifaunal suspension feeder with strong byssus.

Modiolus demissus (Dillwyn): Salinity, 5-25 ‰, (2-30 ‰), true estuarine; spawning months, May through October; substrate, marsh grass and algae, occasionally rocks; mode, semi-buried suspension feeder, weak byssus.

Barnea truncata (Say): Salinity, 13-25 ‰ , (10-30 ‰), true estuarine; spawning months, April through November; substrate, hard clay; mode, infaunal suspension feeder, moderately rapid burrower.

Cyrtopleura costata (Linné): Salinity, 13-25 ‰ , (10-30 ‰), true estuarine; substrate, hard clay; mode, infaunal suspension feeder, moderately rapid burrower [not found living].

Amygdalum papyria Conrad: Salinity, 8-25 ‰ , (5-25 ‰), true estuarine; substrate, marsh grass, algae and oysters; mode, epifaunal suspension feeder with byssus.

Mya arenaria (Linné): Salinity, 5-20 ‰ , (5-25 ‰), true estuarine; spawning months, March through May and September through December; substrate, silt-clay through medium sand; mode, infaunal suspension feeder, slow burrower.

Macoma balthica (Linné): Salinity, 10-25 ‰ , (5-25 ‰), true estuarine; spawning months, March through May and August through November; substrate, silt-clay through medium sand; mode, infaunal deposit feeder, moderately rapid burrower.

Bankia gouldi Bartsch: Salinity, 15-35 ‰ , (10-35 ‰), euryhaline marine; substrate, wood; infaunal suspension feeder, slow burrower.

Teredo navalis Linné: Salinity, 15-35 ‰ , (10-35 ‰), euryhaline marine; spawning months, June through October; substrate, wood; mode, infaunal suspension feeder, slow burrower.

Macoma tenta (Say): Salinity, 15-25 ‰ , (10-30 ‰), true estuarine; substrate, silt-clay through medium sand; mode, infaunal deposit feeder, moderately rapid burrower.

Solen viridis Say: Salinity, 13-28 ‰ , (7-28 ‰), true estuarine; substrate, fine sand and medium sand; mode, infaunal suspension feeder, rapid burrower.

Ensis directus Conrad: Salinity, 13-28 ‰ , (7-32 ‰), true estuarine; spawning months, January through April; substrate, fine sand and medium sand; mode, infaunal suspension feeder, rapid burrower.

Siliqua costata (Say): Salinity, 15-25 ‰ , (15-28 ‰), euryhaline marine; substrate, silt-clay through medium sand; mode, infaunal suspension feeder, rapid burrower.

Tagelus plebeius (Lightfoot): Salinity, 13-30 ‰ , (13-28 ‰), true estuarine; substrate, silt-clay through medium sand; mode, infaunal deposit feeder, slow burrower.

Mulinia lateralis (Say): Salinity, 13-28 ‰ , (10-35 ‰), true estuarine; spawning months, March through November; substrate, silt-clay through medium sand; mode, infaunal suspension feeder, moderately rapid burrower.

Corbula contracta Say: Salinity, 20-30 ‰ , (15-35 ‰), euryhaline marine; substrate, silt-clay and fine sand; mode, infaunal suspension feeder, slow burrower.

Crassostrea virginica (Gmelin): Salinity, 13-30 ‰ , (0-35 ‰), true estuarine; spawning months, June through September; substrate, rocks and shells; mode, epifaunal suspension feeder, in clusters.

Solemya velum Say: Salinity, 17-25 ‰ , (15-28 ‰), true estuarine; substrate, silt-clay and fine sand; mode, infaunal suspension feeder, rapid burrower.

Mysella planulata Stimpson: Salinity, 15-25 ‰ , (13-28 ‰), true estuarine; substrate, algae, hard shell, rocks; mode, epifaunal suspension feeder, weak byssus.

Anomia simplex Orbigny: Salinity, 15-30 ‰ , (10-30 ‰), true estuarine; spawning months, April through October; substrate, algae, hard shells, rocks; mode, epifaunal suspension feeder, calcified byssus.

Pitar morrhuana (Linsley): Salinity, 17-30 ‰ , (15-35 ‰), true estuarine; spawning months, May through August; substrate, silt-clay through medium sand; mode, infaunal suspension feeder, moderately rapid burrower (?)

Mercenaria mercenaria (Linne): Salinity, 15-30 ‰ (10-35 ‰), true estuarine; spawning months, May through October; substrate, silt-clay through medium sand, some shell; mode, infaunal suspension feeder, moderately rapid burrower.

Tagelus divisus (Spengler): Salinity, 15-25 ‰, (15-29 ‰), true estuarine; substrate, silt-clay through medium sand; mode, infaunal deposit feeder, rapid burrower.

Lyonsia hyalina (Conrad): Salinity, 18-30 ‰, (15-28 ‰), euryhaline marine; spawning months, February through May; substrate, silt-clay and fine sand; mode, infaunal suspension feeder, slow burrower.

Tellina agilis Stimpson: Salinity, 13-35 ‰, (12-35 ‰), euryhaline marine; spawning months, March through July; substrate, silt-clay through medium sand; mode, infaunal deposit and suspension feeder, rapid burrower.

Tellina versicolor DeKay: Salinity, 20-35 ‰, (15-35 ‰), stenohaline marine; substrate, fine sand through coarse sand; mode, infaunal deposit and suspension feeder, rapid burrower.

Anadara ovalis (Bruguière): Salinity, 15-30 ‰, (15-35 ‰), euryhaline marine; spawning months, May through October; substrate, fine sand through coarse sand; mode, infaunal suspension feeder, weak byssus, slow burrower.

Argopecten irradians (Lamarck): Salinity, 20-35 ‰, (17-35 ‰), stenohaline marine; spawning months, April through August; substrate, algae; mode, vagile suspension feeder, weak byssus.

Gemma gemma (Totten): Salinity, 18-30 ‰, (13-32 ‰), true estuarine; substrate, silt-clay and fine sand; mode, infaunal suspension feeder, moderately rapid burrower.

Anadara transversa (Say): Salinity, 18-30 ‰, (15-32 ‰), euryhaline marine; spawning months, May through September; substrate, algae, silt-clay through medium sand; mode, infaunal suspension feeder, weak byssus, slower burrower.

Noetia ponderosa (Say): Salinity, 17-30 ‰, (15-35 ‰), euryhaline marine; spawning

months, June through November; substrate, algae, silt-clay through medium sand; mode, infaunal suspension feeder, weak byssus, slow burrower.

Mytilus edulis Linné: Salinity, 20-35 ‰, (15-35 ‰), stenohaline marine; spawning months, January through December; substrate, rock, shell; mode, epifaunal suspension feeder, strong byssus in clusters.

Petricola pholadiformis Lamarck: Salinity, 15-29 ‰, (10-32 ‰), euryhaline marine; spawning months, March through November, substrate, hard clay; mode, infaunal suspension feeder, moderately rapid burrower.

Pandora gouldiana Dall: Salinity, 23-35 ‰, (20-35 ‰), stenohaline marine; substrate, fine sand through coarse sand; mode, infaunal suspension feeder, slow burrower.

Astarte undata Gould: Salinity, 25-35 ‰, (22-35 ‰), stenohaline marine; substrate, medium sand and coarse sand, shell; mode, infaunal suspension feeder, slow burrower.

Nucula proxima Say: Salinity, 25-35 ‰, (20-35 ‰), euryhaline marine; substrate, silt-clay and fine sand, organic mud; mode, infaunal deposit feeder, moderately rapid burrower.

Venericardia borealis (Conrad): Salinity, 25-35 ‰, (22-35 ‰), stenohaline marine; substrate, medium sand and coarse sand, shell; mode, infaunal suspension feeder, slow burrower.

Cerastoderma pinnulatum (Conrad): Salinity, 25-35 ‰, (22-35 ‰), stenohaline marine; substrate, medium sand and coarse sand, shell; mode, infaunal suspension feeder, moderately rapid burrower.

Donax fossor Say: Salinity, 29-35 ‰, (25-35 ‰), stenohaline marine; spawning months, June through October; substrate, medium sand and coarse sand, shell; mode, infaunal suspension feeder, rapid burrower.

Abra aequalis (Say): Salinity, 29-35 ‰, (25-35 ‰), stenohaline marine; substrate, medium sand and coarse sand, shell; mode, infaunal deposit feeder (?), moderately rapid burrower (?)

Yolida limatula (Say): Salinity, 25-35 ‰, (22-35 ‰), stenohaline marine; substrate, silt-clay and fine sand, organic mud; mode,

infaunal deposit feeder, rapid burrower.

Spisula solidissima (Dillwyn): Salinity, 27-35 ‰, (10-35 ‰), stenohaline marine; spawning months, March through May and September through November; substrate, clean, coarse sand, shell, medium sand; mode, infaunal suspension feeder, rapid burrower.

Arctica islandica (Linné): Salinity, 30-35 ‰, (28-35 ‰), stenohaline marine; spawning months, June through October; substrate, clean, medium sand and coarse sand, shell; mode, infauna.

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BOOK REVIEW

THE FRESHWATER MOLLUSCS OF THE CANADIAN INTERIOR BASIN. *By Clarke, Arthur H. 1973. Malacologia, 13(1-2): 1-509, 9 text figures, 9 tables, 87 maps, 28 plates (1-14 in color, 15-28 in black and white), 35 charts.*

Of monographic proportions, this regional study provides an immense amount of data on the biology of 103 species and subspecies in 37 genera and subgenera of an area encompassing more than 1/3 of North America. Ten families (2 bivalve, 3 prosobranch and 5 pulmontate) are reviewed with the sphaeriids, lymnaeids and planorbids being among the more speciose. For certain taxonomic groups this study constitutes the first modern systematic treatment, and many of the taxa have never been critically reviewed, properly described or adequately illustrated.

Geographically, the Canadian Interior Basin comprises both the Hudson Bay Basin and the Canadian portion of the Arctic Basin, including such extensive river systems as the Mackenzie, Churchill, and Saskatchewan. The front endpapers provide a colored map of the principal drainage basins and the rear covers detail, in color, phytogeographic and geomorphic features. Dominating the geologic scene is the Precambrian Shield, a poor source of limestone and therefore not particularly hospitable for shelled animals. A more suitable substrate, the Hudson Bay Lowland provides a more calcium rich environment and is characterized by low species diversity and by large population sizes typical of highly variable environments.

Approximately 10 years of field work during which nearly 600 stations were sampled and over 3000 lots collected, form a basis for this study Including material from various sources, ultimately over 100,000 specimens were examined. In conjunction with fossil evidence, temperature preferences, and distributional data, the probable faunal origins are analyzed for each species. In an enlightening introduction, previous research and the geologic history of the area are surveyed.

The major portion of the text consists of the systematic section. Although each species is provided with a synonymy, the treatment is irregular and incomplete. As the author himself points out, not all synonyms are listed

and few citations of type specimens are included. For example, rather than attempt to assess the validity of all North American nominal *Gyraulus*, an effort is made to evaluate the status of all taxa recorded from the study area. Following a short diagnosis, a longer, more detailed description is given for each species. An illustration, a list of specimens examined and a map of the species' distribution in the study area are augmented with comments on overall distribution, a discussion of biology and ecology, and remarks on closely related species and probable synonyms. Clear, dichotomous keys, with references to page numbers and illustrations, aid in identification of each family, genus, species, and subspecies.

The taxonomy of freshwater mollusks has always constituted a considerable problem. Dr. Clarke employed some biometric methods to describe the variation in these species. He utilized these data to detect subspecies, to discover the meaning or implication of geographically correlated morphometric characteristics, and to describe more fully the variability exhibited by some species. Adducing that evidence of gene exchange between otherwise distinguishable groups of populations is indicative of the existence of subspecies whereas no gene exchange means that two or more distinct species are involved, Dr. Clarke recognized a dozen polytypic species, some with as many as 3 subspecies in the study area. An examination of the distribution of one of these polytypic species, for example *Valvata sincera* with its 3 polytopic subspecies, *V.s. sincera*, *V.s. ontariensis*, and *V.s. helicoidea* shows that all three may live in the same river system (Albany and Severn drainages) and even near or in the same body of water (Lake Nipigon). To me, such a pattern casts doubt on the interpretation of these populations as subspecies since subspecies are, by definition, geographical isolates.

Certain complex nomenclatorial problems are resolved. To insure stability and allow the continued widespread usage of such important hydrobiid generic names as *Amnicola* and *Pomatiopsis*, a neotype is designated for *Paludina lustrica* Say, 1821, the type species of *Amnicola*. An attendant oddity is that this specific name, though having priority, is considered a *nomen oblitum* and *A. walkeri* Pilsbry, 1898, a subjective synonym, utilized.

Among the outstanding contributions in this volume are the extremely useful distinctions between easily confused species, the thorough accounts of previously very poorly known species, and the comprehensive analyses of certain species. *Lymnaea columella* and *Succinea ovalis* are very similar and frequently misidentified, but here they are clearly differentiated conchologically and anatomically (p. 293).

Many intrinsically intriguing biological facts are brought to light. Documenting the tenacity and perseverance of some mollusks are the extreme northern occurrences of certain species: the cosmopolitan sphaeriid *Pisidium casertanum* on Baffin and Victoria Islands, the panboreal physid *Aplexa hypnorum* also on Victoria Island, and the Beringian *Lymnaea atkaensis* at home on the Arctic Coastal Plain. Additional specific results include the synonymization of *Lymnaea emarginata* with *L. catascopium* (p. 328) and the recognition of the European *Gyraulus albus* as distinct from the Nearactic *G. deflectus* (p. 396).

In summary, this work is truly a *magnum opus*, constituting the most comprehensive treatment of the mollusks of a faunal area in North America and the most thorough analysis of many intriguing taxa. Setting a high standard of excellence, it forms the foundation for any future work on the freshwater mollusks of Canada and, indeed, the United States. An invaluable treatise and exemplary source book for the limnologist and aquatic biologist, it is a must for the library of any malacologist and a fitting memorial to the author's late wife, Louise, to whom the work is dedicated.

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FROG MOTIFS ON ARCHAEOLOGICAL MOLLUSKS OF HOHOKAM AND MOGOLLON INDIAN CULTURES

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ABSTRACT

Thirty-seven pendants and eight bracelets carved with frog motifs, or overlaid with turquoise mosaic, comprise this initial checklist. Of the carved pendants without overlay, several motific groups can be identified. Pendants and bracelets were made from whole valves of various species, such as Glycymeris gigantea *(Reeve) and* G. maculatus *(Broderip). Other shells were used but less frequently. Carved frog pendants are found throughout the Hohokam and Mogollon culture areas and were frequently excavated in connection with burials.*

This is a preliminary report on carved shell ornaments from archaeological remains of prehistoric Indian cultures in the Southwest. In the current phase of study, a checklist of frog images is being compiled and motific groups are being catalogued. For reasons which go beyond this assembly and subdivision of objects and data, records are being made of archaeological contexts in which frog images were found in the hope that significant frequency patterns will emerge from the data.

We assume that discovery of carved shell ornaments in archaeological remains means that these objects had intrinsic value to certain prehistoric people. We also assume that by studying these objects we might
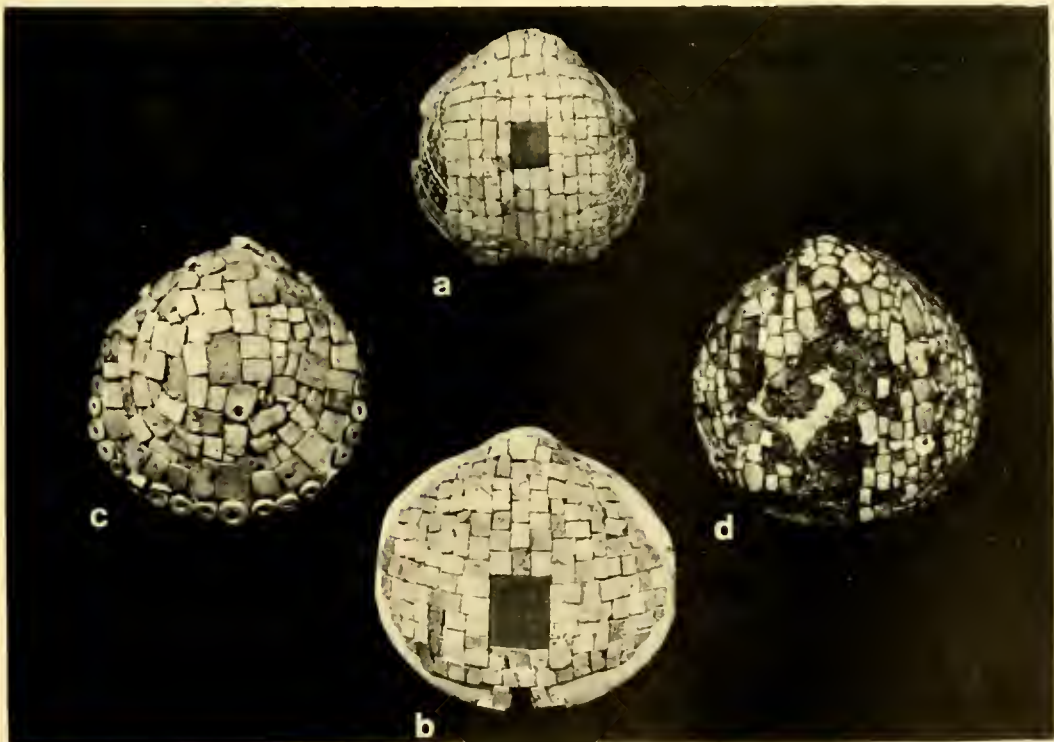

FIG. 1 *Overlaid Shell Pendants. Photograph by Helga Teiwes, Arizona State Museum, catalogue nos. GP39336, GP9895, GP10768 and GP5765.*

contribute to a more thorough understanding of the cultures which left them behind.

The carved shell ornaments come from the Southwest, which is one of nine archaeological culture areas in North America. This area centers on the states of Arizona and New Mexico, spreading northward into Utah and Colorado, and southward to encompass nearly all of the Mexican states of Sonora and Chihuahua (Willey: 1966, pp. 178-181; see also Haury: 1962; Jennings and Reed: 1956). The southeast quadrant of this area is named after the Mogollon Mountains which lie east of the Rio Grande, running diagonally from Arizona into Southwestern New Mexico. To the west of the Mogollon subarea, the Verde, Salt and San Pedro Rivers flow into the Gila River. The Hohokam ancestral lands consist of this Lower Gila River drainage area and the desert country to the south. North of the Hohokam and Mogollon subareas lies Pueblo Indian country. This third subareal division is called by the anthropological designation "Anasazi." There is cultural overlapping among all three cultural subdivisions with a pre-Historic to Historic cultural continuum from Paleo-Indian times (ca. 14,000 B. C.) to the present (see Rouse: 1962; Wheat: 1955; Bullard: 1962; Martin and others: 1952).

The time period of greatest importance to us is from about A. D. 600 to 1400 which includes the last three phases of both the Hohokam and Mogollon cultural traditions, the transition from Basketmaker to Pueblo cultural tradition in the Anasazi subarea and the florescence of cultural habitation at Casas Grandes in Chihuahua. Evidence from Snaketown Ruin (Gladwin, *et al.*: 1937, pp. 135-153), situated north of Tucson on the Gila River, indicates that carved shell industry among the Hohokam during the Santa Cruz Phase (ca. A. D. 700-900) was well in advance of the Georgetown and San Francisco Phases of Mogollon culture, and Pueblo I stage of Anasazi culture. Yet, it was not until the succeeding Sacaton Phase at Snaketown that the carved shell industry reached a high point at that site. The Sacaton Phase (ca. A. D. 900-1100) was the last period of Hohokam habitation at Snaketown (see Gladwin, *et al.*,

1937, p. 247). During the Classic stage of Hohokam culture (ca. A. D. 1100-1400, see Rouse: 1962, Fig. 3; Haury: 1962, Fig. 2, gives the time period ca. A. D. 1200-1500 for the Classic stage), ornamental shell work began to decline both in quality of workmanship and numbers of objects.

Thirty-seven pendants and eight bracelets carved with frog motifs comprise the initial checklist. All the pendant specimens are bivalve shells with the umbo pierced for suspension. Bracelets are also bivalve shells with frogs carved on the umbonal region and the body of the shell ground off to form a circular band. Six shells overlaid with turquoise mosaic have been included with the pendants. Three of the specimens (Fig. 1a and b) are carved as well as overlaid. One is carved with a notch on both the posterior and anterior margins, as well as on the ventral margin of the shell to indicate the retracted legs and feet of a squatting frog. This specimen is painted blue on both the posterior and anterior sides of the convex portion of the shell with twelve rows of turquoise tesserae overlaid on the center portion. In the center of the overlay, there is a large red tessera.

The posterior and anterior margins of a second overlaid pendant are flattened and there is a V-shaped notch cut into the ventral margin opposite the umbo. The turquoise overlay covers all but the edges of the convex portion of the shell, with four tesserae set on either side of the notch in a manner to suggest hind legs. A large red tessera is set in the center of the overlay on this specimen also. The third overlaid pendant is notched on the posterior and anterior margins of the shell. The overlay is in a fragmentary state, but probably covered the entire convex portion of the shell except for the tips of the four flanges on the margin of the shell, which were carved to represent frog legs and feet. There is no carving on three of the mosaic ornaments. Nevertheless, they are pendants and are suggestive of the compact form of frogs.

Of the carved pendants without overlay, several motific groups can be identified. One motific form represents the frog with nearly

straight sides and the front and hind legs widely separated (Fig. 2). Of the most complete specimen, collected in the Flagstaff area, the upper and lower portions of the legs are well-defined and separated from the body of the animal. Incised lines suggest the webbed toes of the frog. A second motific form includes specimens with more bulbous sides. In this type, the legs are more anatomically articulated as well as separated from the body of the animal (Fig. 3). All four specimens of this type at the Arizona State Museum show that their makers were careful in articulating the eyes. Wear, caused by continuous handling of these ornaments, often makes it difficult to distinguish minute features on the pendants. In the case of these specimens, fine quality workmanship is evident even though they are worn down. There is a third straight-sided type. Specimens in this group are rather crudely carved and lack any indication of a dorsal ridge. Two specimens from the Arizona State Museum are polished from cultural use, but when compared to other well-used specimens with carved dorsal ridges still visible, it seems that, for this type, the dorsal ridge was never carved. Two specimens of this type show a distinctly flattened umbo.

One specimen is recorded with a ground-off umbo similar to the preceding type. The specimen is bulbous and crudely carved, and has been assigned to a group of miscellaneous specimens for the time being.

A group of specimens with very curved bulbous sides is a fifth type. The legs of these specimens are compressed to the body and clearly incised, not carved in a rounded, more three-dimensional manner (Fig. 4 and 5). The toes in this type are treated as incised, serrated projections from the legs. On one specimen, an incised line separates the body of the animal from the head, and the eyes are also incised.

Five specimens are included in a sixth type. These specimens are drilled or perforated with holes which seem to represent eyes. Some of the specimens are perforated at the umbo for suspension and some are not. Some are incised with geometric patterns, and some are

cut or ground off to make a large perforation in the center of the shell. One specimen incorporates all of these motifs.

A seventh type includes specimens which are not carved in distinct frog form. These shells are only partially modified by grinding along the ventral margin, and are perforated with a large circular hole generally in the center of the shell. They differ from type six in that they lack drilled or perforated eye treatment.

A triangular shell pendant was found at Broken K Pueblo (Fig. 6) with a relief image of a frog-like animal carved on it. The front and hind legs are extended. The body, head and eyes of the animal are not clearly indicated, but the dorsal ridge is clearly defined. Unlike the other specimens, this pendant was made from a shell blank, a piece cut from a larger shell. The pendants,
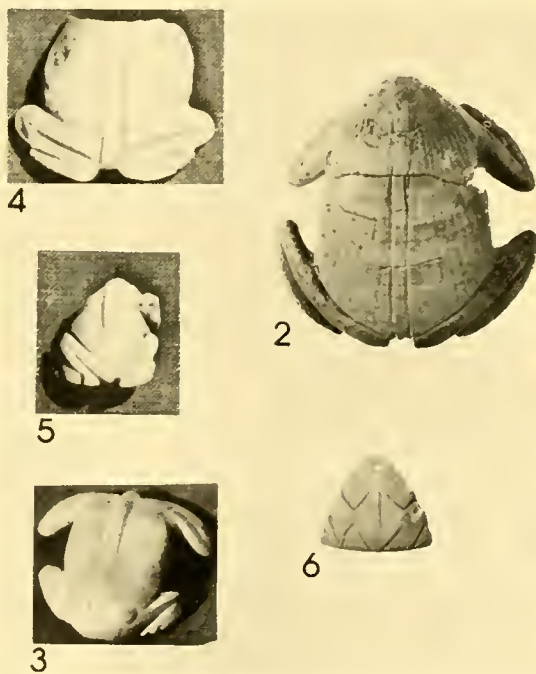
FIGS. 2-6 Shell Pendants (2) photograph by Marc Gaede, Museum of Northern Arizona catalogue no. 1545L/A5838 (3) photographs by the author (4) Arizona State Museum (5) catalogue nos. GP9870, GP49130 and A25300 (6) photograph by Division of Photography Field Museum of Natural History catalogue no. 283703.

previously described, were made from an entire valve of *Glycymeris gigantea* (Reeve) or *G. maculatus* (Broderip) (see Gladwin, *et al.:* 1937, pp. 135-142; Di Peso: 1956, pp. 83-116; personal correspondence with Di Peso: 1973; Van Stone: 1973; Dobrinski and Hitchcock: 1973; Chaffee: 1973).

Finally, all specimens which are too worn or fragmentary or poorly carved to be placed in separate groups are included in a group of miscellaneous specimens.

At the Arizona State Museum there are two fragmentary specimens of open-work carving. One specimen might represent a horned lizard and not a frog because of its elongated form, a head which is separated from the body by a rudimentary neck, and a short tail. The other specimen might represent a frog. Both specimens have been carved so that the animal motif is enclosed within the circular band of the ventral margin. Only the hind section of the second specimen remains so that examination of head and fore-leg features is impossible. The hind legs are partially extended, a feature unlike other frog pendants from Hohokam and Mogollon culture areas, but similiar to the triangular pendant from Broken K Pueblo, the Anasazi site in Northern Arizona. No tail is indicated.

The bracelets with frog images carved on the umbonal region of the shells are less varied in form than are the pendants. All specimens included in the preliminary checklist have been placed in one group. The animals are rectangular in shape and are quite thick (nearly as thick as they are wide). The frog's nose is the umbo of the shell. The body of the frog is carved from the thick umbonal region with the front legs of the frog compressed to the body and the feet placed next to the head, as if the frog were grasping the circular band of the bracelet. The hind legs are carved as if they were overlapping the lower portion of the body, with the heels of the feet touching the posterior end of the frog and the toes spread perpendicularly to the dorsal axis. The hind leg motif takes the form of a capital M. The remainder of the shell was cut away except for a thick circular band,

which was the marginal circumference of the living shell.

Frog motifs are not restricted to worked shell. During an Arizona University expedition in 1965, a cache of carved stone and clay objects was excavated (Ariz. U:31:1, 10-G, Cache 1) which included two bowls. One, carved from stone, depicts a snake devouring a frog and one is made of clay with frog images clinging to the outer walls of the vessel in much the same manner as the frog images appear to cling to the bracelets. A corrugated clay jar from Chihuahua in the collections of The Amerind Foundation, Inc. also incorporates this "clinging frog" motif.

One recurrent archaeological context for frog pendants is evident in the initial data. Of the forty-three carved and overlaid pendants, twenty-eight have a known provenance. Of these twenty-eight, ten are known to have been associated with inhumation or cremation burials. The age of the deceased is known in eight of these ten burial contexts. In each of five contexts, the pendants were buried with the remains of children. The remaining three were associated with young adults and are all of the seventh motific type, *i.e.*, pendants of indistinct frog form (see Fig. 6). All three specimens came from Canyon Creek Ruin, a Salado/Hohokam transitional site.

Research is in progress to find and assemble accounts of frog symbolism in American Indian ethnology. A few legends and practices are known which associate shells and frogs with children and childbirth (for example, see La Flesche: 1925, pp. 251-257). No speculations regarding associations of frog pendants, life and death, burial, children and childbirth or any other extra-ornamental use are made here due to lack of data.

Conclusions which can be drawn to date are: one, incidence of carved shell frog pendants is rather frequent in archaeological contexts throughout the Hohokam and Mogollon culture areas in the Southwest. Two, carved shell frog bracelets are found in the same contexts as the pendants, but with less frequency. Three, the pendants can be divided into several motific groups, and **four,**

that when not found in association with architectural fill and floor debris, the pendants have been excavated most frequently in connection with burials.

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ADDITIONAL RECORD FOR *MESODON LEATHERWOODI* (PULMONATA: POLYGYRIDAE)

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Mesodon leatherwoodi Pratt was recently described from specimens collected at a single locality in western Travis County, Texas (Pratt, 1971). It is of interest to report the occurrence of *M. leatherwoodi* in the Pedernales Falls State Park, Blanco County, Texas, which is approximately 13 miles upstream from the type locality. Four specimens were found near the Pedernales Falls within 1 meter of each other at the base of a large rock on August 6, 1972. The collection site was above flood debris along the river suggesting that the snails were from the general area of the Falls, although, the shells may have been washed down from the oak-juniper community higher on the river bank.

The specimens have been deposited in the collection of the Fort Worth Museum of Science and History (catalog number 94V-3103). W. L. Platt verified the identification of the specimens.

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NEW FLORIDA RECORDS FOR
HYPSELODORIS EDENTICULATA (NUDIBRANCHIA: DORIDIDAE)

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The large and conspicuous chromodorid, *Hypselodoris edenticulata* (White, 1952) was originally recorded only from Dry Tortugas, Florida. Marcus and Marcus (1967, p. 56) gave four other records in the vicinity of Palm Beach, Miami, Alligator Reef, and Lake Worth, all southeast Florida, at depths from 8 to 102 feet.

On March 2, 1971, Ralph Woodring collected a specimen in 35 to 40 feet of water, 20 miles southwest of the Sanibel Island Lighthouse. I maintained this specimen for four weeks in an aquarium and made several photographs of it. The animal was 64 mm. in length and 17 mm. in width. The color was blue-black with brilliant chrome-yellow markings of uneven circles and lines with one line running unevenly completely around the outer edge of the upper part of the body. The sole was a lavender blue. The eleven (Marcus reports 10, and White 9), branchial plumes were outlined in chrome-yellow, with a yellow line running down the center of each plume, with diverse yellow spots on either side. The secondary pinnules on the plumes were lavender; the rhinophores blue-black. White (1952, p. 114) records that the vermilion spawn is laid on the alga, *Caulerpa prolifera.*

In the Spring of 1971, Mr. Russell Jensen of the Delaware Museum of Natural History sent my photographs to Mr. Gale Sphon of the Los Angeles County Museum of Natural History who kindly identified them as *Hypselodoris edenticulata* (White), with the suggestion that this gives a further range for the animal that should be noted in the literature.

In October, 1973, I wrote Mr. William G. Lyons of the Bureau of Marine Science and Technology Florida, for any information he might have on the species. He very kindly gave much additional information:

"*Hypselodoris edenticulata* (White) is perhaps the most common large nudibranch offshore along the Florida west coast. In any event, it was the most frequently collected during Project *Hourglass,* our 28-month study of the fauna on the central west Florida shelf. In addition, I have seen many specimens brought in by divers from as far north as Tarpon Springs. Like your specimen, all I have seen from the Gulf coast are from 30-40 ft. depths out to some as great as 180 ft. Specimens are occasionally taken along the lower east coast of Florida in estuaries where tropical conditions prevail. I have taken them for several years in the Indian River near the St. Lucie Inlet, Martin County, but only when conditions allow intrusion of many other tropical species."

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FIG. 1. *Hypselodoris edenticulata* (White, 1952) from Sanibel Island, Florida, in 35-40 feet of water. Length: 64 mm. Lower view shows details of gills (photos by A. D. Barlow).

FURTHER NOTES AND CORRECTIONS CONCERNING THE
SPAWN OF FLORIDA *CYPHOMA* (OVULIDAE)

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ABSTRACT

The oothecae, manner of capsule deposition, and the operculate veligers of Cyphoma gibbosum *(Linné) from Florida are described. Observations made by Harding B. Owre on the spawn of C.* macgintyi *are published. The egg capsule illustrated by Cather and Crovo (1972, The Nautilus 85(4):113) is now believed to have been that of an* Anachis *(Columbellidae).*

Conflicting accounts of the nature of the oothecae of *Cyphoma gibbosum* have recently been published (Cather and Crovo, 1972; Bandel, 1973; Ghiselin and Wilson, 1966). It now appears that the ootheca illustrated in The Nautilus (85(4):113, fig. 1) by Cather and Crovo is not that of *Cyphoma*, but rather an egg capsule of a columbellid snail, most closely resembling that of *Anachis avara* (illustrated by Scheltema, 1968, p. 5, text fig. 2) and *Anachis* sp. *[catenata?]* (illustrated by Raeihle 1969, p. 26, fig. 2). Cather (in litt.) believes his error may be due to the undetected presence in his aquarium of a columbellid near the base of the sea fan.

Further recent observations by the author substantially confirm the accounts of *Cyphoma* oothecae by Bandel (1973) and by Ghiselin and Wilson (1966).

On November 9th, 1969, four living specimens of *Cyphoma gibbosum* (Linné)

were placed in a five gallon saltwater aquarium. Eleven days later, on November 19, one snail was observed working over a three-inch-square area of glass an inch below the surface of the water. On the morning of November 20 a network of 23 flexible, translucent capsules containing minute white eggs was formed. These capsules were approximately 2.0 x 2.1 mm., irregularly-placed rather than in even rows. Each capsule had a very short, indistinct, slotlike hatch at one end.

Each morning the mollusk returned to her laying area, adding to it until the last of 73 capsules was laid by late evening of November 24. The mother remained close to the mass of capsules, returning each morning, carefully
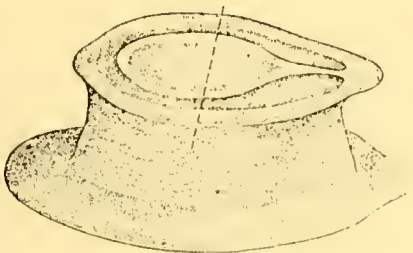

FIG. 1. *Egg capsule of an* Anachis *from Bermuda, erroneously identified as* Cyphoma gibbosum *in The Nautilus, vol. 85, p. 113, 1972.*
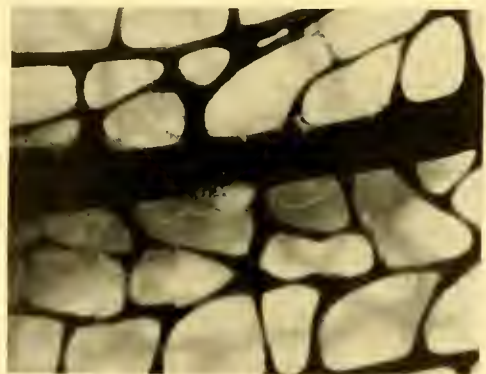

FIG. 2. *Egg capsules of* Cyphoma gibbosum *(Linné), both empty and full, laid on a denuded section of a seafan from Florida. Photo courtesy of R. T. Abbott (greatly magnified).*

working over the area for a period of three to four hours.

Five days after formation of the capsules active embryos were observed within the capsule walls. Ten days later, the capsules became a light flesh-pink color, gradually darkening to a deep-rose as the veligers grew to full size. On the fifteenth day the free-swimming veligers began to escape through a newly-formed slit on the top of each capsule. Without proper food and environment the veligers died after a few days. By carefully opening one capsule with a sharp needle, it was found to contain about 1270 veligers.

Similar observations with other egg-laying *Cyphoma gibbosum* were made in August, 1972. One small male and four larger female *Cyphoma* were collected from one *Gorgonia ventalina* Linné 1758. Each female laid her eggs in a separate area on the same *Gorgonia*, and all produced their capsules within five days. It was noted that warmer room and water temperatures reduced incubation time by 36 to 72 hours. We were also successful in obtaining photographs and measurements of capsules and veligers. The average size of the latter was 0.153 mm. The number of capsules and veligers varies according to the size of the producing adult *Cyphoma*. The veliger count of one full capsule in this series was 780. Adults were several millimeters smaller than those observed in November. Veligers from one capsule lived in a petri-dish of seawater for nine days with no attention other than daily checks on their activity. A tiny operculum is clearly visible on the *Cyphoma gibbosum* veligers, but this organ evidently is lost during metamorphosis.

The following account of the spawn of *Cyphoma macgintyi* Pilsbry and the accompanying drawings were kindly supplied by Dr. Harding B. Owre of Miami, Florida, and were taken from her unpublished Master's thesis (1949, pp. 24-25):

Cyphoma macgintyi "is generally found on an alcyonarian, where it feeds by sucking up polyps as it crawls along a branch. It deposits its spawn on a portion of a branch which has been cleared of polyps. Although it is
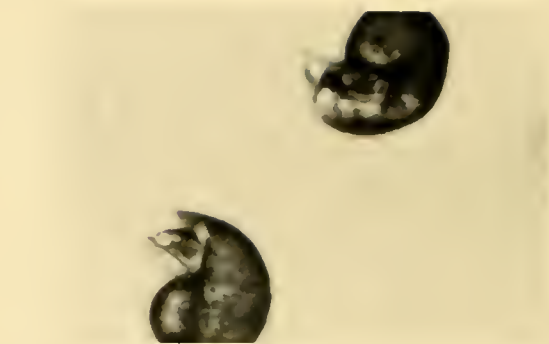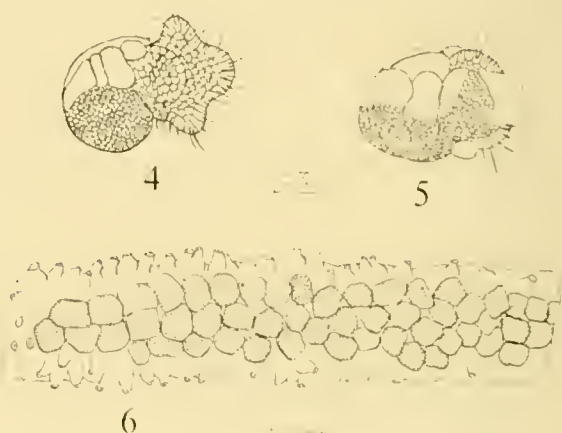

FIG. 3. *Veliger of* Cyphoma gibbosum *(Linné) showing shell, soft parts and operculum (greatly magnified).*

FIGS. 4-6. Cyphoma macgintyi *Pilsbry from Soldier Key, Florida. 4 and 5, preveligers. 6, oothecae on a stem of alcyonarian. (drawings by Harding B. Owre).*

probable that the adults lay eggs at other seasons, spawn has not been found except in the spring.

"Two egg masses were collected on April 10, 1948, in the alcyonarian bed on the ocean side of Soldier Key. In both cases, the spawn was laid on *Eunicea multicavda*, which was growing in water about four feet deep. An adult, presumably the parent, was found on each branch with the spawn. The maintenance of the spawn in the laboratory was difficult, for it could not, with safety, be separated from the cut branch of *Eunicea*, and the latter survived only two days.

"The spawn is laid out in an area which is

roughly rectangular, about 12 cm long and 1 cm wide. The mass is composed of numerous variously-shaped cases, which are gelatinous, thin, and flat or faintly convex on the upper side. In one mass, there were 111 cases, each one measuring approximately 4.5 x 4.0 x 1.0 mm. There are about fifty minute embryos in each case. The color of the spawn varies from white to pale pink, becoming a darker pink as the young mature.

"When collected, the young were late trochophore larvae. By April 13, 1948, the *Eunicea* had disintegrated to such an extent that the larvae in some of the cases were dead and it was necessary to release the rest. The "hatching" was premature, for the veliger stage had not quite been reached, and the larvae did not survive.

"The pre-veliger had a colorless translucent shell of one whorl. The diameter was about 0.12 mm. The heavily ciliated velum was still a single lobe with an extension on either side and one in the middle. There was a tuft of especially long cilia, remaining from the prototroch, on each projection. The foot was ciliated. The eyes and tentacles had not yet appeared."

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VIVIPARUS MALLEATUS IN MONTREAL, CANADA

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Heretofore, the most northerly record for the freshwater gastropod, *Viviparus malleatus* (Reeve), has been New Hampshire (Perron and Probert, 1973, The Nautilus 87(3):90). In the summer of 1973 I found this species abundant in one to two feet of water in a small lagoon in the public park at Cartierville, Montreal Island, Quebec. During the fall and winter, adults move to deeper water. Specimens have been deposited in the Delaware Museum of Natural History.

THE INTRODUCED ASIATIC CLAM, *CORBICULA*, IN CENTRAL ARIZONA RESERVOIRS

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ABSTRACT

Horizontal and vertical densities and biomasses of Corbicula *in two central Arizona reservoirs were estimated employing meter square quadrats and Ekman dredge sampling. Concentrations of clams increased with depth of water and down-lake from inflow areas characterized by greater turbidity (suspended sediment). Densities were highest on rock-rubble slopes and increased directly with complexity (number of components) of substrate. Data suggest food supply, substrate, turbidity and perhaps fish predation as important factors in determining densities and biomasses of clams in the two reservoirs examined.*

INTRODUCTION

Corbicula was first recorded in Arizona in 1956 from the Phoenix canal system (Dundee and Dundee, 1958). Introduction into Arizona, possibly from California, most likely occurred by man in the role of tourist, fisherman, or aquarium hobbyist. It was first recorded in abundance in the Southwest from the Coachella Valley, California, in 1953 (Ingram, 1959). In 1963, *Corbicula* had re-invaded irrigation systems of the Colorado River Indian Reservation after its eradication a year earlier (Ingram, *et al.*, 1964). Since that time it has spread throughout the entire lower Colorado River basin. The rapid spread of this animal upon introduction at various localities in the United States led Sinclair (1971) to describe *Corbicula manilensis* as " . . . currently the most costly liability of all exotic molluscs in North America . . ." This "pest" currently inhabits the Salt River reservoir system, central Arizona, where it occurs most abundantly in Roosevelt and Apache lakes (Fig. 1) *Corbicula* are scarce in the lower two reservoirs, Canyon and Saguaro lakes, for which I have no explanation since they are abundant upstream, and downstream in the Salt River between Stewart Mountain and Granite Reef dams and in the Phoenix canal systems. Locally, they comprise a major component of the benthic fauna of the upper two reservoirs.

METHODS AND MATERIALS
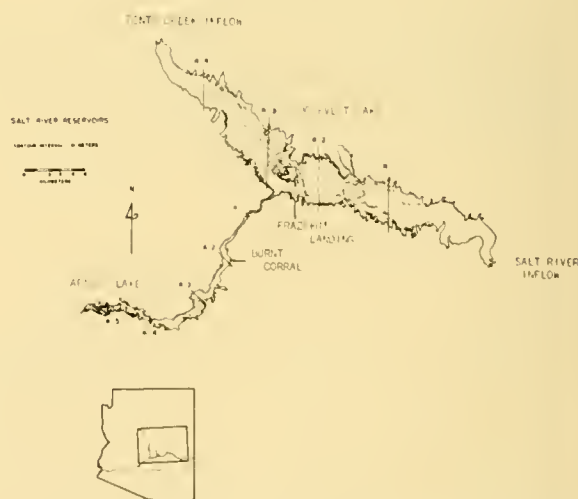
Corbicula were collected sporadically from

FIG. 1. *The two most upstream lakes, Roosevelt and Apache, of the Salt River system of reservoirs showing transect locations and place names used in text.*

Roosevelt and Apache lakes (Fig. 1) in November 1970, 1971 and February 1972. Almost all specimens were collected in a moribund state, or dead, on exposed lake shore during low-water conditions. Several meter-square (m2) quadrats were randomly thrown at a given site. All clams within this area with hinges yet attached were collected, and retained for later examination. In some cases intact valves would break upon handling, or were parted when later examined and measured. In either instance, these were counted. No specific information concerning time required to sufficiently decompose hinges and promote separation of valves was available to me. This undoubtedly varies with conditions following death. Most collections were made after a drop in reservoir level and consisted predominantly of individuals which had died of desiccation. Time-lapse between collection and exposure to drying varied in all cases, and could, indeed, affect density estimates. Autumn 1970 collections in Roosevelt and Apache were both within a month after the substrate was exposed by receding water. The November 1971 sampling in Roosevelt at R-1 was performed near water line and specimens were most likely exposed for only 2 to 3 months. By contrast, November 1971 and February 1972 collections in Apache were subject to approximately 7- to 10-month exposures, respectively, and sampling across from Frazier's Landing (equidistant between R-2 and R-3, see Table 2, Fig. 1) was undertaken on bottom that had been dry for more than a year. Other shortcomings of such collecting techniques were alteration of information by predatory mammals and birds, and activities of man. The last was circumvented to a large extent by selecting sites away from human activities.

Clams were measured (widths) and counted in the laboratory. Live clams were processed to determine dry and ash-free dry weights of animals excluding the valves. Regression analysis of size and weight indicated a power function giving the highest r-value (+0.98; equation: $y = [0.0110608] \times X^{3.0129}$). Mean size of all *Corbicula* within a quadrat was employed to estimate approximate biomass per unit area using the plotted regression line.

RESULTS

Two, shallow-to-deep-water transects at arbitrarily selected locations in Roosevelt and Apache lakes were sampled to determine the possible effect of depth of water on densities, sizes, and biomasses of *Corbicula*. Both transects generally indicated an increase in numbers and biomasses of clams with progression to deeper water (Table 1; Fig. 1), depending somewhat on substrate. Sampling in approximately 3.4 meters (m) of water on the north shore of Roosevelt Lake yielded no clams on rubble bottom. At deeper, down-slope sites, the animal became progressively more dense. Substrate along this transect was generally rocky. However, diversity of the habitat, increased directly with increasing depth. Shallower sites were far more uniform in sizes of substrate components, whereas at deeper levels, sand, rubble, gravel and boulders were interspersed. Average sizes of clams neither consistently, nor significantly, changed with depth.

The transect near A-2 (Burnt Corral, see Figs. 1 and 2) was located on an extremely steep, rock-covered slope, with the exception of several m² quadrats sampled on mud-sand flats. Numbers of clams were low at a depth of 2.2 m on sand-silt substrate (Table 1). Quadrats at 3.4 m were located near the crest of a rock slope (approximately 26% grade). Numbers and biomasses of clams then increased dramatically, remaining high to a depth of 18 m, where a drastic decrease in density occurred. The last site (BC-1-5) was located at the base of the rocky slope and was composed of sand-gravel substrate. Four quadrats were sampled on sand-gravel substrate, lying upon the old river terrace immediately below the rocky slope. Numbers also were extremely low in this area (BC-4-1). Several more quadrats were sampled at 20 and 22 m below full lake level (BC-2-1 and BC-3-1), on a second rocky slope, which dropped toward the old river channel. Densities of clams increased over those on the

TABLE 1. AVERAGE SIZES, DENSITIES, AND BIOMASSES OF CORBICULA AT SHALLOW-TO-DEEP-WATER TRANSECTS IN ROOSEVELT AND APACHE LAKES. RANGES ARE SHOWN IN ( ).

TRANSECT DESCRIPTION	DEPTH BELOW FULL POOL WATER MARK (M)	SUBSTRATE	AVERAGE SIZE (mm)	NUMBER/M^2	BIOMASS KG/HA
APACHE LAKE (BURNT CORRAL)					
BC-1-1	2.2	Sand-silt	19.6(7-38)	7.0(5-9)	6.0
BC-1-2	3.4	Rubble	19.7(5-37)	208.0(27-367)	181.0
BC-1-3	9.0	Rubble	22.5(5-38)	383.0(221-589)	482.6
BC-1-4	13.4	Rubble	19.8(3-38)	380.0(240-499)	338.2
BC-1-5	18.0	Gravel-sand, small rubble	22.5(10-38)	25.0(20-29)	31.5
BC-4-1	17.0	Sand-gravel	25.0(19-28)	3.0(5-9)	5.4
BC-3-1	22.0	Rubble	14.5(6-28)	32.0(0-64)	9.9
BC-2-1	20.0	Sand-rubble	18.4(7-28)	17.0(0-34)	12.2
ROOSEVELT LAKE (NORTH SHORE EQUIDISTANT BETWEEN R-2 AND R-3)					
F-50	3.4	Rubble	0.0	0.0	0.0
F-100	7.0	Rubble	13.8(5-25)	22.0(12,3)	6.6
F-150	10.4	Sand-gravel	20.2(8-36)	124.0(86-166)	117.8
F-200	14.0	Sand,gravel, rubble, boulder	19.2(8-32)	176.0(121-163)	140.8

higher terrace, however, they were far lower than those on the shallower, rocky slope. Mud flats near this locality, despite excavation to depths of 0.5 m yielded no indications of clams.

Another shallow-to-deep transect similar to those discussed above was sampled in the vicinity of R-4 (Fig. 1) on a predominantly silt slope containing little rock or sand. Eleven m^2 quadrats were examined — seven contained no clams, three had 2, and one had 3 clams. Two quadrats at approximately 15 m below high waterline contained only 2 clams/m^2. Two samples from about 17 m of water contained only 2 and 3 clams/m^2. These data also support the evidence for greater densities in deeper water and on rock-rubble slopes.

Variation in average sizes, numbers, and weights per unit area of all *Corbicula* collected in areas as near to established transects as possible in Roosevelt and Apache lakes are in Table 2. No consistent trends in average sizes of clams were detectable among localities in Roosevelt Lake. Greater biomass, however, was present at down-lake transects (*e.g.* R-2). Densities of clams at about a kilometer (km) east of R-2 and on the north shore of Roosevelt roughly equidistant between R-2 and R-3, were 2 to 6 times the mean densities, and 4 to 10 times the biomasses recorded nearer inflow areas. Evident harvesting of clams by humans at Frazier's landing, a major boat launching area, was reflected in drastically lower densities (Table 2). Considering all quadrats sampled in

TABLE 2. AVERAGE SIZES, NUMBERS, AND BIOMASSES OF <u>CORBICULA</u> AT SELECTED LOCALITIES IN ROOSEVELT AND APACHE LAKES. RANGES ARE SHOWN IN ( ).

LAKE LOCALITY	AVERAGE SIZE (mm)	NUMBER/M^2	BIOMASS (KG/HA
ROOSEVELT			
R-1	11.4(10.1-13.7)	53.0(12.0-103.0)	10.0(1.4-14.0)
1 km. E. R-2	14.7(10.0-18.5)	119.0(42.0-243.0)	43.0(10.7-87.5)
Frazier's Landing	21.8(18.8-27.8)	19.0(32.0-243.0)	110.0(10.6-137.8)
N. shore of Roosevelt equidistant from R-2 and R-3	18.6(14.2-20.9)	110.0(32.0-243.0)	110.0(10.6-137.8)
APACHE			
A-2	25.9(23.5-29.0)	26.0(11.0-59.0)	49.9(35.9-105.6)
0.5 km. N. A-2	20.6(10.5-27.9)	177.4(5.0-589.0)	194.1(0.65-1,060.0)
A-3	20.8(17.2-25.9)	73.0(14.0-166.0)	68.9(18.2-164.3)
A-5	18.4(11.5-23.8)	65.0(30.0-152.0	56.2(11.4-214.0)

Roosevelt Lake, numbers of clams ranged from 12 to 243/m^2, and biomasses from 1.4 to 137.8 kilogram per hectare (kg/ha).

Average size, density, and biomass of clams generally decreased downlake in Apache (Table 2). Great variation in these parameters at two sites, one at A-2 and another less than a km north, reflects the influence of bottom type on clam populations (Table 2). At A-2, the substrate consisted of compacted gravel, and clams were scarce; however, in boulder-strewn slopes, up-lake Corbicula were almost eight times as numerous per unit area (Table 2). Furthermore, three sets of adjacent samples taken in February 1972 on rock-boulder (in contrast to the sand-gravel substrate at A-3 in Apache Lake— (Fig. 3) yielded significantly greater densities in all cases in the former, ranging from 2.5 to 9.0 times higher (66-25, 121-14, 38-8) than in A-3's sand-gravel substrate type.

Over-all, densities of Corbicula in Apache Lake ranged from 5.0 to almost 600/m^2, and standing crops from 0.65 to 1,060 kg/ha, excluding weights of shell. Analysis of variance showed non-significant differences between numbers, sizes, and biomasses relative to depth at all transects and in comparison of samples from the two localities at A-2.

Meager data on Corbicula were obtained from Ekman dredge samples (Table 3). Few clams occupied the soft, fine-grained sediments that the Ekman dredge sampled most efficiently. Numbers of live clams taken in Ekman dredge samplings were comparable to those collected in meter square quadrats. For example, 5 of 20 Ekman samples taken at A-2, in Apache Lake indicated clam densities of 43 to 86/m^2 (Table 3), compared to 26/m^2 estimated by the quadrat method (Table 2). Densities of clams at A-5 estimated by these same two sampling methods, also were comparable (Tables 2 and 3).

DISCUSSION

Data from Roosevelt and Apache Lakes were not significantly different at the 0.05 level in either biomasses or numbers of clams between lakes or in most cases, among

TABLE 3.   SUMMARY OF CORBICULA COLLECTED WITH AN EKMAN DREDGE IN APACHE LAKE, 1971.

TRANSECT, STATION	DATE	NUMBER CONTAINING CORBICULA	NUMBER/DREDGING	ESTIMATED NUMBER/M^2
APACHE				
A-2-1	3-30-71	3 of 8 dredgings	1	43.0
A-2-3	3-29-71	1 of 10 dredgings	2	86.0
A-2-3	3-30-71	1 of 2 dredgings	2	86.0
A-3-1	3-23-71	1 of 8 dredgings	4	172.0
A-4-3	3-22-71	2 of 10 dredgings	1	43.0
			2	86.0
A-5-1	3-22-71	3 of 15 dredgings	2	86.0
			1	43.0

transects, but actual values of each of these seemed to vary inversely up- to down-lake, when the two reservoirs were compared. Inflow areas of Roosevelt Lake were more turbid, and normally had more phytoplankton as indicated by chlorophyll-*a* data (Portz, 1973; Rinne, 1973). As given above, clams were far more dense down-lake from inflow areas in Roosevelt Lake. The effect of greater inorganic suspended solids at the Salt River inflow of Roosevelt may well have suppressed the population of clams, despite an adequate food supply.

By comparison, densities and biomasses of *Corbicula* decreased down-lake in Apache Lake in presence of both sparser food and less turbidity relative to that recorded in up-lake sectors. These data indicate that food supply may be more limiting to *Corbicula* than turbidity. Prokopovich (1969) recorded decreases in densities of clams downstream in the Delta-Mendota Canal, California, and attributed this to decreasing food supply. However, turbidity as a factor in affecting dispersion of clams can not be eliminated as indicated by my data and that of others. A high mortality of *Corbicula* in the Ohio River in spring was attributed to increased turbidities (more than 400mg/1) by Bickel (1966).

Vertically, densities of *Corbicula* seemed to increase with depth, modified somewhat by bottom type and location within the reservoir system. This may be an indication of the influence of food supply (phytoplankton) as effected by photic conditions (Portz, 1973; Rinne, 1973). In addition, rocks and boulders upon slopes within these two reservoirs provide protection for juvenile clams from predators. Several species of fishes; carp *(Cyprinus carpio* Linnaeus), smallmouth *(Ictiobus bubalus* [Rafinesque]) and black *(Ictiobus niger* [Rafinesque]) buffalofishes consume large numbers of *Corbicula* (Minckley, *et al.,* 1970; Rinne, 1973). Increase in densities of clams with depth may therefore be a reflection of greater fish predation in shallower areas of the lake.

Corbicula is known to remove suspended organic and inorganic particles from water and deposit them as pseudofeces (Prokopovich, 1969). Heinsohn (1958) reported two to three small *Corbicula* were capable of clearing 500 milliters of "very turbid water" in less than 2 minutes. Precipitation of plankton from aquatic media by *Corbicula* was reported by Greer (1971), and laboratory studies at Arizona State University suggested filtration rates are directly related to concentration of algal cells in solution (Richard

Stephenson, pers. comm.). Above certain critical concentrations of algal cells, clams began indiscriminantly to precipitate food and inorganic particles, presumably to clear their gills and thereby prevent asphyxiation.

Ideal conditions for *Corbicula* seemingly would include both clear waters and adequate food supply. Large concentrations of this clam downstream from hydro-electric dams has been attributed to clear, plankton-rich waters (Heard, 1964). I noted the greatest concentrations of clams (1,500/m^2), in the canal below Granite Reef Dam where both clear water and adequate food were present.

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FIG. 2. *Photograph of a rock-rubble slope typical of central Arizona reservoirs (A) and closeups (B and C) showing complexity of these habitats and interstices providing protection for clams from fish predation.*

MICROSTRUCTURE OF CHALKY DEPOSITS FOUND IN SHELLS
OF THE OYSTER *CRASSOSTREA VIRGINICA*[1]

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ABSTRACT

Scanning electron microscopy has revealed that chalky deposits in shells of Crassostrea virginica *consist of blade-shaped crystals of calcite oriented perpendicular to the inner surface of the shell. From a structural standpoint, these chalky deposits appear to represent a layer of calcite which is a morphologically distinct entity, and not merely a porous and disoriented variant of the calcite ostracum. Chalky deposits are common at all stages of growth and are irregularly distributed across the inner surfaces of the valves. It is suggested that deposition of calcite in the form of chalky deposits occurs as a specific physiological response to environmental stimuli, possibly during periods of maximum respiration.*

The shell of *Crassostrea virginica*, the common commercial oyster of the Atlantic coast of North America, has been described as consisting of two layers of crystalline calcite with a thin, to absent, outer organic periostracum (Galtsoff, 1964). Our examination of various portions of fresh *C. virginica* valves by scanning electron microscopy has revealed that the outer crystalline layer is composed of elongate, prismatic calcite crystals oriented perpendicular to the shell wall and enmeshed in a reticulum of conchiolin which separates and defines the individual calcite prisms (Fig. 1A). The electron micrographs shown here represent specimens which first were cleaned of adhering organic material with a 5% sodium hypochlorite solution, and then etched briefly in a 10% solution of acetic acid in order to bring the crystal structure out in

[1] Contribution number 594, Hawaii Institute of Geophysics

FIG. 1 (opposite page)

A. Cross-section of outer crystalline layer of *C. virginica* showing elongate calcite crystals oriented perpendicular to outer shell surface. Conchiolin has been partially removed by sodium hypochlorite.

B. Cross-section of inner calcite ostracum layers consisting of thin sheets oriented parallel to inner surface of shell.

C. Fractured portion of inner calcite ostracum illustrated in *B* showing structure of calcite sheets.

D. Etched cross-section of hinge area of *C. virginica* showing thick inner calcite ostracum (O) and thinner interbedded discontinuous chalky layers (C).

E. Interface between chalky layer (upper portion of photo) and calcite ostracum (lower portion) showing different orientation and morphology of crystals.

F. High resolution photo of chalky layer showing aggregates of blade-shaped crystals. Clumpy material adhering to crystals are remnants of conchiolin which had been incompletely removed by sodium hypochlorite.
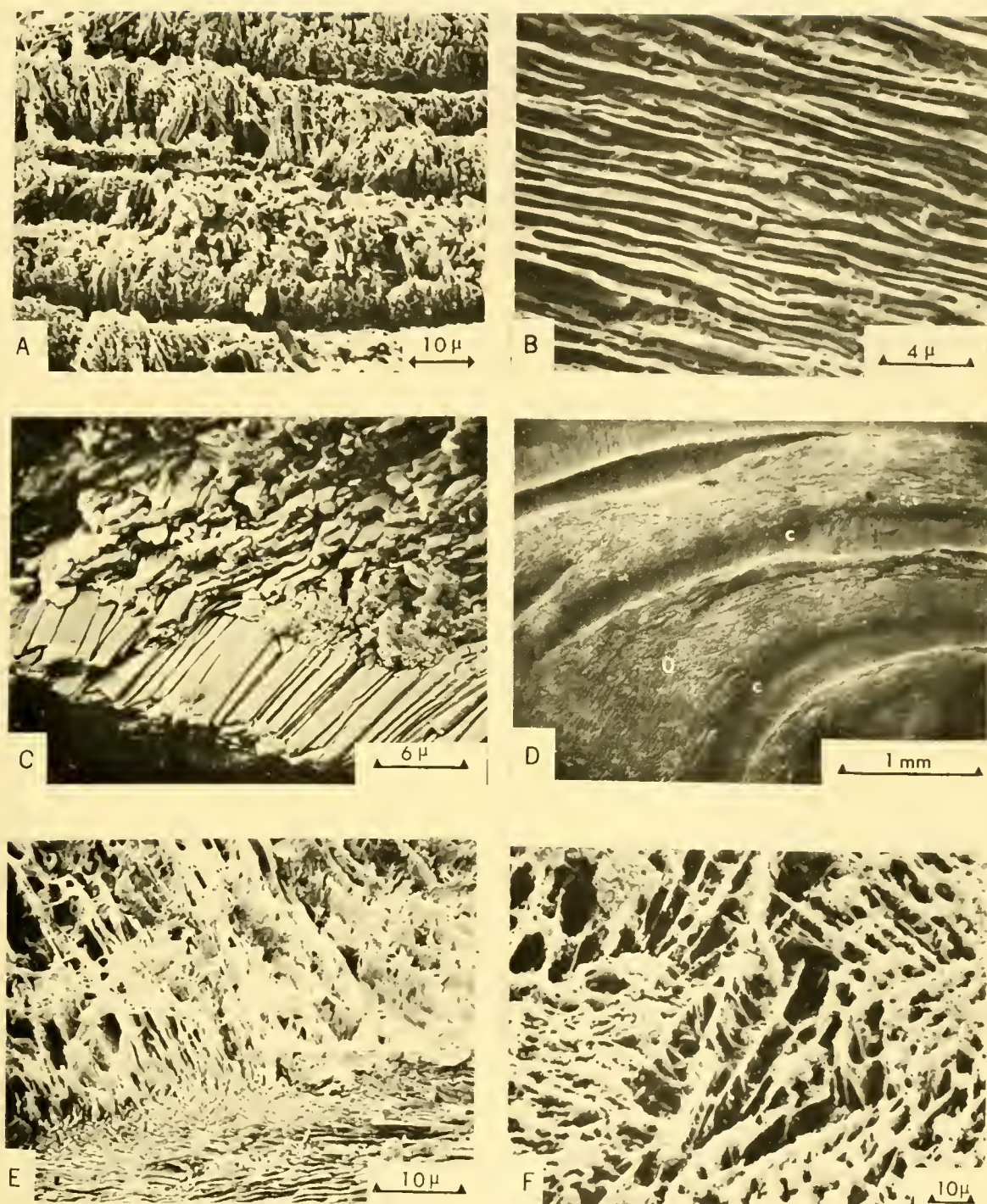
FIG. 1. *Microstructure of Oyster Shell*, Crassostrea virginica
(explanation on opposite page)

relief. The inner layer of calcite is much thicker than the prismatic layer and consists of thin blocks, or sheets, of calcite oriented with the long axes parallel to the inner surface of the shell (Figs. 1B, C). In the inner layer, or calcite ostracum, as in the prismatic layer, each calcite crystallite is completely surrounded by a thin membrance of conchiolin (Watabe et al., 1958). Stenzel (1963) found that the hypostracum, the crystalline material of the areas of attachment of the adductor muscle imprint of Quenstedt's muscle, consists of aragonite, rather than calcite. We also noted slender aragonite crystals in our examination of the hypostracum.

The most intriguing aspect of the shell structure of *C. virginica* and other species of *Crassostrea* is the almost universal occurrence of patches of dead-white, porous material called "chalky deposits" on the interior surface of the shell. Chalky deposits also occur within the body of the shell, interlayered with calcite ostracum (Figs. 1D, E), indicating that they represent temporary phenomena, deposited at some time, when overgrown by the more abundant calcite ostracum. Galtsoff (1964) studied the morphology and distribution of chalky deposits in *C. virginica* and found that they are randomly distributed over the inner surface of the shell and do not appear to be related to either injury or senility. Medcof (1944) and Korringa (1951) had previously suggested that chalky deposits serve to correct the internal volume and curvature of the shell to conform to body size and shape, but Galtsoff found no evidence to support this view.

We report that examination of the "chalky deposits" show them to consist of blade-shaped crystals of calcite oriented perpendicular to the inner surface of the shell. The structure is not porous nor a disoriented phase of the normal calcite-ostracum structure, as has been previously thought, but an entirely different, perhaps physiologically unique, structure. "Chalky deposits" consist of aggregates of blade-shaped calcite crystals (Figs. 1E, F) oriented with long axes perpendicular to the inner surface of the shell. Intermediate axes of neighboring crystals tend to be oriented subparallel to the plane of the shell surface, establishing crystal domains consisting of 5 to 20 similarly oriented calcite crystals. "Spurs" extending from the long axes of calcite crystals at approximately 60° (Fig. 1F) suggest that the long axes are parallel to the *c* crystallographic axis of calcite, the intermediate axes parallel to *a*. The etching treatment was desirable in revealing the internal structure of the chalky deposits, although it somewhat blunted and pitted individual crystallites. Further examination of specimens etched to a lesser degree, revealed that the crystallites and spurs are smooth-walled and sharp-edged, and that spaces between crystals are filled with conchiolin.

The contrast in orientation and morphology between the crystals of the calcite ostracum and the "chalky deposits" (Figs. 1A, B) suggests that the "chalky deposits" perhaps represent selective growth by the oyster of these discontinuous layers as a physiological response to one or several environmental stimuli. Furthermore, the irregular distribution of "chalky deposits" throughout the body of the shell and across the inner surface of the shell described by Galtsoff (1964) indicates that the process of formation of chalky deposits is highly irregular with respect to growth stages of the organism, and with respect to time. Although unknown, the environmental stimuli involved are probably factors which experience episodic fluctuations, and we can draw on the experience of Dugal (1939) for a possible analogy.

Dugal (1939) found that *C. virginica* and *Mercenaria mercenaria* (Veneridae) resorb material during anerobic metabolism resulting from long periods of shell closure, and that the resorption buffers a potential decrease in pH of body fluids basically attributable to accumulation of CO^2 in fluids of the body cavity. The Dugal effect, resorption of shell material to buffer a low body-fluid pH, may be the exact opposite of the physiological process leading to the accumulation of chalky deposits. It may be possible that during periods of maximum ventilation, the CO^2

content of the body fluids decreases, with a consequent increase in pH. Elimination of calcium from the body fluids at this stage by decreasing the $CaCO_3$ saturation would tend to reduce pH and buffer the effect of excess ventilation. We suggest that this type of calcite deposition is physiologically different from that of normal shell growth, and might explain the morphologic difference between the chalky deposits and the calcite ostracum layers.

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UNIONIDAE OF THE PAMUNKEY RIVER SYSTEM, VIRGINIA

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During the Fall and Winter of 1972 and Spring of 1973, the investigators collected over 1200 unionid specimens on the Pamunkey River System (York River Drainage). The following is a listing of species collected:

Elliptio complanata (Lightfoot)
*E. angustata (Lea)
E. lanceolata (Lea)
*Lampsilis radiata radiata (Gmelin)
L. cariosa (Say)
*Ligumia nasuta (Say)
Alasmidonta undulata (Say)
*A. heterodon (Lea)
Lasmigonia subviridis (Conrad)
*Anodonta cataracta cataracta (Say)

Elliptio complanata comprised approximately 85% of the specimens. By the most recent records available (Johnson, 1970), the indicated species (*) are drainage records for the river system. A specimen of Anodonta implicata (Say), also a drainage record, was collected on the James River below Richmond, Va.

The authors are indebted to Dr. J. P. E. Morrison for his assistance in identification.

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ARION SUBFUSCUS IN THE VICINITY OF WASHINGTON, D.C.

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The previously recorded distribution of the introduced European slug, *Arion subfuscus* (Draparnaud, 1805), in eastern North America extended on the west from Greenwich, Connecticut, northward through the Catskill and Adirondack mountains to the St. Lawrence River and eastward to the coast (and onto Newfoundland); there is also a population recorded from the Kipawa Reserve in Eastern Ontario. In addition, there are scattered records from Pennsylvania and one from East Aurora, New York (Chichester and Getz, 1969; Getz and Chichester, 1970).

Spot checks made in the vicinity of Washington, D.C. during July 1973, indicated *Arion subfuscus* to be very abundant in this region. Collections were made in Falls Church, Virginia and Bethesda, Maryland. *A. subfuscus*, along with another introduced slug, *Limax maximus*, was found in high densities in flower beds and lawns at both of these sites. Discussions with individuals living in various places within the District of Columbia and surrounding communities indicated both species to be common throughout the metropolitan region. The only previous record of *Arion* from the District of Columbia is *A. fasciatus* (Nilsson) (as *circumscriptus* Johnston, by Pilsbry, 1948). The abundance of *A. subfuscus* indicates the species has been present in this region for a considerable period of time, however.

Examination of the individuals from the two populations revealed a much more heterogeneous assemblage of color forms than was observed in any of the local populations in New England. Individuals resembling three of the four color forms (Forms 1, 2, and 4; Chichester and Getz, 1969) identified in New England occurred at both sample sites; only the unbanded, yellow-orange form (Form 3) was not observed. In addition there was greater intergradation between color forms than was observed in most other local populations. There was a continuous range of color from an almost completely black dorsum above the lateral bands (as in Form 1) to a very light yellowish-brown form with light lateral bands (Form 4). This intergradation of color forms indicates a possible long existence of the species in the region.

The presence of such an abundant, unreported population of *A. subfuscus* existing in this region emphasizes an earlier comment concerning the need for more detailed information concerning distribution of introduced European slugs (Chichester and Getz, 1968).

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GALÁPAGOS BULIMULIDS:
A TAXONOMIC CORRECTION

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Dr. Abraham S. H. Bruere, Division of Systematic Zoology, University of Leiden, Leiden, The Netherlands, who is studying the Bulimulidae, has kindly and quite properly called my attention to a taxonomic situation that needs correction. Last year I described three new land snails from Isla Santa Cruz (Indefatigable Island), Galápagos, that were presumed to be new species (Smith, 1972). These were *Naesiotus cavagnaroi*, *N. deroyi*, and *N. scalesiana*. At the time this report was being prepared I was totally unaware of the important contribution by the distinguished Swedish malacologist, Dr. Nils H. Odhner, in which two new Galápagos land snail species were described, also from Isla Santa Cruz, as *Bulimulus blombergi* and *B. eos*, respectively (Odhner, 1951). Careful reading of Odhner's descriptions along with a review of his excellent illustrations leave no doubts that *Naesiotus deroyi* A. G. Smith, 1972, is exactly the same species as *N. blombergi* (Odhner, 1951), and that *N. scalesiana* A. G. Smith, 1972, is completely equivalent to *N. eos* (Odhner, 1951). My new names, therefore, should be placed into the synonymies of Odhner's species names. Apologies are in order for the inadvertent creation of two synonyms in the Mollusca: Stylommatophora, family Bulimulidae, and for unnessarily complicating the taxonomy of the family-group to this extent.

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Odhner, Nils Hjalmar. 1951. Studies on Galápagos Bulimulids. Journal de Conchyliologie, 90(4):253-268, 2 pls. (figs. 1-13). Paris. 25 January. [In English].

Smith, Allyn Goodwin. 1972. Three new land snails from Isla Santa Cruz (Indefatigable Island), Galápagos. Proc. California Acad. Sci., (4), 39(2):7-24, figs. 1-25. San Francisco. January 21.

ANOTHER FOSSIL OVOVIVIPAROUS
TURRITELLA

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At the Kenneth E. Rice Fossil Pit of Miocene age at Hampton, Virginia, in September 1973, the writer found a 37-mm specimen of *Turritella alticostata* Conrad that contained 41 preserved immature shells. This is the fifth species of *Turritella* from the Chesapeake and Floridian Miocene which is known to have ovoviviparous reproduction. The species was kindly identified by Druid Wilson, Geologist of the U. S. Geological Survey at the Smithsonian Institution. The specimens are in the collection of the writer at present, but will be given to the Kenneth E. Rice Memorial Museum shortly.

Palmer, Katherine V. W. 1961. Additional Note on Ovoviviparous *Turritella* Jour. Paleont. 35(3): 633.

Sutton, A. H. 1935. Ovoviviparous Reproduction of Miocene Turritellidae. Amer. Midland Nat. 16(1):107-109.

NEWS

LIVING VOLUTES by Weaver and du Pont (1970, 375 pp., 79 colored plates), has had its retail price drastically reduced from $55.00 to $36.00 in order to make it more readily available to malacologists. Send check to the Delaware Museum of Natural History, Box 3937, Greenville, Delaware 19807.

ERRATUM

In the article on "Growth Studies on the Genus *Cerithium* . . ." by R. Houbrick, appearing in the last issue of The Nautilus, vol. 88, no. 1, p. 17, the captions to Figs. 2 and 3 were inadvertently interchanged. In Fig. 2, for *lutosum*, read *eburneum*. In Fig. 3, for *eburneum*, read *lutosum*.

WESTERN SOCIETY OF MALACOLOGISTS

The Seventh Annual Meeting will be held June 19-22, 1974, at the Kellogg West Conference Center on the campus of California State Polytechnic College, Pomona, California. The program will feature contributed papers, symposia, displays, and study workshops on molluscan subjects. In addition to the program of research papers, there will be a concurrently running program of popular presentations on shells or shell collecting.

Inquiries about the meeting should be made no later than May 15th and should be directed to the Secretary, Mrs. Edith Abbott, 1264 West Cienega Avenue, San Dimas, California 91773. Applications for membership should be sent to the Treasurer, Mr. Bertram C. Draper, 8511 Bleriot Avenue, Los Angeles, California 90045.

The President this year is Dr. James H. McLean — *editor*.

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Manuscripts: Authors are requested to follow the recommendations of the *Style Manual for Biological Journals*, which may be purchased from the American Institute of Biological Sciences, 2000 "P" Street, N.W. Washington, D.C. 20036. Manuscripts should be typewritten and doublespaced; original and one copy are required, to facilitate reviews. Tables, numbered in arabic, should be on separate pages, with the title at the top. Legends to photographs should be typed on separate sheets. Explanatory terms and symbols within a drawing should be neatly printed, or they may be pencilled in on a translucent overlay, so that the printer may set them in 8 pt. type. There is a charge of 50 cents per word for this extra service. All authors or their institutions will be charged 50 cents per line of tabular material and taxonomic keys. The publishers reserve the right, seldom exercised, to charge $32 per printed page.

An *abstract* should accompany each paper.

Reprints and covers are available at cost to authors. When proof is returned to authors, information about ordering reprints will be given. They are obtained from the Economy Printing Co., Inc., R. D. 3, Box 169, Easton, Maryland 21601.

MOLLUSK VOUCHER SPECIMENS

It is becoming increasingly important for future research purposes that an identified sampling of species mentioned in publications be deposited in a permanent, accessible museum specializing in mollusks. This is particularly true of mollusks used in physiological, medical, parasitological, ecological, and experimental projects.

The Delaware Museum of Natural History has extensive, modern facilities and equipment for the housing and curating of voucher specimens. Material should be accompanied by the identification, locality data and its bibliographic reference. There is no charge for this permanent curating service, and catalog numbers, if desired, will be sent to authors prior to publication.
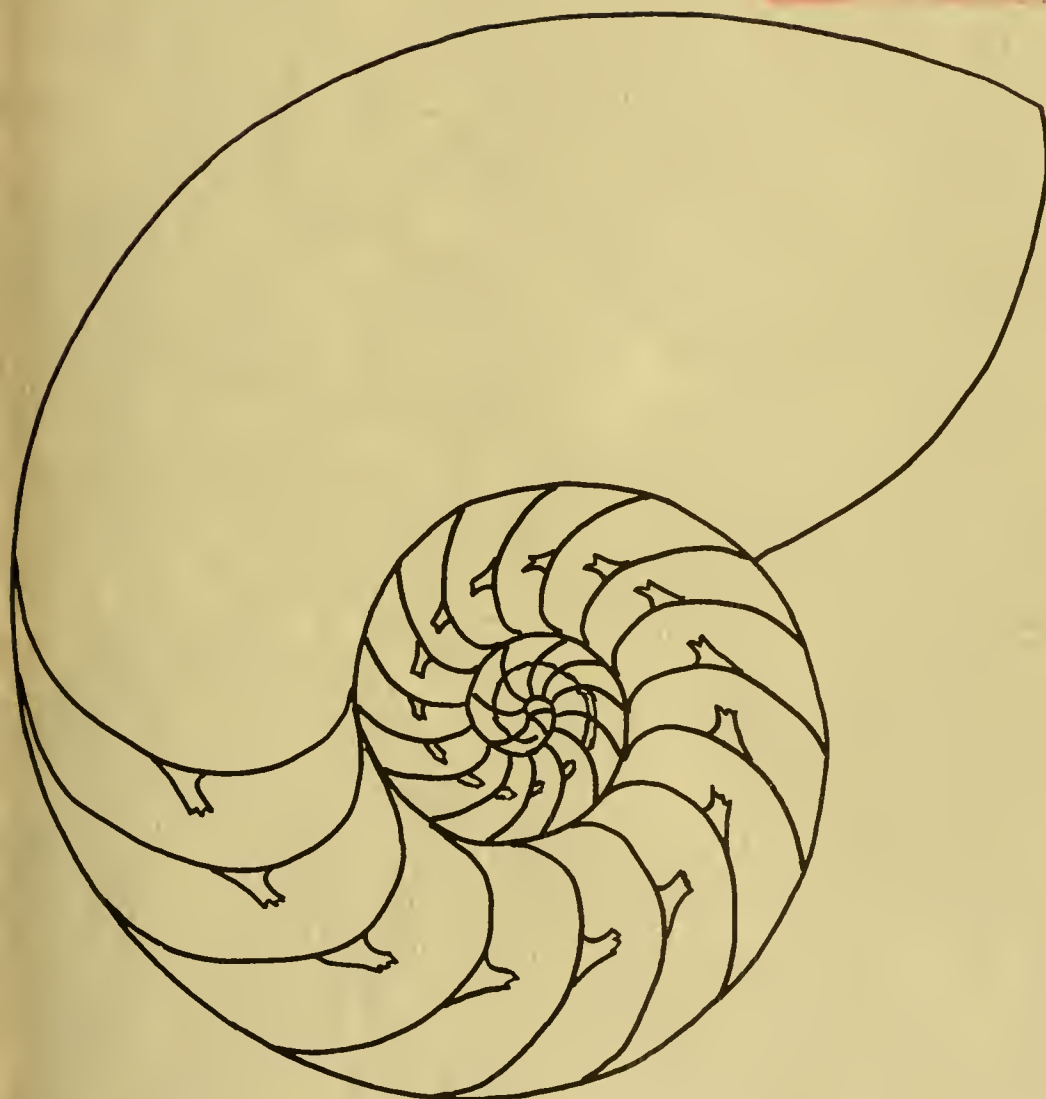
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CONTENTS

A CONTRIBUTION TO THE SYSTEMATICS OF SOME WEST INDIAN *LATIRUS* (GASTROPODA: FASCIOLARIIDAE)

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ABSTRACT

Some West Indian members of the taxonomically difficult genus Latirus *are considered. The two most common species, generally recognized as* Latirus brevicaudatus *(Reeve, 1847) and* L. mcgintyi *Pilsbry, 1939, are highly polymorphic and have been described in the literature under a number of names; due to the present confusion surrounding these species, some nomenclatorial changes appear necessary, and they are herein called* Latirus angulatus *(Röding, 1798) and* L. cariniferus *(Lamarck, 1816), respectively.* Latirus (Polygona) bernadensis *from Barbados is introduced as a new species;* Latirus (Polygona) nematus *Woodring, 1928, originally described from the Bowden Formation, Jamaica, is noted for the first time as a member of the Recent fauna.*

INTRODUCTION

While studying the fasciolariid genus *Latirus* in the western Atlantic, some conclusions have been reached pertaining to the subgenera *Latirus s.s.* and *Polygona* and these results are presented in this paper. It is hoped that a monograph covering all the West Indian species of the genus will be completed in the near future.

The genus *Latirus* includes a variety of fasciolariid species characterized by being spindle-shaped, generally rather heavy-shelled, and with prominent folds on the columella. The great diversity of form has encouraged some authors to create generic and subgeneric names, and some of these appear to be very useful in an evolutionary treatment of the group.

Among the Peristerniinae, the group most closely related to *Latirus* is also composed of diverse members and is well represented in the New World by the genus *Leucozonia*. The latter group can be distinguished from *Latirus* by its more open siphonal canal, which actually forms the lower portion of the aperture; also, there is an interesting difference in the radula, the small node or cusp on the medial end of the lateral tooth being greatly reduced or absent in *Leucozonia*. Some, but not all, *Leucozonia* possess a tooth on the outer lip at the base of the aperture. For these reasons, the genus *Leucozonia* [type species *Leucozonia nassa* (Gmelin) from the West Indies] includes *Leucozonia ocellata* (Gmelin), also Caribbean, and *Leucozonia cerata* (Wood), *L. rudis* (Reeve), and *L. tuberculatus* (Broderip) from the eastern Pacific. While some of these generic combinations were noted by Keen (1971) in her treatment of eastern Pacific Mollusca, *rudis* was incorrectly considered to belong to *Latirus*.

Other Peristerniinae similar to *Latirus*, but apparently more closely related to *Leucozonia*, include: the Indo-Pacific *Latirolagena smaragdula* (Linnaeus) and the eastern Pacific *Opeatostoma pseudodon* (Burrow) which have a typical *Leucozonia*-type radula; and *"Latirus" amplustris* (Martyn), from the Indo-Pacific. It should be mentioned here that the generic differences noted above indicate that the radula of *Latirus gibbulus* (Gmelin), the type species of the genus *Latirus*, will prove to be of the *Leucozonia*-type. The heavy shell of *Latirus gibbulus*, its reduced spiral and axial sculpture, and its open siphonal canal indicate a likely *Leucozonia* affinity. Should the radula of *L. gibbulus* be found to be that of a *Leucozonia*, it would certainly pose an interesting problem concerning the correct generic names for the species presently considered to be *Latirus* and *Leucozonia*. The functional significance of the
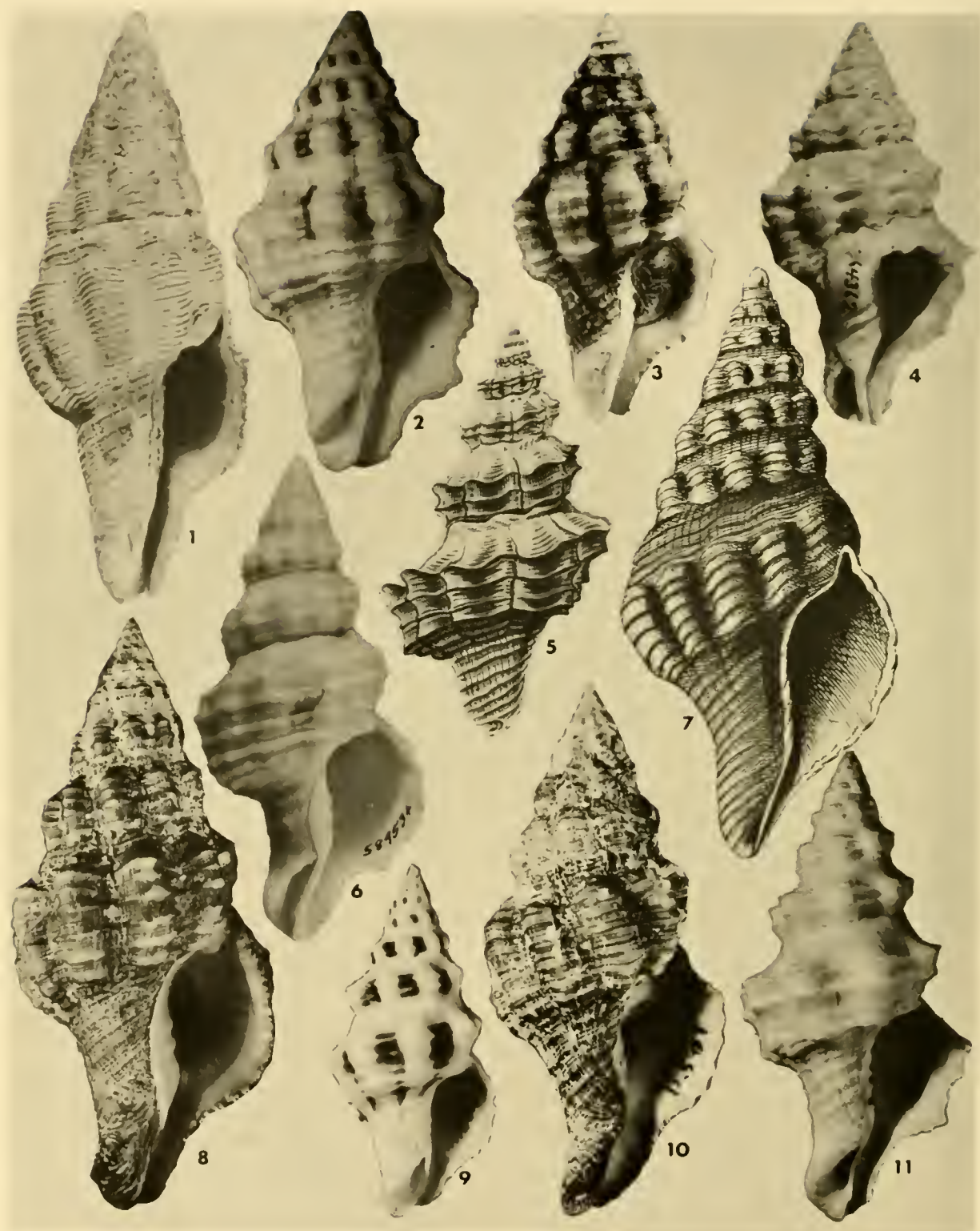
Explanation to *Latirus* figures 1-11 on opposite page

reduced medial node of the lateral tooth of the *Leucozonia*-type radula is not known, and its use as a phylogenetic character is slightly questionable due to the limited amount of material available for study.

Genus *Latirus* **Montfort, 1810**

Latirus Montfort, 1810, Conchyliologie systématique et classification méthodique des coquilles 2: 531. Type species, *Latirus aurantiacus* Montfort, 1810, by monotypy [= *L. gibbulus* (Gmelin, 1791)].

Chascax R. Watson, 1873, Proc. Zool. Soc. London for 1873: 361. Type species, *Chascax maderensis* Watson, 1873, by monotypy [= *Latirus armatus* A. Adams, 1855]; non *Chascax* Ritgen, 1828 (Reptilia).

Hemipolygona Rovereto, 1899, Atti Soc. Ligust. 10:104 (new name for *Chascax* Watson, 1873).

[?] *Ruscula* Casey, 1904, Trans. Acad. Sci. St. Louis 14: 161. Type species, designated by Palmer (1937), *Fusus plicata* Lea.

Subgenus *Latirus* s.s.

Latirus (Latirus) cariniferus **(Lamarck, 1816)**
Figs. 2-6, 9, 11, 18, 22

1816 *Fusus cariniferus* Lamarck, Encyclopédique méthodique, pl. 423, fig. 3. Name and figure only; locality unknown. Type locality herein designated to be Cienfuegos, Cuba. Type not in Musée d'Histoire naturelle, Geneva.

1855 *Latirus distinctus* A. Adams, Proc. Zool. Soc. London for 1854: 314. Locality unknown; type locality herein designated to be off Washerwomans Shoals, Key West, Florida. Lectotype, herein selected, BMNH 196738/1 (see Fig. 2).

1874 *Plicatella trochlearis* Kobelt, [in] Martini-Chemnitz, Syst. Conch.-Cab. 3 (3A): 79, pl. 19, figs. 1, 2. Type locality: St. Jan [= St. Johns, Virgin Islands]. Location of type unknown.

1939 *Latirus mcgintyi* Pilsbry, Nautilus 52: 84, pl. 5, fig. 8. Type locality: Lake Worth, Palm Beach Co., Florida. Holotype ANSP 173960.

Description: Shell highly variable, heavy, up to 73 mm in length and 36.8 mm in greatest diameter. Whorls 8-9, including 1½ whorls of the protoconch. Spire about half the length of the shell, but sometimes slightly less. Aperture almost square and twice as long as the short, thick siphonal canal. Axial sculpture of 8-9 moderately pronounced, squarish ribs. Spiral sculpture of heavy cords which begin at the shoulder of the whorl and continue anteriorly to the tip of the siphonal canal. 2-3 cords visible on the upper whorls, 5 on the body whorl, the 2 lowest closer together and being characteristic of this species. Between spiral cords 6-7 fine threads usually present but may

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FIG. 1. Latirus nematus *Woodring, Holotype, USNM 369442. Miocene of Bowden, Jamaica. 1.6X.*

FIG. 2. Latirus cariniferus *(Lamarck), Lectotype of* Latirus distinctus *A. Adams, BMNH 196738/1. 1.7X. Photograph courtesy of the British Museum (Natural History).*

FIG. 3. Latirus cariniferus *(Lamarck), Steger collection no. 416. Matanzas, Cuba. 1.3X.*

FIG. 4. Latirus cariniferus *(Lamarck). USNM 364362. Vicinity of Cartagena, Colombia. 1.5X.*

FIG. 5. Latirus cariniferus *(Lamarck). Type figure of* Fusus cariniferus *Lamarck, Encycl. Méth. pl. 423, fig. 3. 1.1X.*

FIG. 6. Latirus cariniferus *(Lamarck). USNM 589534. Colon, Panama. 1.5X.*

FIG. 7. Latirus angulatus *(Röding), Type figure of* Fusus angulatus *Röding, Syst. Conch.-Cab. 4, fig. 1315. 1.2 X.*

FIG. 8. Latirus angulatus *(Röding), specimen in MCZ. Just E. of Piscadera baai, Curaçao, Netherlands Antilles. 1.3X.*

FIG. 9. Latirus cariniferus *(Lamarck). AMNH 100575. W. of Cedar Key, Florida, 20 fms. 1.2 X.*

FIG. 10. Latirus angulatus *(Röding). AMNH 125489. Curaçao, Netherlands Antilles. 6 fms. 1.1 X.*

FIG. 11. Latirus cariniferus *(Lamarck). MCZ 234474. Cienfuegos, Cuba. 1.3X.*

be entirely absent. Sutural ramp devoid of major cords, although possibly with numerous spiral threads; at times this area is completely smooth. Columella with 2 folds with a weaker one below; occasionally 4 strong folds. Outer lip crenulated due to spiral sculpture. Within the lip are 13-22 irregular lirae which may be very weak. Fasciole present, sometimes very pronounced. Anal canal partially developed.

Color white, yellow, or light cream-orange. Spiral cords usually the same color as shell, but at times white. Many specimens, but not all, with a reddish brown bar between each axial rib of the earlier whorls. Some specimens have brown between the white spiral cords. Periostracum thin and light brown.

Remarks: This is a highly variable species, but the two conspicuous, heavy, contiguous spiral cords at the base of the body whorl serve to distinguish it from all other *Latirus*. This characteristic is observed in Lamarck's figure of *Fusus cariniferus* (Fig. 5), a name which has been overlooked by recent authors and misunderstood by earlier ones such as Paetel (1873, 1888), Tryon (1881), and Melvill (1891).

Deshayes & Milne Edwards (1843) mentioned that Lamarck had confused *Turbinella spinosa* Martyn with this species; they restricted the name *cariniferus* to the species figured by Lamarck in the Encyclopédique Méthodique.

The well-known names *megintyi* Pilsbry, *trochlearis* Kobelt, and *distinctus* A. Adams are all herein synonymized with *cariniferus* since they represent only a few of the many variations exhibited by this species. The shell of

cariniferus is somewhat similar to *Latirus armatus* A. Adams of the eastern Atlantic and an un-named species from Somalia; both, however, lack the two prominent contiguous spiral cords at the base of the body whorl. Only two western Atlantic specimens have been observed which lack the contiguous cords (ANSP 314265, La Gonave Id., Haiti). Tryon (1881) erroneously mentioned *Chascax maderensis* Watson [= *Latirus armatus* A. Adams] as a West Indian species.

Radular studies reveal that *L. cariniferus* is probably more closely related to *L. tumens* Carpenter from the Panamic Province than to *armatus*. The only other member of *Latirus s.s.* from the Caribbean is *L. varai* Bullock, 1970, which may easily be differentiated by its stronger spiral sculpture, more rounded whorls, and chestnut brown coloration on the axial ribs, not between them.

The fossil record of *cariniferus*-like *Latirus* is incomplete and known mostly from the Pliocene. Pilsbry (1939) described *L. maxwelli*, which differs from *cariniferus* by having stronger spiral cords and less pronounced axial ribs. *Latirus anapetes* Woodring, 1964, from the Chagres Sandstone (Pliocene) of Panama is also an early representative of *cariniferus*, differing by being more attenuate and having strong spiral cords. Woodring compared *anapetes* with a very closely related species, *taurus* Olsson, 1922, from the Gatun Formation of the Toro cays.

Distribution: From Palm Beach and the west coast of Florida in the north, this species ex-

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FIGS. 12, 19. Latirus nematus *Woodring, USNM 414931. Bear Cut, Miami, Florida, 25 fms. 12, 2.2X; 19, 1.9X.*

FIG. 13. Latirus (Polygona) bernadensis *Bullock, n. sp., Holotype, MCZ 275428. Barbados Island, Lesser Antilles. 2X.*

FIG. 14. Latirus infundibulum *(Gmelin), Finlay collection. Aguadilla, Puerto Rico. 1.2X.*

FIG. 15. Latirus infundibulum *(Gmelin), AMNH 115203. From fish traps in 10 fms., Guantanamo Bay, Cuba. 1.3X.*

FIG. 16. Latirus angulatus *(Röding), USNM 663740. Water Id., Virgin Islands. 2.2X.*

FIG. 17. Latirus angulatus *(Röding), USNM*

414897. Cardenas Bay, Cuba, 1-3 fms. 2.1X.

FIG. 18. Latirus cariniferus *(Lamarck), Finlay collection. Off Gibara, Oriente, Cuba, 100 fms. 1.3X.*

FIG. 20. Latirus angulatus *(Röding), AMNH 140148. Off Fortaleza, Ceará, Brazil, 12 fms. 2.2X.*

FIG. 21. Latirus angulatus *(Röding), specimen in MCZ. N. coast of South America, dredged. 2.3X.*

FIG. 22. Latirus cariniferus *(Lamarck), D'Attillio collection no. 1344. Cienfuegos Harbor, Cuba. 0.8X.*
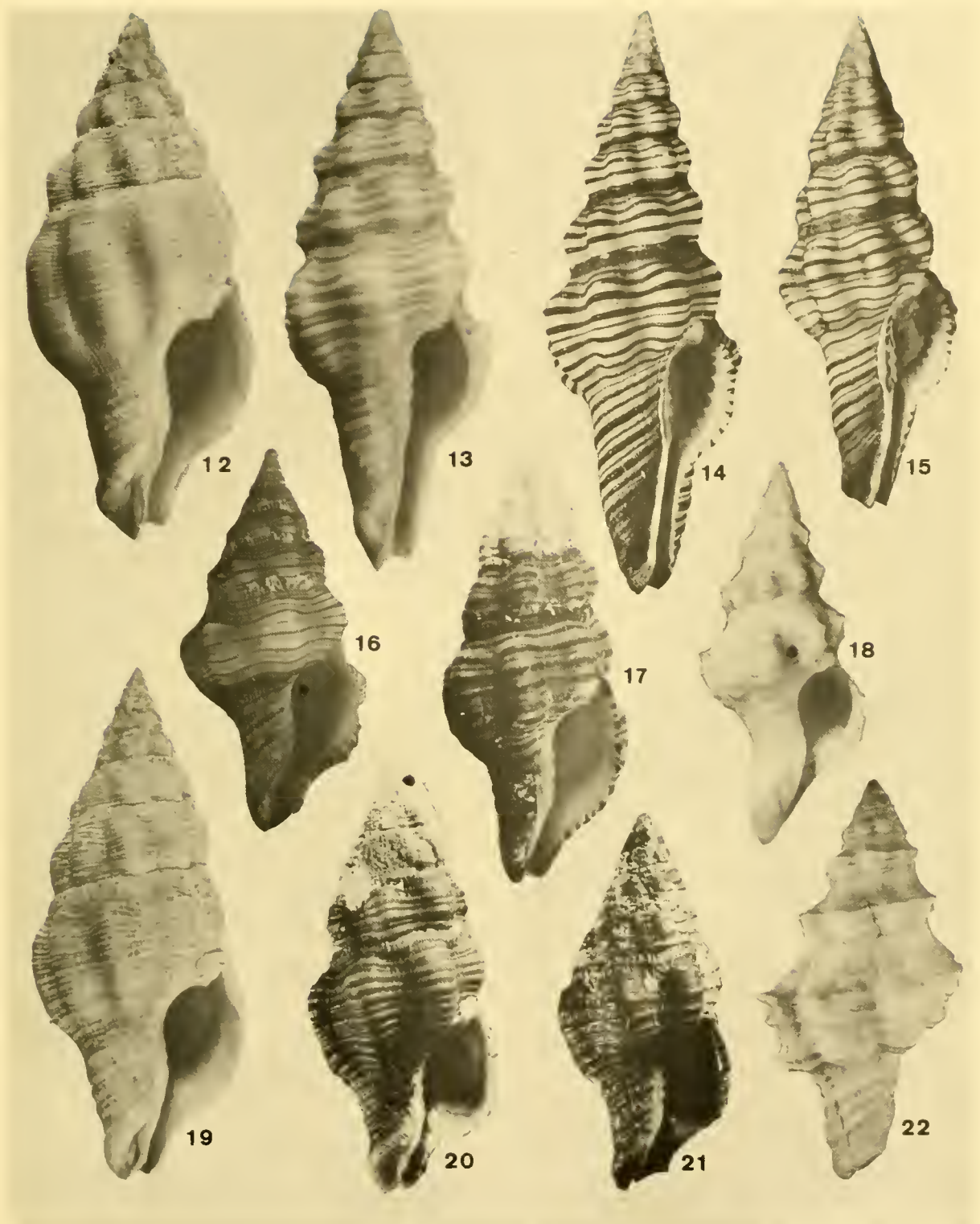
Explanation to *Latirus* figures 12-22 on opposite page

tends throughout the West Indies, and from Yucatan, Mexico, to the northern coast of South America, from shallow water to over 100 fathoms.

Subgenus *Polygona* Schumacher, 1817

Polygona Schumacher, 1817, Essai d'un nouveau système des habitations des vers testacés, pp. 73, 241. Type species, *Polygona fusiformis* Schumacher, 1817, by monotypy [= *Latirus infundibulum* (Gmelin, 1791)].

Plicatella Swainson, 1840, Treatise on malacology, pp. 78, 304. An unnecessary new name for *Polygona* Schumacher.

Remarks: As Woodring (1928) mentioned, *Latirus infundibulum* (Figs. 14, 15) is extremely different from *L. gibbulus,* the type species of *Latirus.* But Woodring admitted that in terms of shell morphology there exist species intermediate between *Latirus s.s.* and *Polygona.* The latter differs from *Latirus* by being smaller, relatively more narrow, having a well developed siphonal canal, and usually with pronounced brown, rather than white, spiral cords. It seems wise at this time to retain the use of *Polygona* at the subgeneric level only.

Species referable to *Polygona* appear commonly in the Miocene of the Caribbean region. This group, as with other *Latirus,* includes some species having a high degree of intraspecific variation of shell characters. Recent West Indian species of *Polygona* include *infundibulum* (Gmelin), *angulatus* (Röding), *nematus* Woodring, and *bernadensis* Bullock, n. sp.; *hemphilli* Hertlein & Strong, *concentricus* (Reeve), and *praestantior* Melvill are eastern Pacific representatives.

Latirus (Polygona) angulatus (Röding, 1798)
Figs. 7, 8, 10, 16, 17, 20, 21, 24-26

1798 *Fusus angulatus* Röding, Museum Boltenianum, p. 118, sp. 1527. Locality not mentioned; type locality herein designated to be San Juan baai, Curacao, Netherlands Antilles. Location of type unknown.

1847 *Turbinella brevicaudata* Reeve, Conchologia Iconica 4, *Turbinella* pl. 10, sp. 50. Locality unknown; figured specimen in BMNH. A doubtful synonym of *Latirus angulatus.*

1847 *Turbinella spadicea* Reeve, Conchologia Iconica 4, *Turbinella* pl. 9, sp. 44. Locality unknown. Possible syntypes in BMNH.

1940 *Latirus cymatius* Schwengel, Nautilus 53: 110, pl. 12, figs. 6, 7. Type locality: off Palm Beach, in about 12 fms. Holotype ANSP 175132. Misspelled *cymatias* on p. 110, but correctly on plate caption.

Description: Shell small to large, up to 76.5 mm in length and 34 mm in greatest diameter. Spire usually more than half the length of the shell, but sometimes less. Whorls 9-10; protoconch consisting of 2 whorls. Aperture oval to squarish and greater in length than the short siphonal canal. Axial sculpture of 7-8 squarish ribs which often are more pronounced just below the shoulder of the whorl. Numerous fine growth lines usually very conspicuous at the suture. Spiral sculpture of 8-10 heavy cords, 4-5 showing on the upper whorls, interspaced with secondary, and sometimes tertiary, threads. Columella with 3 folds and a weaker one below. Outer lip crenulated, the indentations corresponding to the spiral sculpture. Within the lip 7-12 lirae run into the aperture. Fasciole present. Anal canal partially developed.

Color light cream−orange to brown. Spiral cords and threads reddish brown or at times the color of the shell. Shell occasionally banded with light reddish brown. Periostracum very thin, light brown.

Remarks: Much taxonomic confusion has existed concerning *Latirus angulatus.* An indication of the problems associated with this species first came when T. L. McGinty (1966, *in litt.* to Dr. R. D. Turner of Harvard University), who had been working on *Latirus,* stated that the well known name *brevicaudatus* could refer to a Pacific species. A study of many hundreds of West Indian specimens has resulted in the conclusion that this relatively common species exhibits more intraspecific variation than any other *Latirus* I have observed, and not one of the many forms can be compared easily with the clear figure in Reeve (1847) or a photograph of the specimen provided me (Fig. 23) by Dr. Norman Tebble, the former curator

of the Mollusca section of the British Museum (Natural History). When I had the opportunity to examine the figured specimen first hand, I found the Reeve figure to be an exceptionally good one. An additional complication developed when it became apparent that the figured type of *brevicaudatus* seemed to have much in common with a few Indo-Pacific specimens labelled "*Latirus lyratus* Rve." in some museum collections. The problem remained: what should be done in this particular case, especially since the name *brevicaudatus* was prevalent, in spite of the other names applied to this species?

The "type lot" of *brevicaudatus* includes three specimens. In addition to the previously mentioned figured type, there are two specimens (Figs. 24, 26) that are clearly referable to the Virgin Island form of "*brevicaudatus*" (Fig. 16). These two specimens are so very different from the figured specimen that I find it hard to believe that Reeve had access to them when he was completing the *Turbinella* section of the Conchologia Iconica. I feel it is likely that these two specimens were added to the type lot at a later date.

There are four possible courses of action one could take in this particular case: 1) conserve the name *brevicaudatus* for the West Indian species by continuing to accept the figured type as the Caribbean species, 2) conserve the name *brevicaudatus* by ignoring the figured type and declaring one of the other specimens to be the lectotype, 3) avoid the entire problem by using an earlier name, 4) petition the Comission on International Zoological Nomenclature to invalidate the existing types and establish a neotype based on a typical example of *brevicaudatus*. But to conserve the name *brevicaudatus* for the Caribbean species would make it unavailable for future use should it be found that *brevicaudatus* actually occurs in the Indo-Pacific, which seems likely, or in the eastern Atlantic, where it has been reported by Nordsieck (1968).

If one is willing to accept a change of name for this West Indian species, the easiest choice is to use the next available name. But both names from the literature that could be used for this species, *spadiceus* (Reeve, 1847) and *cymatius* Schwengel, 1940, do not represent typical forms, and since the great intraspecific variation observed is still not clearly understood, the use of these names might institute confusion. A better solution does exist, however. In the Museum Boltenianum, using the name *Fusus angulatus,* Röding (1798) made reference to a certain specimen figured by Chemnitz (my Fig. 7) in the Systematisches Conchylien-Cabinet (vol. 4, figs. 1314, 1315). These two figures, which have been cited repetitiously by earlier authors as two of a number of figures of *Latirus polygonus* (Gmelin, 1791), are definitely not conspecific with Gmelin's abundant and well understood Indo-Pacific species; they represent a large "*brevicaudatus*" nearly identical to a typical form occurring in the southern Caribbean (compare Figs. 7, 8, and 10). The mention by Chemnitz of brown spiral threads is especially convincing.

Because of the uncertainty regarding the use of the name *brevicaudatus* for the Caribbean species, and because some typical West Indian forms closely match the Chemnitz figure, I have decided, with more than a little reluctance, to
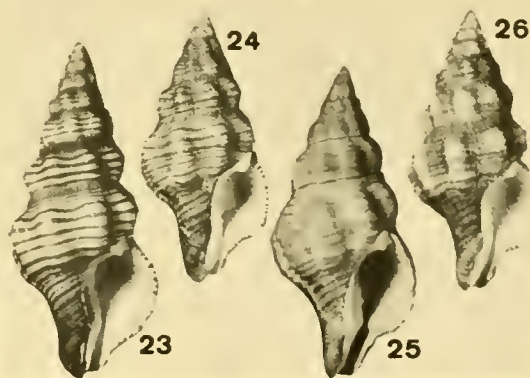

FIG. 23. Latirus brevicaudatus *(Reeve), Figured type. Locality unknown. 1X. Photograph courtesy of the British Museum (Natural History).*
FIGS. 24, 26. Latirus angulatus *(Röding). "paratypes" of* Turbinella brevicaudata *Reeve. Locality unknown. 1X. Photographs courtesy of the British Museum (Natural History).*
FIG. 25. Latirus angulatus *(Röding), possible syntype of* Turbinella spadicea *Reeve, fide Dr. Norman Tebble. Locality unknown. 1X. Photograph courtesy of the British Museum (Natural History).*

propose the use of the name *angulatus* (Röding, 1798) for this species. It is felt that the establishment of the name *angulatus* will prove not only to have been an expedient move, but one that will have promoted nomenclatorial stability, one of the ultimate goals of most taxonomists.

As previously mentioned, *Latirus angulatus* exhibits a great amount of intraspecific variation. Typical *angulatus*, similar to the "paratypes" of *brevicaudatus*, occur on St. Thomas and St. Johns, Virgin Islands (Fig. 16), and in the Bahama Islands. The Lesser Antilles afford the largest *angulatus* known, those from Curacao (Figs. 8, 10) being especially large and identical to the figure in Chemnitz (my Fig. 7); these differ from the typical form only in the adult, which has somewhat more swollen whorls and slightly more squarish axial ribs. The frilled sutural region of Curaçao specimens (mentioned by Benthem Jutting, 1920) and those from off Florida (Schwengel, 1940) is characteristic of most *angulatus*, as well as many other *Latirus*, and its expression is probably dependent upon environmental conditions.

Major variations of *angulatus* occur throughout the rest of its range. Several specimens from South America show very heavy spiral sculpture and a relatively small aperture (Figs. 20, 21). *L. cymatius* Schwengel from Florida is closer to typical *angulatus* than many of the other variations, and it is herein considered conspecific with *angulatus*. The type specimens of *cymatius* are unicolored Sayal brown and heavy-shelled; most specimens examined were immature. Numerous forms of *angulatus* occur along the northern coast of Cuba (one such form, Fig. 17).

The identity of *Latirus spadiceus* (Reeve, 1847) (Fig. 25) remains a little uncertain, although I feel certain that some specimens of *Latirus angulatus* will eventually be collected that will show *spadiceus* to be conspecific with *angulatus*. Hertlein & Strong (1951) and Keen (1971) stated that the west American *Latirus hemphilli* Hertlein & Strong, 1951, was the *spadiceus* of authors, but not of Reeve. Some older museum collections have some *angulatus* specimens from unknown locality which seem referable to *spadiceus* Reeve.

Some Miocene and Pliocene *Latirus* appear to be possible ancestors of *angulatus*. The closest relative, *L. angulatus santodomingensis* Pilsbry from the Miocene of the Dominican Republic, differs from typical *angulatus* by having a shorter, wider siphonal canal and a sharp angulation of the axial ribs. Pilsbry's description fits some Recent *angulatus*, and a few specimens (fossil?) dredged from the harbor at Roosevelt Roads Naval Base, Puerto Rico, appear to be intermediate between these two subspecies.

Distribution: From the lower east coast of Florida and the Bahama Islands in the north, this species is found throughout the West Indian Province, from Yucatan, Mexico, and Cuba to the Lesser Antilles and Brazil. Peile (1927) recorded a "*Latirus* sp. near *sanguifluus*, Rve." from Bermuda, but I have been unable to locate his specimen. Recently, Waller (1973) collected *Latirus angulatus* off the south shore of Tucker's Town, Bermuda, 51 meters depth. Nordsieck (1968) reported this species from the west coast of Africa, but the present author has seen no eastern Atlantic specimens and cannot verify this record.

Latirus (Polygona) bernadensis **Bullock, new species**
Fig. 13

Description: Shell small to medium in size, up to 44.2 mm in length and 16.5 mm in greatest diameter. Spire slightly greater than half the length of the shell. Aperture oval to squarish and as long or slightly longer than the moderately long siphonal canal. Whorls 9. Axial sculpture of 7 broad ribs which are slightly more pronounced on the shoulder of the whorl. Spiral sculpture of about 8 cords with occasional secondary cords between; 4-5 cords show on the upper whorls, and a number of cords, some stronger than others, are prominent on the siphonal canal. Columella with 3 folds with a weaker fold above and below these. Outer lip crenulate due to the spiral sculpture; within the lip 6-9 lirae run into the aperture. Periostracum thin, light brown. Shell light cream-orange, including the spiral cords. Aperture slightly lighter in color.

Measurements: Holotype 44.2 mm in length, 16.5 mm in greatest diameter; paratypes (both from the type locality) 36.7 and 36.4 mm in length.

Type Locality: Barbados, Lesser Antilles.

Location of Types: Holotype, Museum of Comparative Zoology, Harvard University, 275428; two paratypes, Mus. Comp. Zool. 275429.

Remarks: When compared with other West Indian *Latirus, bernadensis* appears most similar to *L. infundibulum* (Gmelin, 1791), but differs by being relatively stouter, having broader axial ribs, and lacking the brown coloration on the stronger spiral cords. *L. praestantior* Melvill, 1892, from West Mexico is closely related, but its spiral sculpture is not as strong, especially on the body whorl. This species is named after Bernados Island, a name for Barbados appearing on an early sixteenth century manuscript chart located in the British Museum.

Latirus (Polygona) nematus Woodring, 1928
Figs. 1, 12, 19

1928 *Latirus (Polygona) nematus* Woodring, Miocene mollusks from Bowden, Jamaica. Part II, Gastropods and discussion of results, p. 254, pl. 15, fig. 6. Type locality: Bowden Formation [Miocene], Jamaica. Holotype USNM 369442.

Description: Shell moderately large, up to 60.4 mm in length, 23 mm in diameter. Spire usually about half the length of the shell, but sometimes less. Whorls 10, including 1½ whorls of the protoconch, which is often broken off or eroded. Aperture oval and larger than the rather short siphonal canal. Axial sculpture of 8-11 ribs. Numerous fine growth lines are present. Spiral sculpture of many cords, usually of even thickness, but occasionally showing some secondary cords. In the region below the shoulder and on the body whorl of some specimens, the crossing of the growth lines and the spiral cords gives the shell a cancellate appearance. Columellar folds 4, with the lower 2 partially fused. Outer lip minutely crenulate with the formation of small teeth arranged in pairs. Within the lip 10-14 irregular lirae run into the aperture, the anterior one thickened

and corresponding to the most anterior columellar fold and appearing to almost close the apertural entrance to the siphonal canal. Fasciole well developed; pseudoumbilicus slit-like. Anal canal well defined.

Shell light cream-orange to almost white with light orange on the siphonal canal, and occasionally partially banded with reddish brown. Early whorls Sayal brown. Aperture yellowish white; columella light orange. Periostracum thin and light greenish brown.

Remarks: Latirus nematus previously was known only from the Bowden Formation, and this marks the first time it has been reported from the Recent fauna. The Recent specimens I examined do differ in some respects from the fossil form, particularly when immature specimens are compared, and I at first thought that perhaps they were specifically or subspecifically distinct. Most Recent specimens are immature and exhibit quite inflated whorls; the immature paratypes of *nematus* do not have inflated whorls, and are more elongate. It seems best in this case to delay introduction of an additional name until more material, both fossil and Recent, is available for study.

When compared with other species, *nematus* can possibly only be confused with some forms of *angulatus.* The latter species usually can be differentiated easily by its stronger spiral cords, often with intermediate secondary cords which are usually brown in color. In addition, the axial ribs tend to be somewhat round. In *nematus,* the spiral cords are fine and more numerous, lack color, and the axial ribs are more squarish in outline.

Distribution: Known only in the Recent fauna from off Miami, Florida, and Gibara, Oriente, Cuba. Usticke (pers. comm.) has a specimen from the north coast of Puerto Rico which is probably this species.

Specimens Examined: FLORIDA: Miami; Miami, 20 fms.; Bear Cut, Miami, 25 fms. (all USNM). CUBA: off Gibara, Oriente (Finlay collection).

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A NEW BLIND *PHYSA* FROM WYOMING WITH NOTES
ON ITS ADAPTATION TO THE CAVE ENVIRONMENT

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ABSTRACT

Physa spelunca, new species, is described. The ecology of the cave and adaptations of the Physa *to the cave environment are discussed.*

While looking for crustaceans, particularly amphipods of the genus *Stygobromus*, in Lower Kane Cave, Wyoming, Dr. John R. Holsinger collected a number of blind *Physa* which he sent to us for identification. There were no *Stygobromus* in the cave and, in fact, other than the snails, all he found were a few clusters of oligochaetes, probably tubificids. He did not find anything in the spring outside the cave.

In his letter to us about the cave Dr. Holsinger wrote:

"Lower Kane Cave is a solution cave developed in Paleozoic limestone. It's entrance is situated just above and east of the Big Horn River, about 12 miles east of Lovell and at an altitude of 3,000 feet. A stream flows through the cave and passes to the surface through a spring just below the entrance. The water from this spring flows directly into the Big Horn River. The source of the cave stream is a 'hot spring' at the far end of the cave, some 1,000 feet from the entrance. The stream temperature was 70° to 72° F [21-22° C] and that of the air in the cave was 78° to 80° F. The water was hard and had a strong sulphurous odor."

According to Dr. Holsinger, warm or hot cave streams are extremely rare. In fact the only other such cave with which he is acquainted is Warm River Cave in Allegheny County, Virginia. Brues (1932: p. 274-277) listed 19 species of gastropods occuring in hot springs and stated that *"Physa* seems to be the dominate type in thermal waters." In addition to thermal tolerance, species in this genus can tolerate brackish water, and they are usually the last of the snails to succumb when a stream becomes heavily polluted. Thus it is not surprising that *Physa* was the only snail found

in Lower Kane Cave, particularly as the works of Henderson (1924, 1936) indicate that hydrobiids, species of which commonly occur in caves, are rare in this area. He did not list any hydrobiids in his Wyoming paper (1918) nor did Beetle (1961) report any from streams in the Big Horn Mountains.

In Lower Kane Cave the *Physa* were common on the surface of small rocks submerged in rather fast-moving water well-back in the dark zone of the cave, some 800 to 900 feet from the entrance. Some were found on a colony of 'tubificid' worms in the sludge at the bottom of the stream.

In the United States the molluscan fauna of caves is rather limited and the majority of species found are readily identified with those living on the surface in the surrounding area. Cave specimens are usually somewhat smaller and have thinner, lighter-colored shells than their surface living relatives, but are otherwise similar (Hubricht, 1940b). Land snails living near the entrance or in the twilight zone are probably deposited in the cave on debris carried in by floods and it is doubtful if they are able to maintain themselves for many generations (Hubricht, 1941). Eighteen species and subspecies of land snails have invaded the dark zone of caves in Kentucky, Tennessee and Alabama (Hubricht, 1964). Six of them (5 *Helicodiscus* and *Carychium stygium* Call) are known only from these caves. They were found feeding on decaying plant material and the guano of cave crickets. When discussing the wide distribution of *Carychium stygium* in the Kentucky caves, Hubricht (1960) stated that the eyes of some specimens were somewhat reduced

but he did not mention any other modifications to cave life.

Freshwater snails, especially Hydrobiidae, have become adapted to cave habitats and viable colonies are found well-back in the dark zone. A white, blind hydrobiid, *Fontigens tartarea*, was described by Hubricht (1963) from the stream in Organ Cave, Greenbrier Co., West Virginia, and Culver (1970) reported it from the "Greenbrier Caverns, the Hole (37° 56' 22" N; 80° 21' 12" W) and Martha's Cave." According to J. R. Holsinger (personal communication) large populations of troglobitic species of *Fontigens* have been found in the cave streams of the Applachians in Virginia and West Virginia but to date these have not been reported upon. Hubricht (1940a, 1971) described three unpigmented, blind *Amnicola* and *Antrobia culveri* (a new genus and species of blind Hydrobiidae) from caves in the Ozark Plateau.

In 1950 he listed five species (two *Amnicola* and undertermined species of *Physa, Ferrissia* and *Musculium*) as living in the dark zone of these caves.

The small size of the species which have been able to successfully invade and survive in caves is undoubtedly a reflection of the scarcity of food in such habitats. No suspension feeding gastropods occur in such areas and among the bivalves only the Sphaeriidae are found.

In addition to being unpigmented and being one of the smallest species known, the *Physa* collected by Dr. Holsinger appear to be making modifications to cave life in the apparent reduction of the eye (see figure 19) proportionate increase in size of radular teeth (figs. 14-15), and an increase in the size of the embryo as evidenced by the size of the protoconch (Figs. 11-13). This large protoconch suggests that the young are more developed at the time of hat-
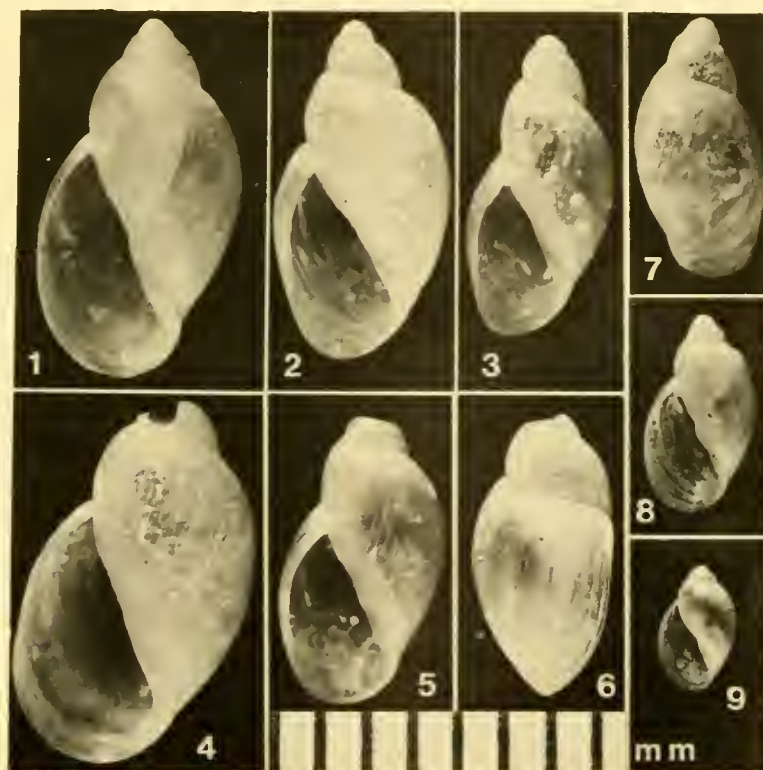
Physa spelunca *Turner and Clench, new species.* FIG. 1, *Holotype.* FIGS. 2-9, *Series of paratypes to show range of variation in the 75 specimens collected.* FIG. 3, *the most elongate.* FIG 4, *The largest, though lacking the spire.* FIG. 6, *Side view showing curvature of the lip.* FIG. 7, *Dorsal view of typical specimen.* FIGS. 5 and 8, *Specimens showing thickening of the columella area.* FIG. 9, *The smallest specimen collected.*

ching. Greater size would increase the mobility and search-range of the young, and a more fully developed radula' would increase the range of food-particle size available to it. Both these factors would enhance its chances of survival in an environment where food is likely to be limited.

This increase in embryo size agrees with the findings of Poulson and White (1969) who worked with cave fish and cave beetles. They hypothesized that species which successfully invade caves tend toward smaller population size, lower reproduction rates, larger size at hatching, late maturity and longer life. These adaptions to a stable environment and low food supply suggest that this new species is opting for K selection as proposed by MacArthur and Wilson (1967). They are also in agreement with the Stability-Time hypothesis proposed by Sanders (1968) for many deep-sea infaunal species. Further research is needed to test this hypothesis for cave snails but to our knowledge this is the first time that such adaptations have been noted for any troglobitic mollusk.

The fact that epigean species of *Physa* are opportunistic probably allowed them to invade this hot spring cave. They are small-sized detritus feeders, capable of surviving under varying conditions of temperature, salinity and oxygen tension, as noted previously. These are characteristics that would preadapt them for the cave environment. Further adaptations, including the larger size of the young on hatching and the loss of eyes, are in agreement with the theories of Barr (1968). Cave mollusks are ideal organisms for evolutionary genetic studies such as those of Avise and Selander (1972) on cave fish of the genus *Astyanax*, but to date no work has been attempted along these lines. The large populations of *Fontigens* in the caves of Virginia and West Virginia mentioned by Holsinger would provide material for such a study.

Physa spelunca, new species
Figs. 2-9, 11, 14, 16-17, 19

Description. Shell reaching 9 mm in length and 4.5 mm in greatest diameter (a somewhat larger, broken specimen has a body whorl length of 7.8 mm and a width of 5.0 mm which would
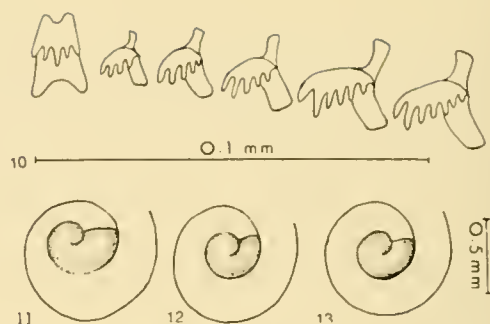

FIG. 10. *Radular teeth of* Physa spelunca *showing long denticles and apophyses.* FIGS. 11-13. *Comparative sizes of protoconchs in relation to adult size.* FIG. 11. Physa spelunca, *adults may reach about 11 mm in length.* FIG. 12. Physa virgata *Gould, adults reach 18 mm in length.* FIG. 13. Physa propinqua *Tryon, adults reach 21 mm in length.*

give a proportional total length of about 11 mm). Shell highly polished, white with a very thin transparent periostracum; translucent, fragile and smooth. Sculpture consisting of exceedingly fine growth lines only, with no evidence of spiral sculpture. Whorls 4½ to 5, rounded, rapidly increasing in size; body whorl large, slightly shouldered; spire short, acute; spire angle about 65°. Sutures moderately impressed, aperture ear-shaped. Upper margin of thin, outer lip inserting on the body whorl well-below the periphery. Parietal callus thin to rather thick in older specimens. Columella oblique, curved, flattened and continuous with the outer lip. Protoconch of about 1¼ whorls, rounded, colorless and minutely malleated (see figure 11). Radula with v-shaped rows of teeth, typical of the genus, the formula being about 100-1-100 in the median portion (Fig. 10 and Fig. 14).
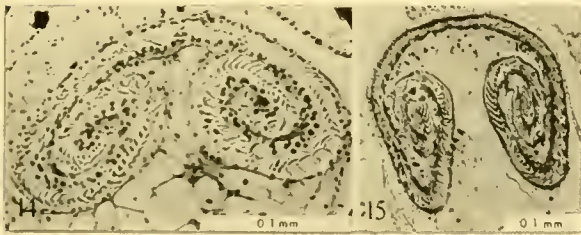
Anatomical notes. Only preserved specimens were available for study and these unfortunately were not in ideal condition. The animal was a uniform whitish, the tentacles short, broad and apparently lacking eyes at the base. Histological sections, however, showed a distinct eye cup but the retina was not developed and the lens was apparently lacking. A comparison of the eye of *Physa heterostropha* Say with that of *spelunca* is shown in Figs. 18-19. Digitations of the mantle were minute but

this could have been a result of preservation.

The digestive system appears typical for the genus. The crop was packed with debris, minute sand grains and what appeared to be fungal hyphae. The reproductive system is typical for the genus, the male portion being of the 'Physodon' type as described and figured by Clampitt (1970). The penis sheath is about ⅔ the length of the praeputium, not constricted and is unpigmented. The praeputium has a slightly grayish tinge, and the praeputial gland is located in the lower half. The vas deferens is fine, about 4 times the length of the penis sheath, and about one fourth was buried in muscles of the body wall.

Measurements.

Length	Width
9.0 mm	4.5 mm
8.3	4.2
8.0	4.2
8.0	4.0
7.5	4.1
7.0	3.3
5.9	3.1
7.8	5.0 (broken specimen, body whorl only)

Type locality. Cave stream, about 800-900 feet from the entrance, in the dark zone, in Lower Kane Cave, near Kane, about 12 miles east of Lovell, on the east side of the Big Horn River, Big Horn County, Wyoming, at 3,000 feet elevation. Dr. John R. Holsinger, collector, June 18, 1969.

Repository of type specimens. Holotype, Museum of Comparative Zoology no. 280016; Paratypes MCZ nos. 280017-280019. Additional paratypes from the same locality are in the Museum of Zoology, Ohio State University;

Transverse sections through posterior end of the odontophore of (FIG. 14) Physa spelunca *and (FIG. 15)* Physa heterostropha Say *showing the lateral incoiling of the radula when retracted. These specimens were preserved in alcohol and had not been properly fixed for histological work. The marked differences in shape may well result from differences in fixation and probably are of no taxonomic value. It is interesting to note that the radular teeth of* spelunca *from a specimen 6 mm long are proportionally larger than those of* heterostropha *from a specimen 12 mm long, suggesting that the cave specimens may be feeding on coarser material than surface living species.*

Two views of male reproductive system of Physa spelunca, *typical of the "Physodon" group. FIG. 16, Standard dorsal view. FIG. 17, Specimen turned to right to show muscle attachment.*

Museum of Zoology, University of Michigan; United States National Museum, Delaware Museum of Natural History and the Academy of Natural Sciences of Philadelphia.

Remarks. Physa spelunca is characterized by its transparent, colorless, highly-polished shell, its relatively blunt apex and large colorless

0.1mm

0.1mm

Sections through the tentacles and eyes of Physa heterostropha *and* Physa spelunca. *Specimens of both species were preserved in alcohol and had not been properly fixed for histological work. Consequently the quality of the sections is poor but they are comparable. FIG. 18,* Physa heterostropha, *showing the lens and large heavily pigmented retina. FIG. 19,* Physa spelunca, *lacking both the pigmented retina and lens.*

protoconch (see figure 11). Based on the characters of the shell and the male reproductive system *spelunca* belongs to the 'Physodon' species group as modified from Baker (1928) by Clampitt (1970). The whorls are shouldered, the sutures impressed and the penial sheath of the male is not constricted (Figures 16-17). Baker (1928) described and figured the male reproductive system of *Physa integra* Haldeman and *P. walkeri* Crandall and placed them along with other species, the anatomy of which was unknown, in his group 'Physodon'. Clampitt (1970) reported that *P. michiganensis* Clench and *P. anatina* Lea also had the 'Physodon' type reproductive system and anatomical studies by Te (1973) in addition to confirming Baker's work on *integra*, showed that *P. virgata* Gould also belonged in this group. See Clampitt (1970) for discussion of the status of 'Physodon'.

Both *P. anatina* and *P. integra* have been reported from Wyoming (Henderson, 1918, 1936; Beetle, 1961) and both bear resemblances to *P. spelunca*. However, *spelunca* differs from them in being colorless, transparent and nearly glass-like; in lacking any indication of spiral sculpture or of thickened opaque axial lines indicating former margins of the lip. In addition, the columella of *spelunca* is oblique and curved rather than nearly straight, and the protoconch is white rather than amber-brown.

Physa propinqua Tryon, *P. gabbi* Tryon and *P. coniformis* Tryon, all closely related species from the northwestern states and British Columbia, are unknown anatomically but, on the basis of shell characters, could belong in 'Physodon'. Both *propinqua* and *coniformis* differ from *spelunca* in having fine axial and spiral sculpture, a straight columella, and in having the lip extended anteriorly well-beyond the base of the columella. *Physa gabbi* lacks spiral sculpture but has pronounced axial growth ridges, a strongly twisted columella, and more acute spire. *Physa virgata* Gould from Arizona which is known to have the 'Physodon' type anatomy also has both spiral and axial sculpture as well as a strongly twisted columella. All of these species have small dark protoconchs.

ACKNOWLEDGEMENTS

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NESOPUPA GALAPAGENSIS, A NEW INDO-PACIFIC ELEMENT IN THE LAND SNAIL FAUNA OF THE GALAPAGOS ISLANDS (PULMONATA: VERTIGINIDAE)[1]

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ABSTRACT

Nesopupa galapagensis, a new species of the pulmonate family Vertiginidae is described from the Galápagos Islands. This is a new record of the genus Nesopupa, *typically of Indo-Pacific distribution, in the Galápagos fauna.*

INTRODUCTION

As the first part of a study of the evolution and ecology of the land snails of the Galápagos Islands, I have collected on the islands of Santa Cruz (Indefatigable), Santa Maria (Floreana, Charles), Isabela (Albemarle) and San Salvador (Santiago, James) during the summer of 1970. Of the material obtained, one finding will be discussed below in detail, *Nesopupa galapagensis*, because it represents a new species and a new record of an Indo-Pacific genus in the Galapagos land snail fauna.

DESCRIPTION

The shell: the height is 1.6 — 1.9 mm, the width 1.0 — 1.1 mm, the width — height ratio, .53 —

.65, the height of the last whorl including the aperture is 0.9 — 1.2 mm, that of the aperture alone, 0.6 — 0.7 mm; in percentage of the total height these values correspond to 53 — 67 and 35 — 41%, respectively; the whorl number varies from 4¼ to 5. The *shape* of the shell is nearly cylindrical in 9 specimens, cylindrical-oval or oval in the others; the whorls are convex, the sutures deep, particularly so in the cylindrical specimens; the last whorl ascends upon the penultimate one prior to the aperture, slightly in the oval specimens, more distinctly in the cylindrical ones. The *umbilicus* is minute. The *aperture* is oval-triangular with a notch on the outer lip formed by the inward and forward projecting middle part of the outer lip (this region is

FIG. 1. Nesopupa galapagensis *Vagvolgyi, new species. 1.9 mm Holotype.*

FIG. 2. *Collecting sites on Isla San Salvador, Galápagos.*

sometimes termed "auricle"); the lips are slightly reflected; the parietal wall is covered by a weak callus that connects the origin of the outer and inner lips; the lip swelling is weak but wide, deeply receded from and parallel to the edge of the lips; corresponding to the lip swelling there is a weak and wide annular crest on the outside of the shell. The *armature* consists of a parietal, angular and columellar lamella and an upper and lower palatal fold; the parietal lamella is large, the angular, small; both lie moderately deep in the aperture, and are separated from one another; the columellar lamella is medium large, deeply seated, its inner end is straight; the lower palatal fold is large, the upper, medium to small, both lie deep in the aperture; a sulcus may mark on the outside of the shell the position of either palatal fold. *Sculpture:* the embryonic whorls are smooth (30X magnification); the postembryonic whorls have a fine striation and a shiny, lustrous appearance except in the region of the annular crest where the striation is coarser; there is no sign of any pits. The *color* of the fresh shell is dark brown, that of the folds and lamellae, very light with a brownish tint.

Holotype (fig. 1) and *paratypes* are deposited in the collection of the Academy of Natural Sciences of Philadelphia, nos. 332451, 332452, respectively. Other paratypes in the collection of the Delaware Museum, nos. 70650 and of the author. *Type locality:* Peak 2974', central highlands of Isla San Salvador (James Island), Galápagos Islands (fig. 2).

Material examined: Four samples, 2-32 specimens each, 38 specimens altogether.

DIFFERENTIAL DIAGNOSIS

Nesopupa (Infranesopupa) anceyana Pilsbry and Cooke and *N. (Infranesopupa) subcentralis* Pilsbry and Cooke of the Hawaiian Islands closely resemble the new species in size (Table 1), armature and sculpture; on this basis, *N. galapagensis* is assigned to the subgenus *Infranesopupa.* Both species differ, however, from the new species in being more oval and having shallower sutures, larger aperture and less pronounced auricle. Another similar species is *N. (Nesodagys) wesleyana* Ancey, of the Hawaiian Islands, which agrees with *N. galapagensis* in shape, convexity of the whorls and dentition

but has fine periostracal riblets and a very weak auricle. However, the most similar species is an undescribed one, from Surinam, Dutch Guiana, South America, in the possession of the Academy of Natural Sciences of Philadelphia; the only difference is that the outline is a bit more oval and the dentition a bit weaker than in *N. galapagensis.*

Some species of the genus *Vertigo* also closely resemble *N. galapagensis* in shape, sculpture and auricle but their dentition is different.

The new species does not show a great deal of similarity to *Nesopupa (Cocopupa) cocosensis* (Dall) of Cocos Island as one might expect from the relative proximity of the areas of distribution of the two species. *Nesopupa cocosensis* is larger (Fig. 1) and has a pitted sculpture.

ECOLOGY

Nesopupa galapagensis lives in the high and moist central region of Isla San Salvador (fig. 2). It was found in the thickets and the open fields as well. In the former it lived in the litter layer and the moss pads growing on trees, in the latter, on the ground at the base of the grass. The description of the collecting localities follows:

Station 36. A few hundred yards from Peak 2974', on the southern slope, at about 2900' of elevation. Good soil; impenetrable brush, composed primarily of *Psychotria rufipes* and *Tournefortia rufosericea.* Moss pads on the horizontal branches of many trees (mostly belonging to the species *Zanthoxylum fagara*). Four squares of 25 X 25 cm each were sifted from the litter, and 3 moss pads were taken without measuring size. July 25, 1970.

Station 37a. Pampa or open grassy field at the southern foot of Peak 2974', at about 2300-2400' of elevation. Soil good, wet from several days' drizzle (garúa). Two samples of 25 X 25 cm were taken. The pampa habitat may be a secondary one; according to some botanists, pampas develop only when the original forest cover is destroyed by the introduced goats, pigs and cattle. July 30, 1970.

Station 38. Southwestern side of the crest between Peaks 2974' and 2965', at about 2600-2900' of elevation. Grass, bushes and the giant

fern *Cyathea* make up the vegetation. Five samples of the usual size were taken, 2 from grassy areas, 2 from the base of bushes and 1 from a wash. Soil wet from garúa. July 30, 1970.

Pilsbry noted (1920: 289) that species of *Infranesopupa* are usually found on fronds of ferns and leaves of low plants or occasionally on trunks of trees. My observations that *N. galapagensis* lives both on the ground and on trees are in partial agreement with this.

DISTRIBUTION

Nesopupa galapagensis is endemic to the Galápagos Islands. It is the only representative of its genus there. Its apparent ancestors are the species of *Infranesopupa* in the Hawaiian Islands. It thus represents a new Indo-Pacific element in the Galápagos land snail fauna. Such elements are rare; the only other species of Indo-Pacific relationships among the Galápagos land snails is *Tornatellides chathamensis*. Numerically the Indo-Pacific elements represent somewhat less than 3% of the fauna (2 species of the total reported of 76; based on Smith 1966). The majority of the species are of Neotropical relationships.

The marine molluscs of the Galápagos mirror this composition. According to Emerson (1967) only 25 species or a little more than 4% of the 600 species reported have Indo-Pacific affinities. The similarity may be merely coincidental, however. On the one hand, the rarity of the Indo-Pacific elements among the marine mollusks — as Emerson argues convincingly — is due to the scarcity of suitable habitats: coral reefs for the reef dwellers common in the Indo-Pacific region. His contention is supported by the fact that Clipperton Island, which also lies in the Eastern Pacific but is a coral atoll, has 47% Indo-Pacific elements in its fauna. On the other hand, the reason for the scarcity of the Indo-Pacific elements among the Galápagos land snails appears to be primarily the distance and isolation from that region.

DISPERSAL

The Hawaiian Islands, where *Nesopupa galapagensis* presumably originated, lie roughly 4000 miles northwest of the Galápagos Islands.

Geological evidence indicates no previous land connection between the two archipelagoes or between the Galápagos and the South American mainland (McBirney and Williams 1969). Thus *Nesopupa galapagensis* in all likelihood reached the Galápagos Islands by overseas dispersal, whether by ocean currents, winds, insects or birds it is impossible to say. I do not believe, however, that human introduction was responsible, for two reasons. First, because the species does not occur near human settlements or cultivated areas, in disturbed habitats as introduced species often do (e.g. species of *Subulina, Lamellaxis* and *Deroceras* in the Galápagos, Smith 1966); rather it occurs in remote regions, in the litter layer and moss pads which are undisturbed habitats. Another habitat where it also occurs, the pampa, may be a disturbed one; but even this habitat is far away from human settlements. Second, because the species has not been found on the inhabited, cultivated islands of the archipelago; rather, it has been found on San Salvador which has been free of cultivation, although for a while a salt mine was operated on its southwestern shore. Admittedly, future collecting may discover the species on the inhabited islands as well and this fact may then refute the argument. Another possible objection, namely that San Salvador has some special ecological setting which favors *Nesopupa* whereas the other islands lack such seems to have no validity at all as all the islands in question have wet zones which at least in basic features are counterparts of the wet zone of San Salvador.

The process of overseas dispersal is generally considered a fortuitous one and in our case it indeed appears to be so. First, because *Nesopupa galapagensis*, after having crossed a vast extension of open ocean, only colonized one of the 15 major islands of the Galápagos Archipelago, not the other 14. Second, it also failed to colonize the relatively nearby Cocos Island; the latter has been reached independently of *N. galapagensis* by another, not closely related, species of *Nesopupa, N. cocosensis*. Third, from the Galápagos the species made another huge jump across 600 miles of open ocean and 1200 miles of land to reach Surinam

(refer to undescribed *Nesopupa*). This in itself is remarkable as colonization usually proceeds in the opposite direction, from the continents to the islands. — It is possible that future collecting will prove *Nesopupa* to be a more widespread genus in South America than hitherto assumed, in which case the origin of the Galapagos *Nesopupa* becomes a mute question. However, according to our present knowledge, the Hawaiian origin appears more probable.

ACKNOWLEDGEMENTS

I gratefully acknowledge the assistance received from the Research Foundation of the State University of New York. I also thank Messrs. Roger Perry and Rolf Sievers of the Charles Darwin Research Foundation for their help during our stay on the islands, Mr. Daniel Weber of the same institution for identifying several plants, my wife Alice for help in the field work and Dr. Robert Robertson for allowing me to use the collection of the Academy of Natural Sciences of Philadelphia for comparisons.

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AMERICAN MALACOLOGICAL UNION
40th ANNUAL MEETING

Springfield, Massachusetts, will be the site of this summer's annual meeting of the A.M.U., from Saturday, August 3, 1974 (preliminary registration, 2:00 to 5:00 p.m.) through Wednesday, August 7; to be held in the Museum of Fine Arts and the Museum of Science in downtown Springfield. 1974 President is Harold D. Murray, Biology Dept., Trinity University, San Antonio, Texas 78284; local host is Earl H. Reed, Museum of Science, 236 State St., Springfield, Mass. 01103.

NEGLECTED PAPERS ON NAIADES BY W. I. UTTERBACK

Samuel L. H. Fuller

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To the list of papers on naiades by W. I. Utterback which was compiled by Johnson (1969) may be added the following, less familiar work.

1928. Phylogeny and ontogeny of naiades. Proceedings of the West Virginia Academy of Science 2: 60-67.

This paper is primarily a recapitulation of the naiad classification initiated by Ortmann (1910). Since Utterback provides no references to authorities other than himself, it is impossible to ascertain the source(s) of some of his more intriguing remarks, such as the statement that *Cumberlandia monodonta* (Say) can produce two broods of glochidia in a single summer. Noteworthy contributions are a description of volvocoid naiad sperm bodies (see Utterback, 1931) and a discussion of some remarkable aspects of the biology of *Megalonaias gigantea* (Barnes). The latter contribution offers no advance over Utterback (1915-1916) or the earlier account by Howard (1914).

1930. A new genus of freshwater mussels (naiades). *Ibid.*, 4: 66-69, text figures 1-3.

This paper is a discussion of *Utterbackia*, which Baker (1928) had already described and based on *Anodonta imbecilis* Say. Superior notes on the natural history of this species had been provided by Allen (1924) and Tucker (1927, 1928).

1931. Sex behavior among naiades. *Ibid.*, 5: 43-45.

Little advance is made beyond Utterback's (1915-1916, 1928) earlier works.

1933. New glochidia. *Ibid.*, 6: 32-36, text figures A-C.

Descriptions and discussions of the glochidia of seven naiad species and alleged subspecies are given. Much of this information had not previously been published.

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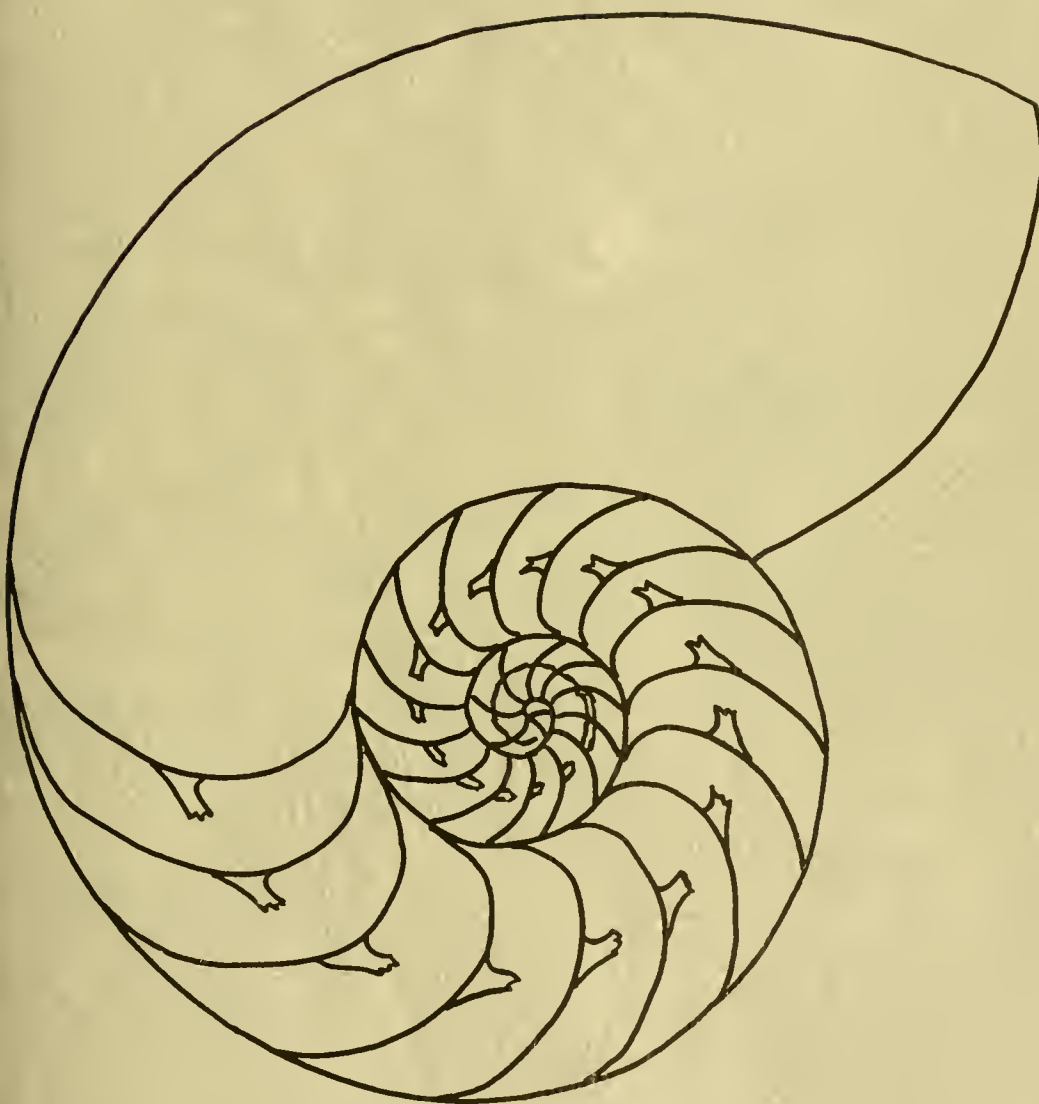
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CONTENTS

TWO NEW LAND GASTROPODS FROM TEXAS (*ZONITOIDES AND STENOTREMA*)

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ABSTRACT

Zonitoides kirbyi (Zonitidae) is described from Schulze Cave, approx. 28 miles northeast of Rocksprings, Edwards Co., Texas. It is most closely related in form to Zonitoides arboreus (Say) but differs by being larger and glossier with less distinct growth lines. Stenotrema leai cheatumi (Polygyridae) is described from Palmetto State Park, Ottine, Gonzales Co., Texas. It differs from the most closely related species in form Stenotrema leai leai (Binney) by being much smaller, more depressed, and with a much larger fulcrum.

An undescribed zonitid was sent to the late Dr. E. P. Cheatum by Dr. Walter Dalquest of Midwestern University, Wichita Falls, Texas. The fossil shells were collected by Dr. Dalquest and his colleagues in Schulze Cave which is located approximately 28 miles northeast of Rocksprings, Edwards County, Texas. Living specimens were later obtained from the site by the author. Dr. Dalquest's report on the statigraphy and vertebrate remains found in the cave, was published in 1969.

According to their report, the cave is of the sinkhole type and "probably formed by solution from a vertical tissue that penetrated two limestone layers of the Upper Cretaceous Edwards formation." The shells were found in association with mammalian bones in a zone of matrix designated as layer C. Many of the shells were stained by yellowish sediments. A part of a bone from a grizzly bear, in this same layer, was sent to the Socony-Mobil Laboratories in Dallas, Texas for dating. The C14 test revealed an age of 9,680 ± 700 years BP, which indicated a late Pleistocene age.

On July 25, 1972, a collecting trip was made by the writer accompanied by Dr. E. P. Cheatum and Wayne Seifert, staff member of the Dallas Museum of Natural History that sponsored the trip. The main purpose of the trip was to ascertain if the species still lived in the cave and if it was extant in the surrounding environs. Equipped with headlights, Seifert and myself entered the cave and, in the same zone from which the fossil shells had been collected, we found living specimens of this species. The living snail is described as follows: the entire pale-grey body was visible through the transparent shell. Each transparent eyestalk was capped by the dark eye. The cave was damp and fungal growths were abundant. Unfortunately, only one living snail was collected and this was an immature form with a shell diameter of 3.19 mm. A diligent search was made of the area surrounding the cave in hopes that we could find the living snail or at least dead shells of this species. None were found, so the origin of this snail remains a puzzle.

This species is named for Mr. Hal P. Kirby, Director of the Dallas Museum of Natural History who has encouraged and greatly aided Molluscan research in the Southwest.

Zonitoides kirbyi new species
Figs. 4-6

Description-Shell pale, glossy, translucent, and weakly sculptured with rather evenly-spaced but crowded growth lines which are more pronounced on the basal whorl. Under magnification, fine parallel striae are visible on the upper surface of the whorls exclusive of the embryonic whorl which is smooth. The striae, although present on the lower surface of the
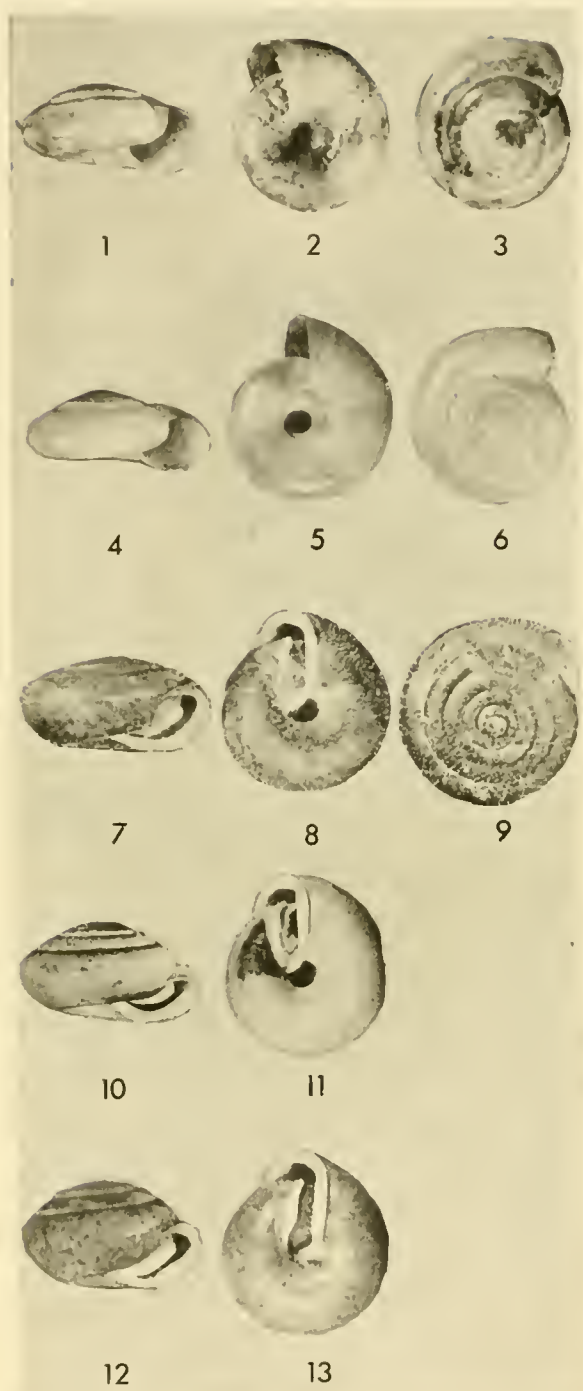
FIG. 1-3, *Zonitoides arboreus (Say); x 4.3;*
FIG. 4-6, *Zonitoides kirbyi n. sp.; x 3.8;* FIG. 7-
9, *Stenotrema leai cheatumi n. subsp.; x 2.6;*
FIG. 10-11, *Stenotrema leai leai (Binney); x 2.2;*
FIG. 12-13, *Stenotrema leai aliciae (Pilsbry); x
2.9.*

whorls, are more subdued. The umbilicus is con-
tained approximately 3.2 times in the shell
diameter. The whorls are well-rounded, the aper-
ture is ovoidal and the peristome is thin.
Measurements in mm. of holotype: diameter:
6.3; height: 3.4; aperture height: 2.04; aperture
width: 1.53.

Holotype: No. 3286 Dallas Museum of
Natural History; paratypes in Delaware Mus.
Nat. Hist. No. 72862; paratypes will be
deposited in the National Museum of Natural
History, Carnegie Museum, Museum of Com-
parative Zoology, Academy Natural Sciences of
Philadelphia, and the Museum of Zoology,
University of Michigan. Type locality: Schulze
Cave, Edwards Co., Texas, July 25, 1972.

Discussion — *Zonitoides kirbyi* is most closely
related in form to *Zonitoides arboreus* (Say)
(figs. 1-3), but differs in several respects. *Z. kir-
byi* is much larger and glossier with less distinct
growth lines. It also has a much larger um-
bilicus which abruptly expands in the last
whorl. The aperture is very ovately-lunate and
not deeply rounded ‿ as in *Z. arboreus.*
Zonitoides arboreus abounds in the area im-
mediately surrounding the cave and only dead
shells were found inside the cave. *Z. kirbyi* (live
& dead shells) is found only in the cave. It ap-
pears that *Z. kirbyi* may be a form of *Z. ar-
boreus* that has been microgeographically
isolated long enough to become a separate
species.

Stenotrema leai cheatumi *new subspecies*
Figs. 7-9

An undescribed polygyrid was collected by
Dr. E. P. Cheatum and myself in Palmetto
Park at Ottine, Gonzales County, Texas, on
November 11, 1971. The locality is an
ecologically isolated area that is low, swampy
and thickly studded with shrubs and trees.
Palmetto plants are extremely abundant. The
surrounding environment is typical of the
Texan Biotic Province as defined by Blair
(1952) but being much drier. The undescribed
snails were abundant on the moist ground un-
der palmetto plants and under rotten logs.

Description — The shell is umbilicate, with a
low, convexly conoid spire and 5.5 rather
closely-set whorls. Except for the embryonic

whorl, the remaining whorls are covered with irregularly-placed growth lines which, although not coarse are more conspicuous on the basal whorl. Under magnification the embryonic whorl is beset with fine radiating lines crossed by delicate striae confined to the embryonic whorl; a few very short hairs are present on the ventral surface of the basal whorl and on the upper surface of the last two whorls. The aperture length is 4.25 mm., and the slightly curved white parietal tooth is 2.38 mm. long, resting obliquely on the exceedingly thin parietal callus. The umbilicus is openly perforate with the exception of a flare-out of the lower lip which covers the inner edge of the umbilicus. The white peristome is thickened within and reflected on its outer and inner margin thus leaving a conspicuous groove just back of the outer lip. The umbilicus is contained approximately five times in the shell diameter. A large white rounded fulcrum is present which extends from the top of the basal whorl to its floor. Holotype measurements in mm.: diameter: 8.2; height: 4.6; No. of whorls: 5.5.

Holotype: No. 3288 Dallas Museum of Natural History; paratypes in the Delaware Mus. Nat. Hist. No. 72861; paratypes will be deposited in the National Museum of Natural History, Carnegie Museum, Museum of Comparative Zoology, Academy Natural Sciences of Philadelphia, and the Museum of Zoology, University of Michigan. The type locality is Palmetto Park, Ottine, Gonzales Co., Texas. November 11, 1971.

Discussion — *Stenotrema leai cheatumi* is most closely related in form to *Stenotrema leai leai* (Binney) (fig. 10-11). *Stenotrema l. cheatumi* differs in the following respects: it is smaller, more depressed than *S. l. leai* and has, on the average, fewer whorls, is much less hirsute, and has a much larger fulcrum. Radially-lengthened granules are absent on the embryonic whorls but cross-striae are present. *S. l. cheatumi* differs from *S. leai aliciae* (Pilsbry) (fig. 12-13), in the same features that differentiate it from *S. l. leai.*

The *Stenotrema leai* complex is as yet unresolved. Pilsbry (1948) made *S. monodon* (Rackett) synonomous with *S. leai.* Pilsbry in 1940 differentiated *S. leai leai* from *S. leai aliciae* in that, "the parietal tooth is higher in *S. monodon,* and the axial end continues in a tapering ridge, at the end curving partly around the axis." *S. l. leai* is also separated from *S. l. aliciae* by its open umbilicus while the umbilicus of *S. l. aliciae* is generally imperforate. In Texas, *S. leai leai* is usually found only as a fossil, while *S. l. aliciae* is usually found only in the living state (Cheatum and Fullington, 1971). In almost any series from the same locality, variants may be found that conform to either *S. l. leai* or *S. l. aliciae.* Due to these facts, I am giving *S. leai cheatumi* only subspecific rank until the *Stenotrema leai* complex is further studied.

I am naming this subspecies in honor of the late Dr. E. P. Cheatum. This article was actually begun by him but he was unable to finish it. The work on the two gastropods named here was the last of many such endeavors accomplished by Dr. Cheatum.

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PERIPHERAL SPECIES OF THE *OREOHELIX METCALFEI* COCKERELL COMPLEX (PULMONATA: OREOHELICIDAE)

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ABSTRACT

New data is presented concerning past and present distribution of land snails of the Oreohelix metcalfei *Cockerell complex, especially as regards species on the periphery of the range of the complex. Two new species are described:* Oreohelix caballoensis *and* O. confragosa. *Some trends concerning evolution of the shells are noted.*

INTRODUCTION

Treated herein are several taxa of the *Oreohelix metcalfei* Cockerell complex of land snails (Pulmonata: Stylommatophora: Oreohelicidae). These taxa occur, living and fossil, in several mountain ranges of south-central New Mexico and seem restricted to areas of limestone bedrock. *O. metcalfei* was described by Cockerell as a subspecies of *O. strigosa* (1905:113-114) from a specimen collected by O. B. Metcalfe from "Mountains near Kingston, New Mexico," in the east-central foothills of the Black Range in Sierra County (Fig. 1). O. B. Metcalfe (not to be confused with the present author) collected botanical and other specimens in south-central New Mexico in the early 1900's. Pilsbry (1939:509-514) recognized several subspecies of *O. metcalfei* and one related species as appertaining to the complex.

Major aims here are to present additional data regarding the distribution of the complex and to point out the existence of fossil localities, of small extent areally and easily overlooked. Hopefully this may contribute to an eventual thorough analysis of the entire *O. metcalfei* complex. Such an undertaking would require much additional field work in the fastnesses of the Black Range (Fig. 1) where access is largely by hiking and horseback. This Range comprises the Black Range Primitive Area of approximately 300 square miles plus an area of approximately equal extent outside the Primitive Area. Until such time as a definitive analysis is undertaken it remains highly problematic as to which taxa in the complex more properly deserve specific recognition and which should only be considered subspecies of *O. metcalfei*. This is, of course, a common problem in the systematics of montane snails, which in their evolutionary zeal have taken little heed of the strictures of binomial or trinomial nomenclature. Herein two new names are provided chiefly as a utilitarian measure to facilitate future revisions. As a practical expedient, I refer to species rank several kinds from mountains or mountain groups peripheral to the Black Range (Fig. 1) and separated from it by extensive intermontane basins. Variants from the Black Range itself are considered as comprising a number of subspecies of *O. metcalfei* as treated by Pilsbry (1939) for all taxa of the complex except *O. pilsbryi* Ferriss, which he relegated to species rank.

I thank Mr. William de Socarraz for preparation of micrographs and Drs. Arthur H. Harris and Richard D. Worthington for providing me with some of the specimens reported.

Abbreviations used for museums in which materials have been deposited are: ANSP = Academy of Natural Sciences of Philadelphia; DMNH = The Delaware Museum of Natural History; MALB = Museum of Arid Land Biology, The University of Texas at El Paso.

DESCRIPTIONS OF NEW SPECIES
Oreohelix caballoensis *new species*
Figs. 2, 3

Description of Holotype: (Fossil shell, ANSP 332307) Shell heavy, moderately elevated, convex dorsally and ventrally, 19.4 mm in diameter and 12.0 mm in height; slightly angular peripherally; last whorl descending markedly to aperture; aperture 9.0 mm wide and 8.1 mm high; umbilicus relatively narrow, 6.0 mm wide, contained 3.2 times in diameter; relatively tightly whorled, with 5.15 whorls; embryonic whorl with low, regular wrinkles, grading to low, regularly-spaced riblets on second whorl, remainder of dorsal surface with low, irregular growth striae, becoming coarser towards aperture; ventral surface relatively smooth except for occasional growth striae (spiral striae not observed); shell generally white but light tan on first 2½ whorls dorsally and with two reddish brown bands, one immediately below peripheral angularity on body whorl, intersecting upper edge of lip and obscured from that point on, proximally; the other a lighter spiral band in center of dorsal whorls from beginning of whorl three, distally, fading near aperture on body whorl. Type locality, Locality 1 in "List of Localities," hereafter, and in Fig. 1.

Variation: (Paratypes: DMNH 70647 and MALB 3343, Loc. 1; ANSP 332308 and MALB 3631, Loc. 2). Only three entire mature shells and several broken shells were obtained at the type locality (Loc. 1). Paratypes (also fossil) from Locality 2, in the lower western foothills of the Caballo Mts., seem to have been slightly smaller at maturity with more tightly whorled shells. For ten specimens from this locality, diameter/number of whorls averaged 3.22, while three measurable specimens from the type locality averaged 3.46. Umbilicus is relatively larger for specimens from Locality 2, with diameter/width of umbilicus averaging 3.27 for ten specimens against 3.89 for the three specimens from Locality 1.

Comparisons: Compared to the subspecies of *O. metcalfei, O. caballoensis* most resembles *O. m. hermosensis* Pilsbry and Ferriss and *O. m. cuchillensis* Pilsbry and Ferriss. These kinds are from northeastern foothills of the Black Range

and the nearby Cuchillo Mts. (Fig. 1), *ca.* 30 miles northwest and north-northwest, respectively, of the northern part of the Caballo
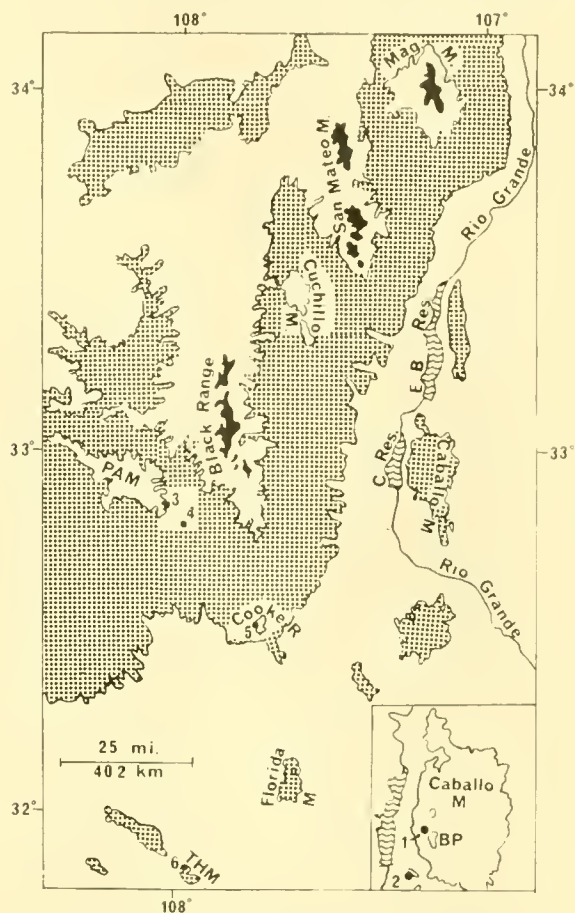
FIG. 1. *Map of south-central New Mexico indicating features mentioned in text. Contours at 5000, 7000 and 9000 feet indicated by contour lines, with elevations between 5000 and 7000 feet dotted and elevations above 9000 feet black. Reservoirs on Rio Grande indicated by wavy lines. Localities mentioned are indicated by number and black dot. Inset at lower right is of central and northern part of Caballo Mts. (5000 and 7000 feet contour lines indicated) and of Caballo Reservoir.*

Abbreviations: BP = Brushy Peak of Caballo Mts.; C. Res. = Caballo Reservoir; E B Res. = Elephant Butte Reservoir; M = Mountains; Mag. M. = Magdalena Mts.; PAM = Pinos Altos Mts.; THM = Tres Hermanas Mts.

Range and seem a likely source for propagules reaching the Caballos. Shells of *O. m. hermosensis* and *O. m. cuchillensis* are, however, more depressed with a slightly larger umbilicus than in *O. caballoensis*.

Etymology: From *Caballo* (Sp., horse), in reference to the Caballo Mts., in which the species occurs.

Oreohelix confragosa *new species*
Figs. 4-7, 9

Description of Holotype: (Fresh shell with desiccated soft parts, ANSP 332309). Shell heavy, convex dorsally and ventrally, 17.7 mm in diameter and 10.3 mm in height, bearing rounded keel peripherally at *ca.* mid-height, keel reduced to an angularity on distal-most part of body whorl, keel bordered by spiral, occasionally coarsely punctate grooves above and below, these also fading out on last $1/4$ of body whorl; aperture round except for slight angularity in outer lip at position of keel, 8.2 mm wide and 8.3 mm high; umbilicus relatively narrow, 4.7 mm wide, contained 3.8 times in diameter; 5 whorls; embryonic whorl with regular, smoothly arcuate wrinkles, these
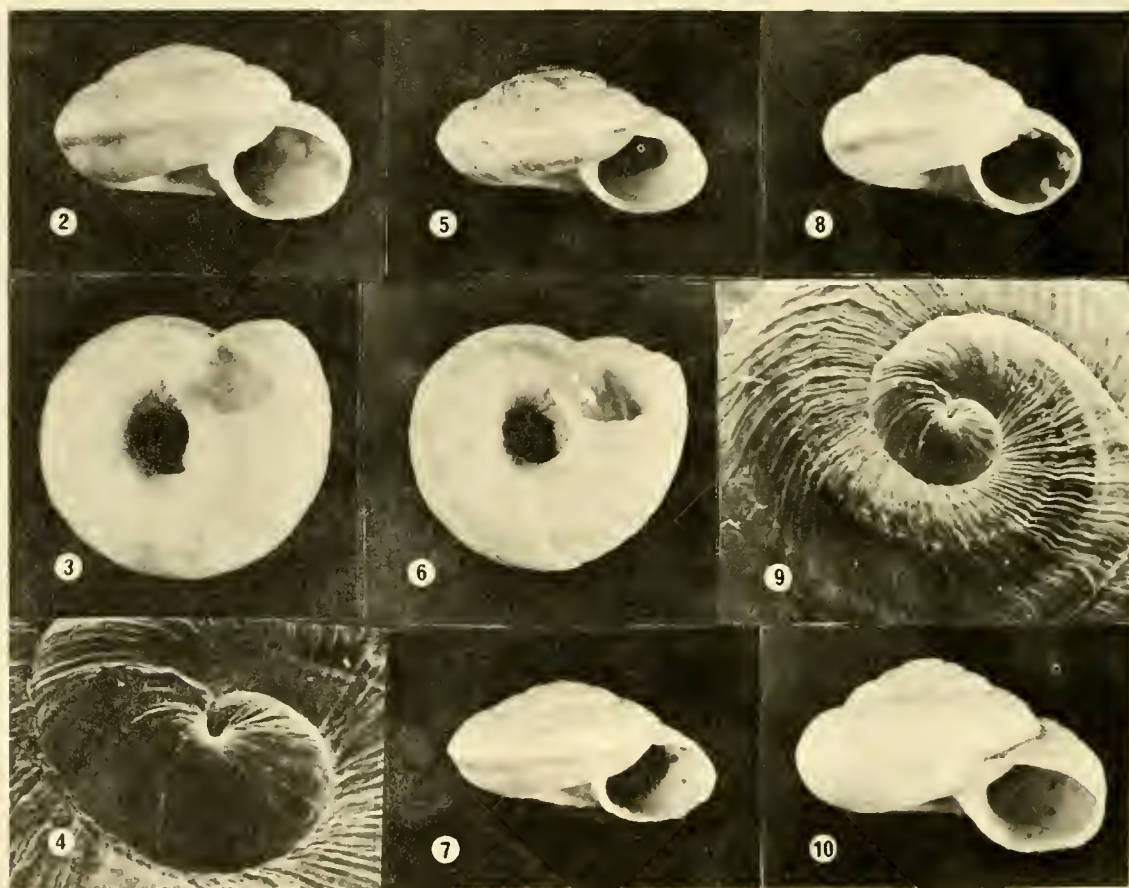
FIGS. 2, 3. *Holotype of* Oreohelix caballoensis *n. sp., (19.4 mm diameter).* FIG. 4. *Embryonic whorls of* Oreohelix confragosa *n. sp. (scanning electron micrograph, 100X).* FIGS. 5, 6. *Holotype of* Oreohelix confragosa *n. sp., (17.7 mm diameter).* FIG. 7. *Fossil specimen of* Oreohelix confragosa *n. sp. from Locality 4, (17.6 mm diameter).* FIG. 8. *Fossil specimen of* Oreohelix florida *Pilsbry from Tres Hermanas Mts., Locality 6. (16.6 mm diameter).* FIG. 9. *Apical whorls of* Oreohelix confragosa *n. sp. (scanning electron micrograph, 50X).* FIG. 10. *Fossil specimen of* Oreohelix florida *Pilsbry from Cooke Range, Locality 5, (21.1 mm diameter).*

wrinkles becoming higher and sinuous at 1 to 1¾ whorls (sinuosity in riblets caused by their intersection with two very low spiral ridges and with the spiral groove atop keel), wrinkles grading into sharp, well-defined riblets at 1¾ to 2½ whorls, these riblets fading out at 2½ to 2¾ whorls with irregular coarse growth wrinkles on remaining whorls dorsally; exceedingly fine, close-spaced spiral striae visible at many places on both dorsal and ventral surfaces of shell; irregularly round to elongate scattered pits on both surfaces; coarse growth wrinkles on ventral surface; shell generally whitish, with extremely faint, diffuse, grayish brown band immediately below keel on proximal half of body whorl, covered proximally by upper margin of lip; a few light gray spots on ventral surface with a faint, shadowy, gray spiral band (with interruptions) on proximal ⅓ of body whorl; dorsally, initial 2½ whorls light grayish brown, irregular gray to brownish gray splotches on whorls 2½ to 4 and a few gray spots on proximal part of body whorl. Type locality, Locality 3 in "List of Localities" and in Fig. 1.

Genitalia: (Data from paratypes from Locality 3; see Fig. 11). Penis swollen in middle part but narrowed distally, bearing a small lateral cornuted appendix distally; internally, wall of proximal 45% bears fleshy longitudinal folds, while that of the distal 55% bears "checkrows" of small quadrate papillae, except for one longitudinal groove that is free of papillae; area of tract joining penis to epiphallus slightly inverted back into penial cavity; retractor muscle strands attached to both penis and epiphallus at their area of juncture; epiphallus short and stout and vas deferens relatively short as in *O. metcalfei radiata* and *O. pilsbryi* (Pilsbry, 1939; Fig. 331); free oviduct short, talon darkly pigmented. Lengths for some organs for three specimens with shell diameters of 14.0, 14.5 and 17.3 were, respectively: penis: 6.4, 7.5, 8.2; epiphallus: 2.2, 2.6, 2.5; vas deferens: 4.7, 6.5, 5.9; vagina: 2.4, 2.7, 3.3; free oviduct: 1.7, 1.5, 2.1; spermathecal duct and sac: 7.8, 8.4, 11.5.

Variation: (Paratypes: ANSP 332310, DMNH 70649, Dallas Museum of Natural History 3867, MALB 3495, Locality 3; ANSP 332311 and

MALB 3494, Locality 4). For 30 paratypes from the type locality (Loc. 3) the following proportions were obtained (mean outside parenthesis; range inside parenthesis): Diameter/number of whorls: 3.54(3.16-4.02); Diameter/width of aperture: 2.34(2.12-2.50); Diameter/height of aperture: 2.33(2.14-2.63); Diameter/height of shell: 1.76(1.53-1.97); Diameter/width of umbilicus: 3.67(3.32-4.19). Proportions of fossil shells from Locality 4 are similar to the above but shells are slightly less tightly coiled, more depressed and with relatively larger apertures but smaller umbilici. For 20 specimens from Locality 4 proportions were: Diameter/number of whorls: 3.42(3.01-4.01); Diameter/width of aperture:
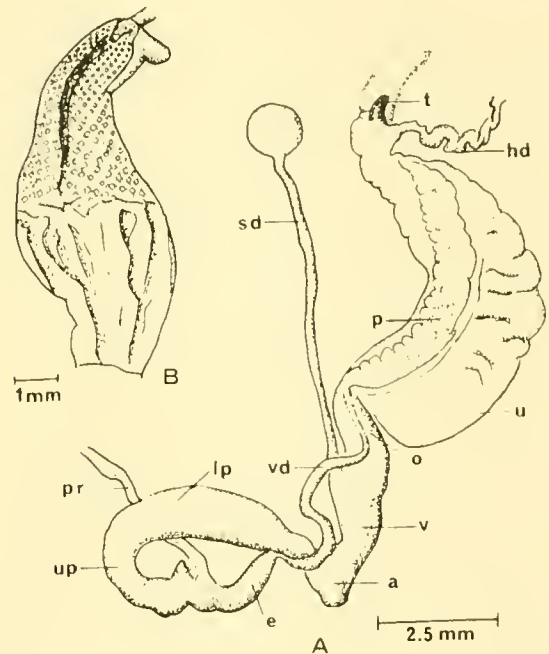
FIG. 11. A. *Genitalia of* Oreohelix confragosa *new species (paratype and topotype). Abbreviations:* **a** =*atrium;* **e** =*epiphallus;* **hd** =*hermaphroditic duct;* **lp** =*lower part of penis;* **o** =*free oviduct;* **p** =*prostate;* **pr** =*penial retractor;* **sd** =*spermathecal duct;* **t** =*talon;* **u** =*uterus;* **up** =*upper part of penis;* **v** =*vagina;* **vd** =*vas deferens.*

B. *Longitudinal section of penis of* O. *confragosa showing lower, costulate and upper papillose areas, inverted distal end and small lateral appendix.*

2.12(1.98-2.39); Diameter/height of aperture: 2.17(2.01-2.39); Diameter/height of shell: 1.81(1.62-2.01); Diameter/width of umbilicus: 3.83(3.40-4.50).

Fossil shells from Locality 4 retain, even in their fossil condition (Fig. 7), a well-defined reddish brown band below the keel. An equally well-defined brownish band is located centrally on the dorsal surface of all whorls succeeding the first two. A brown band is also found below the keel on younger (up to *ca.* 4) whorls on living (topotypic) specimens. In larger living specimens the ultimate (usually fifth) whorl covers much or all of this band. On younger shells, also, a dim brown band is observable on the upper surface of whorls as in fossils from Locality 4. This band fades with age, however, and is usually indiscernible on older shells. In regard to banding, then, living specimens seem ontogenetically to pass through a stage when they resemble the fossil specimens from Locality 4 as well as the more heavily banded "peripheral" species mentioned hereafter. Pilsbry (1939:413) discussed loss of the supposedly primitive bands in some kinds of *Oreohelix.*

Embryos closely resemble those figured by Pilsbry (1939: Fig. 333) for *O. m. radiata* and *O. m. hermosensis.* Young shells up to *ca.* two whorls bear several spiral rows of hairlike cuticular processes ventrally and on the keel and on each of two or three low spiral ridges dorsally (ridges observable in left part of Fig. 9). Short cuticular hairs are also produced on the keel of the third whorl and these persist in the shelter of the sutural depression on specimens up to 15 mm in diameter. Fig. 4 indicates presence of minute pustules on dorsal surface of the embryonic whorl at its origin.

Shells commonly exhibit rough radial corrugations and areas in which the outermost shell layers are broken or missing. Pits, scars and other irregularities also are common, these accumulating and becoming especially noticeable in older shells. The common occurrence of such areas suggested the name *confragosa,* L., broken, rough, uneven.

Comparisons: O. confragosa seems closer to the nominal subspecies of *O. metcalfei* than to any of the other named taxa of the complex.

However, it is not as sharply keeled as is *O. m. metcalfei* and it is more convex (less pyramidal) dorsally. The surface of *confragosa* is more roughly sculptured radially. The distinct subcarinal brown spiral band of *O. m. metcalfei* is similar to that of fossil specimens of *O. confragosa* from Locality 4 but is lacking on adults from the type locality.

DISCUSSIONS

The *O. metcalfei* complex seems to include the following components (locality numbers and geographic features mentioned are indicated in Fig. 1).

(1) In the Black Range and nearby Cuchillo Mts. occur six subspecies of *O. metcalfei* Cockerell. These are, in addition to the nominal subspecies, *acutidiscus, concentrica, cuchillensis, hermosensis* and *radiata,* all described by Pilsbry and Ferriss. One species, *O. pilsbryi* Ferriss, was also ascribed to the complex by Pilsbry (1939:514).

(2) In several isolated mountains to the south of the Black Range occur fossil or dead, bleached shells here assigned to *Oreohelix florida* Pilsbry. *O. florida* is a relatively distinctive member of the *O. metcalfei* complex, being robust, having the highest spire of any member of the complex, lacking spiral striae and possessing coarse, radial growth lines. As such, it seems deserving of specific status. Pilsbry (1939:513) described *O. metcalfei florida* from the Florida Mts., Luna County, from old, bleached shells (ANSP 103243). He also assigned two fossil shells from the Tres Hermanas Mts. *ca.* 25 miles southwest of the Florida Mts. to this taxon. I have taken one additional fossil specimen at Locality 6 in the Tres Hermanas Mts. (MALB 2642). I have also taken fossil specimens (DMNH 70648; MALB 3634) at Locality 5 in the Cooke Range, located between the Florida Mts. and the Black Range. Thus, *O. florida* seems formerly to have penetrated southward at least some 70 miles along these isolated montane "islands." It is doubtful whether it is still living in any of them, however, as the Tres Hermanas Mts. are a low and arid range and the Cooke Range lacks limestone in its higher, more mesic parts. Baldy Peak in the Florida Mts., a high, isolated,

massive limestone outcrop, may have been the last refuge of the species but collections made in this century suggest that *O. florida* is no longer living there. In 1970 I found only a few weathered fragments on the north side of Baldy Peak (MALB 1201). Pilsbry (1939) did not illustrate *O. metcalfei florida.* Figs. 8 and 10, herein, show shells from the Tres Hermanas Mts. and Cooke Range, respectively.

(3) The localities cited herein for *O. caballoensis* extend the range of the *O. metcalfei* complex to the east. This is the only member known to occur east of the Rio Grande Valley. It is doubtful that the complex ever extended any farther east as the next mountain range eastward, the San Andres Mts., seems, on the basis of fossils recovered, to have been inhabited only by *O. socorroensis,* discussed below.

(4) Localities of occurrence indicated for *O. confragosa* extend the range of the *O. metcalfei* complex to the west into the Pinos Altos Mountains.

(5) In the Magdalena Mts., some 50-60 miles north-northeast from the indistinct northern end of the Black Range, occurs *Oreohelix magdalenae* Pilsbry, shells of which, although slightly smaller, are close to those of *O. m. cuchillensis* and *O. caballoensis.* Pilsbry (1939:515) considered *O. magdalenae* to be a subspecies of *O. socorroensis* Pilsbry. This seems improbable, however, as (a) shells of the two differ morphologically, with *O. socorroensis* being more depressed, strongly carinate, with well developed spiral striae and lacking the brown banding of *O. magdalenae* and (b) *O. socorroensis* seems to occur only east of the Rio Grande Valley, chiefly as a fossil in mountains surrounding the Tularosa-Hueco Basin (Metcalf and Johnson, 1971:102-103), whereas *O. magdalenae* seems to occur only in the Magdalena Mts., west of the Rio Grande Valley. Probably *O. socorroensis* dispersed southward from a northern source in the *O. yavapai neomexicana* Pilsbry complex, whereas *O. magdalenae* seems more likely a northeastern derivative of the *O. metcalfei* complex.

The *O. metcalfei* complex probably has had its center of dispersal in the relatively large, high and complex massif of the Black Range

from which it seems to have radiated propagules in all directions (Fig. 1). Most of the peripheral kinds *(O. magdalenae, O. caballoensis* and *O. florida* along with *O. m. hermosensis* and *O. m. cuchillensis* of the eastern foothills and adjacent ranges of the Black Range) show considerable similarity in having elevated, biconvex shells, in lacking a keel, in possessing relatively smooth shells lacking spiral striations and in possession of prominent brown spiral bands. Kinds of the central Black Range, on the other hand, exhibit to various degrees depression and carination of the shell, development of elaborate spiral and/or radial striae, ridges and grooves and the loss of brown banding. *O. confragosa* seems closer to the first (peripheral) group discussed but does possess fine spiral striae. Brown banding is extremely weak in living specimens of *O. confragosa* but fossils have better developed bands, suggesting that evolution towards loss of banding has taken place.

It seems probable that in the *O. metcalfei* complex shells of the "peripheral group," many of which are known only as fossils, are more conservative. Conversely, members of the complex inhabiting the Black Range in the highest, best watered part of the distributional range of the complex seem to show evidence of a greater degree of speciation than their more conservative, peripheral relatives.

Probably ancestors of the *O. metcalfei* complex managed to occupy in one or more Pleistocene pluvial episodes a number of mountain ranges in the region, possessing at that time the shell characters suggested above as being "conservative." Subsequent desiccation in one or more interpluvial episodes has resulted in extinction in some and restriction of range for other members of the complex. Peripheral representatives in smaller, lower mountains have been especially adversely affected. In the Black Range "heartland" of the complex, however, survival has been more successful and speciation has been relatively accelerated.

LIST OF LOCALITIES

1. Sierra Co.; 107° 14' W Long, 32° 56' 13" N Lat; 6200' elev.; Caballo Mts., from hillslope

colluvium of Pleistocene age at mouth of canyon on northwest side of Brushy Mt. This is a straight box canyon, the first canyon N of prominent mine on W face of Brushy Mt., and debouches near last "0" in "6000" elevation designation on Upham 15' Topo. Quad. A few specimens were also taken at mouth of a more tortuously branched canyon, located .65 mi. S, in colluvium.

2. Sierra Co.; SW¼,NE¼,SW¼, Sec. 28, T. 16 S. R. 4 W; 5000' elev.; western foothills of Caballo Mts., 2 mi. SSE of E end of Caballo Reservoir Dam, from Pleistocene hillslope colluvium on steep hillside *ca.* 100 ft. below massive limestone rimrock at top of prominent cuesta east of extensive mining area.

3. Grant Co.; near center of NE¼, Sec. 12, T. 17 S, R. 12 W; 6700' elev.; Pinos Altos Mts., .3 mi. WSW of west side of ruins of Georgetown (abandoned mining village) on S (N-facing) wall of Willow Springs Canyon, below massive limestone outcrop; snails living under flat limestone rocks derived from the cliffs above and strewing the slope; dominant plants on slope were *Juniperus monosperma*, *Pinus edulis*, *Quercus gambelii*, *Yucca baccata*, *Garrya wrightii* and *Symphoricarpos* sp.; collected Sept. 15, 1973.

4. Grant Co.; .45 mi. S of NE corner of Sec. 26, T. 17 S, R. 11 W; 6000' elev.; from whitish hillslope colluvium of Pleistocene age immediately NW of intersection of N.M. Hwy. 90

with paved road leading to San Lorenzo and Mimbres, at base of escarpment flanking Mimbres Valley on W side (E side of Pinos Altos Mts.).

5. Luna Co.; SE¼,SE¼,NW¼, Sec. 24, T. 20 S, R. 9 W; 6600' elev.; Cooke (or Cook) Range; cuts along road in steep hillside W of and above abandoned mining village of Cooke (Cook) at head of prominent NE-draining gulley (with trail shown on Lake Valley 15' Topo. Quad.) in central part of village; road cuts in Pleistocene hillslope colluvium of salient whitish color (visible several miles away) that contains fossils.

6. Luna Co.; center, N boundary of SE¼, Sec. 26, T. 27 S, R. 9 W; 4540' elev.; NE part of Tres Hermanas Mts., in alluvium exposed in arroyo bank immediately S of mine that is, in turn, WSW of Lindy Ann Mine (both shown on North Peak 7.5' Topo. Quad.).

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LYMNAEA EMARGINATA, A POSSIBLE AGENT FOR THE CONTROL OF THE SCHISTOSOME-SNAIL HOST, BIOMPHALARIA GLABRATA[1]

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ABSTRACT

Lymnaea emarginata *controlled laboratory populations of* Biomphalaria glabrata *by destroying the latter's egg-masses. Previous exposure to* B. glabrata *egg-masses accelerated predation by* L. emarginata. *This phenomenon was considered to be due to sensitization rather than conditioning, since repeated exposures could not be correlated with an increase in the efficiency of predation.* L. emarginata *was capable of distinguishing between the egg-masses of* B. glabrata *and* Helisoma caribaeum, *and destroyed primarily those of the former; however, neither the egg-masses nor their products appeared to attract the predator.*

Gastropod mollusks exhibit a greater diversity of diet and of feeding mechanisms than, perhaps, any other group of animals (Owen, 1966). However, to our knowledge, there are no freshwater gastropods which normally act as "true" predators; i.e., actively seek prey. An exception may be *Marisa cornuarietis* (Linné) and, possibly, other members of the Pilidae (Paulinyi and Paulini, 1972). Chernin *et al.*, (1956) demonstrated that *M. cornuarietis* controlled *Biomphalaria glabrata* (Say) populations by ingesting their egg-masses and newly hatched snails. They believed this "predation" to be accidental and due to the *Marisa's* insatiable appetite for vegetation and its proclivity for continuous browsing. On the other hand, Demian and Lutfy (1965 a & b) reported that *Marisa* deliberately preys on young and older snails and can be "conditioned" to "prefer" a snail meal to its normal herbivorous diet. Observations, in our laboratory, indicated that a North American pulmonate snail, *Lymnaea emarginata* Say, would feed avidly upon the egg-masses of *B. glabrata*.

In the present study we assessed the ability of *L. emarginata* to destroy *B. glabrata* egg-masses, the effect of sensitization on the rate of predation, and determined if this predation
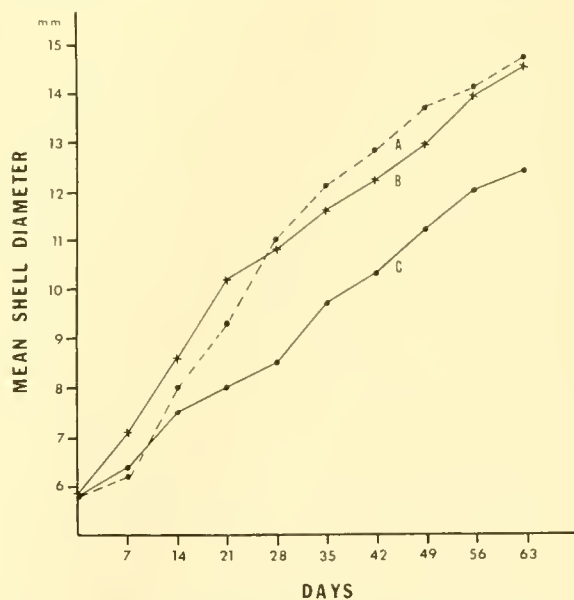

FIG. 1. *Mean shell measurements of* Biomphalaria glabrata *populations comprised of 10* B. glabrata *(A), 10* B. glabrata *plus 20* L. emarginata *(B), and 30* B. glabrata *(C). Experiment 5.*

TABLE 1. *Destruction of* B. glabrata *eggs by* L. emarginata. *Twenty snails were used in each trial. Experiment 1.*

| Trial | Eggs | (masses) | % eggs destroyed by day: | | | |
			1	2	3	4
1	221	(12)	–	–	43.4	84.2
2	257	(8)	5.1	–	–	32.3
3	191	(6)	–	34.6	–	–
4	114	(3)	9.6	14.0	39.5	54.4
5	110	(4)	76.4	95.5	99.1	100
6*	190	(5)	19.5	42.1	78.9	97.9

Snails used in this trial were the same as in trial 4.
*Snails used in this trial were starved for 24 hrs prior to testing.

could, in fact, limit or control the size of *B. glabrata* populations.

MATERIALS AND METHODS

A Puerto Rican strain (PR-1) of *Biomphalaria glabrata* (Say), a Virgin Island strain (CB) of *Helisoma Caribaeum* (Orb.), and a North American strain (Michigan) of *Lymnaea emarginata* Say were maintained as described (Michelson, 1966). The snail we call *L. emarginata* is placed by some workers in the genus *Stagnicola* (Inaba, 1969; Burch, 1960 a & b) and is considered by Walter (1969) to be a synonym of *L. catascopium* Say.

All experiments were conducted in a temperature controlled room (25 ± 1° C). In some experiments, 600 and 1000 ml beakers were used as aquaria; in others, 3-liter plastic tubs. Aquaria were filled with equal parts of "conditioned" aquarium water and distilled water, were exposed to 12 hr of fluorescent light daily, and for some experiments continuously aerated. Snails were fed excess amounts of romaine lettuce during the experimental period. All snails were measured with Vernier calipers or an ocular micrometer (nearest 0.1 mm) and eggs were examined and counted with the aid of a stereomicroscope (x15). Egg-masses were collected on sheets of plastic-film as described by Olivier and Haskins (1960). No attempt was made to match the stage of embryonic development in the eggs of different masses.

EXPERIMENTAL STUDIES AND RESULTS

Observations on feeding behavior:

B. glabrata egg-masses and individual *L. emarginata* were confined to small Petri dishes (50 mm) and observed with the aid of a stereomicroscope. In most instances, the snail moved randomly about the dish until an egg-mass was encountered. An exploratory period followed in which the snail stroked the mass with its tentacles, occasionally crawled part-way onto the mass or across it to the opposite side, and finally adopted a position in which the labial flaps and mouth were in juxtaposition to the edge of the mass. Feeding was initiated by the rapid flexing of the radula and the movement of the jaws. The snail rasped through the external and egg membranes and then devoured the egg contents and embryo. No preference was noted for eggs at a particular stage of development and eggs of all ages were eaten. Destruction of the mass was not a continuous process, but occurred at intervals with the

TABLE 2. *The effect of repeated exposure to* B. glabrata *egg-masses on the ability of* L. emarginata *to seek and destroy the eggs of* B. glabrata. *Experiment 2.*

Trials and groups*	Eggs	(masses)	% eggs destroyed by day:			
			1	2	3	4
1. exposed	110	(4)	73.6	85.5	98.1	100.0
non-exposed	109	(4)	33.0	75.2	80.7	90.8
2. exposed	106	(4)	17.0	18.9	84.0	100.0
non-exposed	104	(4)	4.8	4.8	28.9	51.9
3. exposed	112	(4)	100.0	–	–	–
non-exposed	112	(4)	0	0.9	44.6	68.8
4. exposed	68	(3)	60.3	72.1	94.1	–
non-exposed	75	(3)	14.5	15.8	28.0	–
5. exposed	84	(3)	63.1	90.5	100.0	–
non-exposed	81	(3)	29.6	50.6	55.6	–
Mean values						
exposed			62.8	73.4	95.1	100.0
non-exposed			16.4	29.5	47.6	82.5

*10 snails were used in each group, and the exposed snails of trial 1 were used as the exposed group for each subsequent trial.

snail leaving and then returning after a period of browsing.

EXPERIMENT 1

Destruction of B. glabrata *eggs by* L. emarginata *in the presence of vegetation.*

Small squares of plastic-film, each containing a single egg-mass, were anchored to the bottoms of 1-liter beakers containing 900 ml of water. Twenty *L. emarginata* (8.0-11.0 mm in alt.) were introduced into each beaker and an abundant supply of lettuce added. Egg-masses were examined daily for 4 days to determine the number of eggs destroyed. The data (Table 1) clearly indicates that *L. emarginata* preys on *B. glabrata* eggs, even in the presence of excess vegetation, and is capable of destroying 50% or more of the test samples after 4 days. Except in one trial (#5), none of the *L. emarginata* had had previous exposure to *B.*

glabrata egg-masses. This trial suggested that previous exposure to *B. glabrata* egg-masses may "sensitize" *L. emarginata* to actively seek and destroy such eggs.

EXPERIMENTS 2 & 3

Effect of pre-exposure on the rate of predation.

The following experiments were designed to test the hypothesis that *L. emarginata* pre-exposed to *B. glabrata* egg-masses became sensitized and thus destroyed egg-masses more rapidly than non-exposed snails. A group of 10 snails were exposed for 4 days to *B. glabrata* egg-masses. The same group of "exposed" snails were then used in 6 consecutive trials and their predatory activity compared with groups of non-exposed snails. Trials of "exposed" and "non-exposed" snails were run simultaneously in 1-liter beakers containing 900 ml of water and an abundance of lettuce.

TABLE 3. *The effect of previous exposure to* B. glabrata *egg-masses on the ability of* L. emarginata *to seek and destroy the eggs of* B. glabrata. *Experiment 3.*

Trials and groups*	Eggs[+]	% eggs destroyed on day 1:
1. exposed	101	63.4
non–exposed	100	4.0
2. exposed	100	31.0
non–exposed	97	3.1
3. exposed	96	30.2
non–exposed	103	1.0
4. exposed	101	9.9
non–exposed	100	30.0
5. exposed	101	18.8
non–exposed	100	0
6. exposed	99	10.1
non–exposed	102	0
7. exposed	98	22.5
non–exposed	103	2.9
8. exposed	100	0
non–exposed	100	0

*5 snails were used in each group per trial.

+ 3 egg-masses were used for each group in all trials.

Results (Table 2) appear to indicate that "exposed" snails find and destroy egg-masses more quickly than do "non-exposed" snails. Since it was possible that the snails of the "exposed" group were in some manner atypical, another experiment was set up to overcome this contingency. In this experiment (#3), 8 groups of pre-exposed snails were compared with similar groups of non-exposed snails. Each group consisted of 5 *L. emarginata* (7.0-9.5 mm in alt.) and the trials were conducted in 600 ml beakers filled with 500 ml of water and a supply of lettuce.

The results (Table 3) clearly support the premise that pre-exposure to *B. glabrata* eggs increased the rate of destruction of such eggs by *L. emarginata*. The rate of egg destruction by "ex-posed" snails was found to be significantly greater than that of "non-exposed" snails when the data was analyzed by the Wilcoxsin rank test for unpaired measurements; p = 0.02.

EXPERIMENT 4

Selectivity of L. emarginata *for planorbid egg-masses.*

This experiment was designed to determine if *L. emarginata* was selective in its choice of egg-masses or would attack any planorbid egg-masses. Trials were set up as in Experiments 2 and 3, but used either *H. caribaeum* egg-masses or a mixture of *H. caribaeum* and *B. glabrata* masses. Results are summarized in Table 4 and indicate that *L. emarginata* preys only to a limited extent on the eggs of *H. caribaeum*. Moreover, when both types of egg-masses were presented simultaneously, only those of *B. glabrata* were eaten.

TABLE 4. *Failure of* L. emarginata *to destroy* Helisoma caribaeum *egg-masses. Experiment 4.*

Trial* and Egg type	Eggs	(masses)	% eggs destroyed by day:			
			1	2	3	4
1. H. caribaeum	46	(3)	0	0	0	0
2. H. caribaeum	46	(3)	0	0	0	0
3. H. caribaeum	41	(3)	0	0	0	0
4. H. caribaeum	53	(4)	0	1.9	1.9	1.9
5. H. caribaeum	94	(10)	0	0	0	3.2
6. H. caribaeum	88	(8)	0	0	0	6.8
7. H. caribaeum[+] and	50	(4)	0	0	0	0
B. glabrata	53	(4)	9.4	34.0	50.9	64.2
8. H. caribaeum[+] and	53	(3)	0	1.0	1.0	1.9
B. glabrata	52	(3)	15.4	19.2	21.2	23.1

*8 snails were used in trials 1 + 2. 5 in trials 3 + 4, and 10 in all others.
+ In these trials both types of egg-masses were placed in the same beaker.

EXPERIMENTS 5 & 6

Control of B. glabrata *populations by* L. emarginata.

The following series of experiments explore whether or not the predation exercised by *L. emarginata* is sufficient to limit the growth of *B. glabrata* populations. Two 3-liter aquaria were set up so that "A" contained only 10 *B. glabrata* (mean diam. = 7.8 mm) and "B" contained 10 *B. glabrata* (mean diam. = 7.8 mm) plus 20 *L. emarginata* (mean alt. = 11.8 mm). Snails of both species were approaching sexual maturity at the onset of the experiment, and eggs deposited by both species were permitted to hatch. The experiment ran for 6 wks, at which time all snails and egg-masses were identified and counted.

The results of· the experiment were as follows: 1) aquarium "A" contained, in addition to the original 10 snails, 1225 new *B. glabrata* and 59 egg-masses; 2) aquarium "B" contained 10 and 16 respectively of the original snails, 190 new *B. glabrata*, 244 new *L. emarginata*, 4 *B. glabrata* egg-masses, and 8 *L. emarginata* egg-masses. Thus, in the presence of *L. emarginata*, *B. glabrata* increased only 19-fold as compared to a 122.5-fold in the control aquarium. In a replicate experiment, the *B. glabrata* population increased 11.5-fold in the mixed-species aquarium, whereas, the controls showed a 99.8 fold-increase.

The previous experiment failed to rule out the possibility that the slower rate of growth of the *B. glabrata* population in the mixed-species aquarium was related as much to "crowding" by *L. emarginata* as to predation. Experiment 6, therefore, was designed to determine if the "crowding phenomenon" (i.e., concomitant reduction in growth and fecundity) observed in

TABLE 5. *The effect of* L. emarginata *on the fecundity of a population of* B. glabrata. *Summary of observations over a period of 9 weeks. Experiment 6.*

Criteria of fecundity[°]	Fecundity of Populations		
	10 B. glabrata (A)	10 B. glabrata + 20 L. emarginata (B)	30 B. glabrata (C)
Total egg-masses	193	116	323
Total eggs*	4509	3098	5572
Mean eggs/snail	459.4	322.7	186.4

[°] In populations A and C, egg deposition began during the 3rd week of the experiment; in B during the 4th week.

* Based on mean number of surviving snails per week.

crowded mono-specific populations of pulmonate snails (Chernin and Michelson, 1957; Szumelwicz, 1958; Wright, 1960; Shiff, 1964; Jobin and Michelson, 1969; Sturrock and Sturrock, 1970) would also operate in mixed-species populations. Accordingly, three 3-liter aquaria were set up as follows: "A" with 10 *B. glabrata*, "B" with 10 *B. glabrata* and 20 *L. emarginata*, and "C" with 30 *B. glabrata*. The experiment ran for 9 weeks and was replicated twice. Egg-masses were removed weekly and eggs counted.

The results indicate that *L. emarginata* did not exert a "crowding effect" on the *B. glabrata* population with respect to growth (compare A and B in Fig. 1). However, the differences between the means of populations A and C were highly significant when analyzed by the students "t" test; $p = < .01$. Egg production (per snail) of the isolated *B. glabrata* populations was, as expected, greater in the less crowded aquarium ("A") than in the more crowded aquarium ("C"); however, fecundity was lower than expected in "B" considering that the growth of the *B. glabrata* population was not inhibited by the presence of *L. emarginata* (Table 5). Replicate experiments gave essentially the same results.

MISCELLANEOUS EXPERIMENTS

Efforts to disguise the egg-masses of *B. glabrata* by immersing them, for 1 hr, in an extract prepared from *L. emarginata* egg-masses failed to protect them from predation.

To determine if a chemo-attractive substance was released by egg-masses of *B. glabrata*, we employed a plastic maze (Michelson, 1960) and used as bait either intact egg-masses, punctured egg-masses, or filter paper discs impregnated with egg extracts. Each bait was tested in 24 individual trials and employed a new snail (7.0-9.0 mm) for each trial. No evidence of a chemo-attractive response was elicited from *L. emarginata*.

DISCUSSION

Our data indicate that *Lymnaea emarginata* was effective in controlling laboratory populations of *Biomphalaria glabrata*. Control appeared to be exercised as a result of egg destruction, and was not associated with a reduction of fecundity imposed by crowding. Although previous exposure to *B. glabrata* egg-masses appears to enhance *L. emarginata's* ability to destroy eggs, "conditioning", in the sense that repeated exposures can be directly

correlated with an increase in effectiveness, has not been demonstrated. Our observations support the studies of Wells and Wells (1971) and of Cook (1971) that pulmonate snails can be sensitized, but are incapable of being conditioned. *L. emarginata* appeared to be able to differentiate between *H. caribaeum* and *B. glabrata* egg-masses, attacking only those of the latter. However, we could detect no chemoattractant emitted from the egg-masses of *B. glabrata*, and recognition may be tactile. In nature, *L. emarginata* and species of *Helisoma* occur together; whereas, species of *Biomphalaria* are restricted geographically to the tropics and sub-tropics. One might speculate, therefore, that the predation of *B. glabrata* egg-masses is an adaptive mechanism by which *L. emarginata* limits potential competitors.

L. emarginata appears to be restricted to the Northern Temperate Region of North America and has been found rarely below 40° North Latitude (LaRocque, 1968; van der Schalie and Berry, 1973). Recently, van der Schalie and Berry (1973) have shown that this species, in the laboratory, has optimal longevity and reproductive potential at temperatures ranging from 22° - 26° C; at temperatures approaching 30° C, marked mortality occurs. It should be noted, however, that contrary to popular belief, many aquatic habitats in the Tropics rarely have temperatures which regularly exceed 28 C (Jobin, 1970).

Although *L. emarginata* could be reared at tropical temperatures in the laboratory and showed no evidence of stress, there is no indication that the control exercised by this snail in the laboratory could occur under natural conditions. In fact, the ability of *L. emarginata* to serve as a host for non-human schistosomes (McMullen and Beaver, 1945) may preclude its use as a control agent. Nonetheless, in this era of environmental sensitivity, alternatives to molluscicides warrant further attention.

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BOOK REVIEW

DICIONARIO CONQUÍLIO e MALACOLÓGICO. *By Maury Pinto de Oliveira and Maria Helena Rodriques de Oliveira. 1974. 190 pp. Ministerio da Educação, Univ. Federal Juiz de Fora, Minas Gerais, Brazil. Paperback.*

This handy dictionary and glossary of conchological and anatomical terms will serve well those who consult the Portuguese literature of mollusks. Also included are the Portuguese names for various geographical regions. — *R. Tucker Abbott.*

DEVELOPMENT OF BROOD SACS IN *MUSCULIUM SECURIS* BIVALVIA: SPHAERIIDAE

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ABSTRACT

In Musculium securis *(Prime) brood sacs develop from and remain associated with certain filaments of the inner gill. Brood sacs do not migrate along the filaments as reported in the literature for other species of Sphaeriidae, but remain stationary. The brood sac filament relationship enables determinations of the numbers of litters produced by back-calculation of brood sacs.*

INTRODUCTION

Sphaeriids are ovoviviparous with the fertilized egg developing in brood sacs on the inner gill of the parent until the young are mature enough to be released to the outside. Okada (1935) and Gilmore (1917) have described the structure and development of three types of brood sacs (primary, secondary, and tertiary) which occur during larval development of sphaeriids. The development of brood sacs in *M. securis* is markedly different from descriptions in the literature of other sphaeriids but the structure appears to be similar. The present paper reports these differences and describes the significance of brood sac development in life history studies.

MATERIALS AND METHODS

Four populations of *M. securis* were studied. Two populations were from temporary forest ponds, one from a permanent pond, and the fourth from a river bed. All habitats are within a 45 km radius of Ottawa, Ontario, and are described by Mackie (1973). Samples of 30-100 clams were removed from each habitat usually at two week intervals during the summer and one month intervals during the winter. Each specimen was isolated and preserved in a two dram vial containing 70% ethanol.

The shell length (anterior to posterior) of each adult was measured to two decimal
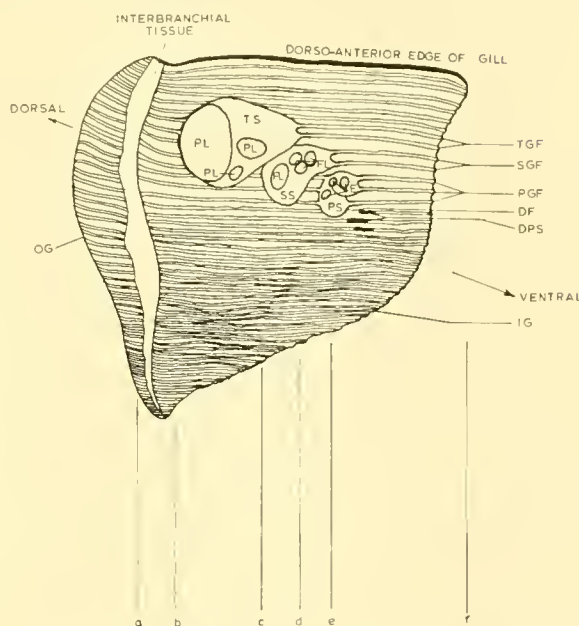
FIG. 1. *Position of the brood sacs and their relation to the gill filaments of the inner gill.* **DF:** *degenerating filaments.* **DPS:** *developing primary sac.* **E:** *embryo.* **FL:** *fetal larvae,* **IG** *inner gill,* **OG** *outer gill,* **PGF** *gill filaments supporting primary sac.* **PL:** *prodissoconch larvae.* **PS:** *primary sac.* **SGF:** *gill filaments supporting secondary sac;* **SS** *secondary sac.* **TGF:** *gill filaments supporting tertiary sac. See text for explanation of a, b, c, d, e, and f.*

places in millimeters with a Precision Tool and Instrument Co., Ltd. microscope micrometer, model 14. The left and right inner gills

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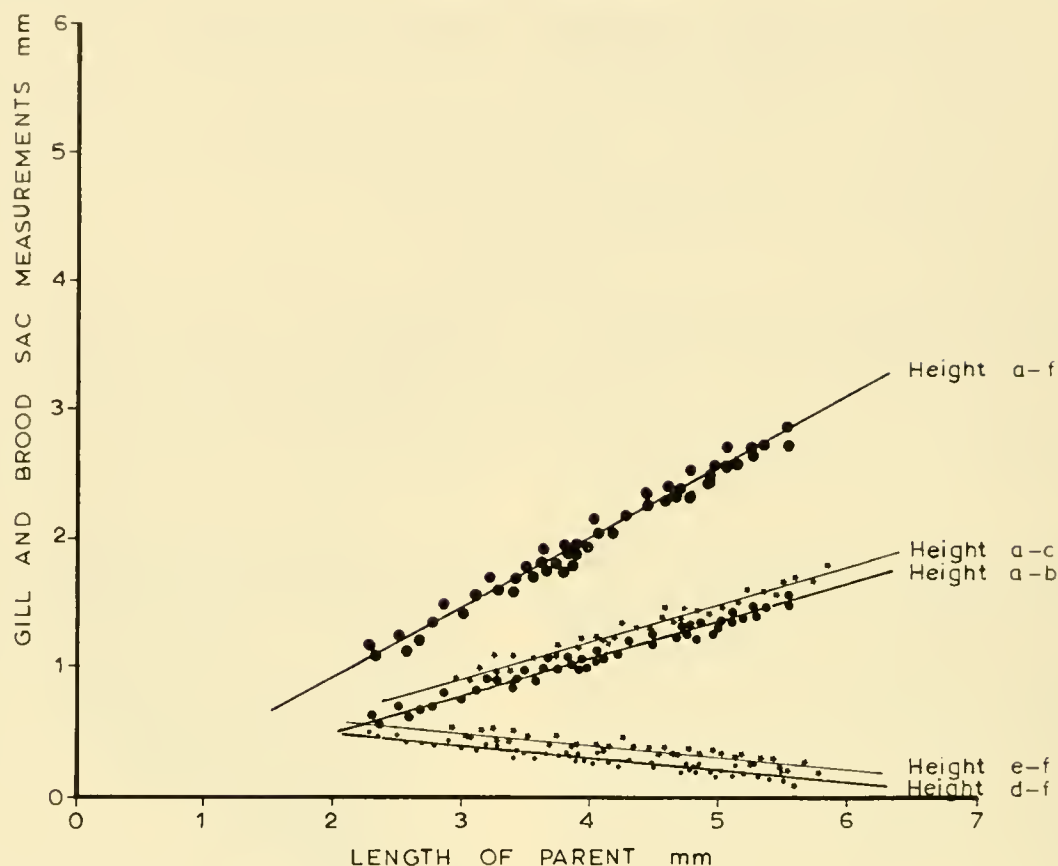
FIG. 2. *Growth of the inner gill and various aspects of the first and second brood sacs in relation to growth in shell length of parents of* Musculium securis. *See text and Fig. 10 for explanation of a-f, a-b, e-f, and d-f.*

were excised from each parent and the brood sacfilament relationship was determined in the following manner. Filaments were numbered consecutively beginning at the dorso-anterior edge of the gill (Fig. 1). Brood sacs were designated as first, second, third, or fourth, depending on the sequence in which they developed. Data was recorded to show which brood sac was associated with which filaments in each parent.

In addition, several measurements were taken to determine the relationship between the growth in height of inner gills and brood sacs and the growth in shell length of parents. Referring to Fig. 1, the total height of the gill (a-f) and the height of brood sacs (b-d and c-e), were measured in parents of several ages. Only the first two sacs were measured because

M. securis usually produces only two litters (Mackie, 1973). The lengths a-b, a-c and d-f, e-f are measures of growth of first and second brood sacs in the dorsal and ventral directions, respectively.

There were no significant differences (P>0.05) in the brood sacfilament relationship nor in the relationship between the growth of gills and brood sacs and the growth of parents among populations. Therefore, clams from each habitat were combined and treated as a sample population.

RESULTS

In *M. securis* the brood sacs are associated with certain filaments of the inner gill (Fig. 1). Of an estimated 10,000 brood sacs examined, all develop from either two or three gill filaments. Counting down from the dorso-anterior edge of the gill (Fig. 1), the first sac usually develops on the 7th and 8th gill filaments, the second on the 9th and 10th, the third on the 11th and 12th, and the fourth on the 13th and

14th gill filaments. Each sac remains associated with the filaments from which it arises until the sac ruptures, releasing the enclosed pro- dissoconch larvae. Occasionally brood sacs de- velop from three filaments so that the first sac is on filaments 7, 8, 9, the second on 10, 11, the third on 12, 13, and the fourth on 14, 15, 16 or the first is on 7, 8, and the second on 9, 10, 11, the third on 12, 13, and the fourth on 14, 15, 16. Nearly all combinations of gill fila- ments occur except two adjacent sacs each co- cupying three filaments.

Measurements of 150 parents showed that the growth of brood sacs and gills are directly related to the growth of parents (Fig. 2). Also the growth of brood sacs is linearly re- lated to the growth of gills (Fig. 2). The dis- tance between the dorsal edge of the gill (a, Fig. 1) and the dorsal edge of the first sac (b, Fig. 1) decreases with increasing age of the parent, indicating that the sac advances dorsally (Fig. 2). However, the distance between the ventral edge of the first sac (d, Fig 1) and the ventral edge of the gill (f, Fig. 1) remain constant and is exactly one half the length of the gill in all parents (Fig. 2). Since the gill grows in a ventral direction (Raven, 1958), the brood sacs must advance in the ventral direction at an identical rate.

DISCUSSION

Okada (1935) does not associate the brood sacs with gill filaments in *M. heterodon* but maintains that "the sac moves upwards along the descending lamella" by formation and re- formation of new sac stalks. This does not occur in *M. securis* since the ventral edge of the sacs advance ventrally (i.e. downwards) at an identical rate of the growth of gills. More- over, there is no evidence of the sac stalks forming and reforming since the sacs are always attached dorsally and ventrally to the gill filaments. Okada (1935b) also states that the sacs move from "the lower part to the upper part of the branchial chamber". This cannot occur in *M. securis* because the sacs remain attached to the filaments from which they arise. Rather, the sacs merely enlarge with the growth of the enclosed larvae.

Since brood sacs are associated with certain gill filaments, the numbers of litters produced by a parent can be determined by *back cal- culation of brood sacs*. Thus, parents that have produced one litter will not have brood sacs on filament numbers 7 and 8, but will have brood sacs on filaments 9-14, 9-15, or 9-16. Similarly, parents that have produced two lit- ters will not have brood sacs on filament num- bers 7 and 8 nor on 9 and 10. This technique can be applied to parents in which brood sacs develop from two filaments. For parents in which brood sacs develop from three filaments, two litters were produced if filament numbers 7, 8, 9, 10, 11 have no brood sacs (we have never seen the 12th filament used in the for- mation of the second brood sac), three litters if filament number 7-13 inclusive (or 7-14 inclusive) have no brood sacs. Usually sac remnants remain to determine whether a sac has developed from two or three filaments. If no sac remnants are present, one only needs to refer to filament numbers 8, 10, and 12, since they are always present in the formation of the first, second and thrid brood sacs, respectively, regalrdless of the number of filaments used in sac development. If indeed the 12th filament is used in the develop- ment of the second brood sac, errors would be introduced into the estimation of the third and fourth litters. This is particularly true if sac rem- nants are not present to determine the number of filaments used in sac development.

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DESTRUCTION OF KELP POPULATIONS
BY *LACUNA VINCTA* (MONTAGU)

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ABSTRACT

A localized population expansion of Lacuna vincta *(Montagu) has caused a marked depletion of kelp populations near Newcastle Island, New Hampshire. As many as 277 snails per* Laminaria *plant were observed. The stipes and blades of* Laminaria *plants become riddled with holes (up to 12 holes/25 cm²) from* L. vincta; *eventually only residual holdfasts and stipes remain. A grazing rate of 0.326 cm² of* Laminaria saccharina *blades/ snail/day was recorded in the laboratory. Respiration studies indicate that* L. vincta *is an osmoconforming species with a salinity optimum of about 25‰. It is suggested that the population increase of* L. vincta *may have been initiated after a period of extensive rainfall, - i.e. reduced salinities.* Lacuna vincta *may be a major grazer of seaweeds in a variety of locations.*

While conducting subtidal studies of the benthic marine algae of New Hampshire we have observed extensive grazing of *Laminaria* populations by the prosobranch gastropod, *Lacuna vincta* (Montagu). The gastropod is a small (1.0-1.5 mm wide and 1.0-1.8 mm long) littorinid snail (Fig. 1) that is often found in limited numbers on kelps and other seaweeds along the northeast coast of North America (Miner, 1950). During 1972 we have observed a "population explosion" of *L. vincta* at Newcastle Island, New Hampshire (43° 04' 05" Latitude and 70° 42' 45" Longitude), and a marked depletion of *in situ* kelp beds. Subsequently we have seen continued destruction of kelp populations at Newcastle Island, as well as at adjoining open coastal and estuarine sites in Southern Maine and New Hampshire.

In June, 1972, we examined 64 randomly collected specimens of *Laminaria saccharina* and *L. digitata* within a 1000 m² area at Newcastle Island at 3 to 6 m below mean low water. All of the plants exhibited severe damage, for their fronds and stipes were riddled with round or ellipsoidal holes that were 3-10 mm in diameter (Fig. 2 and 3). As many as 12 holes per 25 cm² were found on many blades. The majority of the holes penetrated through the entire plant(s). In most cases the blades were more heavily grazed than other portions of the plants. The intercalary meristem, or the transitional zone between the blade and stipe, was rarely damaged. At sites with heavy grazing only residual holdfasts and stipes of *Laminaria* were present.
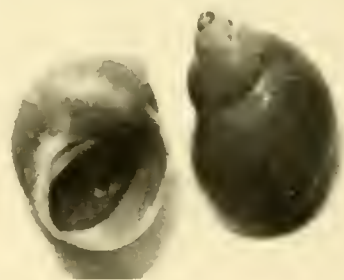
During July, 1972 we found as many as 277

FIG. 1. *Two New Hampshire specimens of* Lacuna vincta *(Montagu).* 30 X.

snails per *Laminaria saccharina* plant at Newcastle Island - at 3 to 6 m below mean low water. In the early part of the summer few snails were found on the understory vegetation beneath the kelp canopy. However, as the summer progressed a variety of economically important species such as *Chondrus crispus, Gigartina stellata* and *Rhodymenia palmata* (Mathieson, 1969) also showed extensive grazing by *Lacuna vincta.*

Kain (1971) and R. Waaland (personal communication to A.M.) also report abundant populations of *L. vincta* on seaweeds in Norway and Washington, U.S.A., respectively. Thus, *Lacuna* may be a major grazer of seaweeds in a variety of locations. Kain and Svendsen (1969) record extensive grazing by the gastropod *Patina pellucida* on *Laminaria hyperborea* in western Norway and Great Britain; they state that *P. pellucida* may cause considerable loss of plants due to weakening of the holdfast or damage to the frond or stipe. In Great Britain they observed that the animals initially settled on the frond and then migrated to the holdfast, where they created large cavities. Preliminary

observations indicate that *L. vincta* may show a similar pattern of attachment and migration on New England kelps. According to Kain (1971) O. Vahl (unpublished data) has found considerably higher densities of *L. vincta* than *P. pellucida* on *Laminaria hyperborea* populations in Norway, and the holes it makes are much deeper than those of *P. pellucida.*

Preliminary culture experiments were conducted in August and September, 1972, in order to determine grazing rates of *L. vincta* on *Laminaria saccharina.* A small section of frond (25 cm^2) was placed in a crystallizing dish with 200 ml of filtered sea water (30 ‰) and 10 snails. The dishes were incubated at 300-400 foot-candles and at 10°C in a Sherer-Gillete Incubator. After 5 days the fronds were remeasured and the consumption of plant material was determined. An average grazing rate of 0.326 cm^2/snail/day was recorded. It should be emphasized that this is an approximation and further studies should be conducted to determine the effects of differential temperatures, salinities and plant materials on grazing.

Respiration rates of *L. vincta* at 10C and in three different salinities (20, 25, and 30 ‰) were measured in a Gilson Differential Respirometer (Model GRP-14), according to the methods outlined by Mathieson and Burns (1971). The temperature was maintained at about 0.1 C; it was the same as the ambient temperature when the snails were collected. Two flasks containing ten snails per flask were run at each of the test salinities. The respiration rates for the three salinities were recorded simultaneously in the same instrument. Figure 4 illustrates the results of the

FIG. 2. *A* Laminaria saccharina *plant showing severe damage from* L. vincta.

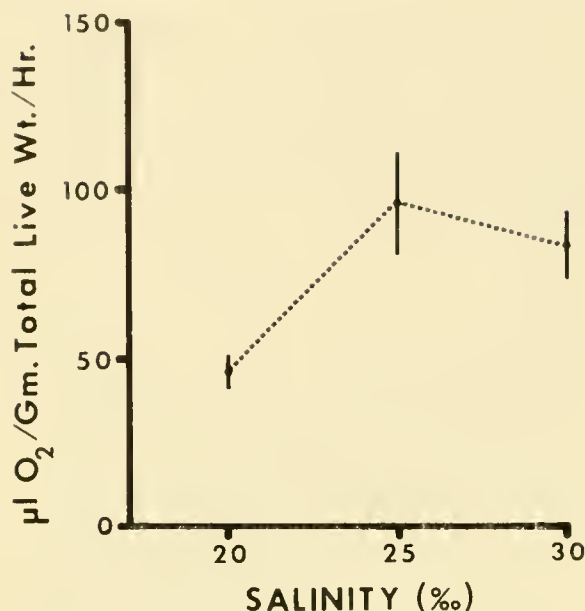FIG. 3. *A stipe of* Laminaria saccharina *riddled by* L. vincta.

FIG. 4. *Respiration of* L. vincta *at 10C and in three different salinities.*

experiment. The lowest respiration rates were found at 20 ‰ and the highest was recorded at 25 ‰. The results suggest that *L. vincta* is an osmoconforming species with a salinity optimum of about 25‰.

In conclusion the extensive grazing of seaweeds at Newcastle Island, New Hampshire, appears to be directly associated with a localized population expansion of *L. vincta.* Our laboratory studies confirm the field observations that *L. vincta* was the causative organism. It should be emphasized that previous seasonal investigations at Newcastle Island (Mathieson, *et al.,* in press) have never shown extensive seaweed grazing by *L. vincta.* It is suggested that the population increase of *Lacuna* may have been associated with a spring season

(1972) with abnormally high rainfall, and thus periods of reduced salinities. Our respiration studies confirm the tolerance of *L. vincta* to low salinity regimes recorded prior to the period of severe grazing. It is apparent that further studies of gastropod/algal grazing should be conducted in the New England area.

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ROLE OF THE INCURRENT SIPHONAL VALVE IN THE SURF CLAM, *SPISULA SOLIDISSIMA* (MACTRIDAE)

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ABSTRACT

Observations of the behavior of the surf clam, Spisula solidissima *have indicated that debris such as sand may be entrapped in the incurrent siphon cavity temporarily before being expelled by a jet of water from the mantle cavity. The morphology and responses of the incurrent siphonal valve are well suited for mediation of a possible sand storage behavior. The incurrent siphonal valve is positioned across the opening between the incurrent siphon cavity and the mantle cavity, hence can, when extended, separate the two cavities. Extension (closing) of the valve occurs in response to mild tactile stimulation of the siphons. Contraction (opening) of the valve only occurs in response to strong tactile stimulation. The responses of the incurrent siphonal valve and the adductor muscles (which cause the jet of water) are co-ordinated in such a way that during the cleaning reflex the valve is open when shell valve adduction occurs thus allowing free passage of water out of the mantle cavity.*

While studying the neural control of siphon withdrawal in the surf clam, *Spisula solidissima* (Dillwyn), it was necessary to examine siphonal behavior in detail, (Prior, 1972).

The siphons of *Spisula* respond in a progressively more complex fashion as the intensity of tactile stimulation of the siphonal tentacles (papillae) is increased. In response to touching a single siphonal tentacle with a glass stylus the siphon apertures close (a local reflex mediated by peripherally located neurons). As the intensity of tactile stimulation is increased (touching several tentacles or the inner wall of the incurrent siphon) the siphon musculature responds with progressively greater contractions until finally, the siphon retractor muscles respond, withdrawing the siphons into the mantle cavity.

Often in response to gentle tactile stimulation, such as touching several tentacles, siphon closure is rapidly followed by contraction of the adductor muscles, which by drawing the shell valves together, cause the expulsion of a jet of water out the incurrent siphon (the excurrent siphon remains closed). This "Cleaning reflex" occurs regularly and serves to eliminate feces and debris, such as sand, drawn in through the incurrent siphon.

In one of the very few reports on observations of *Spisula* in their natural habitat, Jacobson (1972) describes the siphonal behavior of young individuals in a sandy intertidal zone. During the interwave periods the clams kept their siphons open. But in response to each sand laden wave, the siphons were observed to close rapidly. The siphons remained closed until the sand settled and was no longer being roiled about. Jacobson further noted that at somewhat regular intervals a small jet of water, laden with sand grains, was ejected from the incurrent siphon (the cleaning reflex). Jacobson points out that this cleaning reflex is of adaptive value in that it minimizes the build up of sand in the mantle cavity. Furthermore, he suggests that sand is probably stored briefly in the incurrent siphon before being expelled, as a further means of preventing accumulation in the mantle cavity.

The present report describes the anatomy and general responses of a muscular flap of tissue (incurrent siphonal valve) in *Spisula* that is positioned across the opening of the incurrent
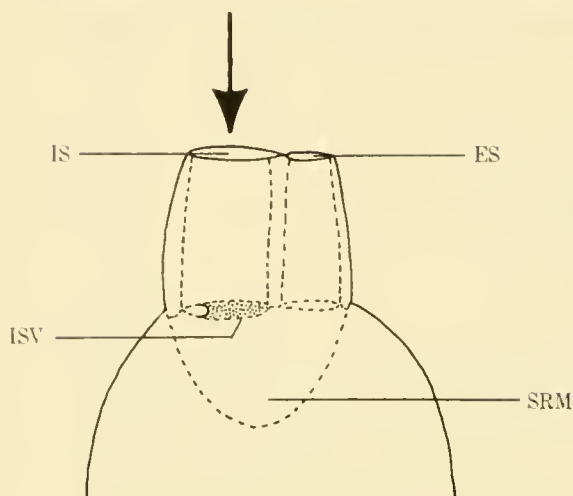
FIG. 1. *A schematic of the posterior end of a clam with the incurrent siphon* **(IS)** *and excurrent siphon* **(ES)** *in an extended position. One of the siphon retractor muscles* **(SRM)**, *which adhere to the inner surface of the shell valves, is indicated. The incurrent siphonal valve* **(ISV; stipled)** *is shown partially extended across the opening between the siphon cavity and the mantle cavity. The incurrent siphonal valve is attached to the lateral walls of the incurrent siphon and to the septum between the incurrent and excurrent siphons.*

FIG. 2. *This is an illustration of the incurrent siphonal valve* **(ISV)** *as seen by looking into the external opening of the incurrent siphon (see arrow in Figure 1.). The* **ISV** *(stipled area) is composed of a pair of distinct valve muscle bundles* **(VMB)** *and diffuse muscle fibers that are spread throughout the valve sandwiched between two epithelial layers.*

siphon leading to the mantle cavity (a detailed report of the electrophysiological properties of the muscle fibers will appear separately; Prior, 1974). This valve is attached to the base of the muscular wall separating the two siphonal cavities and to the lateral walls of the incurrent siphon cavity (Fig. 1). The valve protrudes across (partially occluding) the inner incurrent siphon opening. The incurrent siphonal valve is composed of two bundles of smooth muscle fibers and a diffuse array of muscle fibers sandwiched between two layers of epithelium (Fig. 2).

The activity of the incurrent siphonal valve was examined by removing from the animal the entire siphonal apparatus (mantle musculature, siphon retractor muscles and intact visceral ganglion) to a wax dish of cold (10° C) sea water. With this sort of arrangement the tentacles and inner walls of the siphons could be

tactily stimulated while observations were being made on the activity of the siphonal valve.

In response to gentle tactile stimulation of siphonal tentacles the dispersed muscle fibers of the valve contract, resulting in extension of the flap across the incurrent siphon cavity. This movement of the valve effectively separates the incurrent siphon cavity from the mantle cavity.

In response to stronger tactile stimulation (e.g. poking the siphon wall with a stylus) the paired muscle bundles of the valve contract in synchrony. The contraction of these muscle bundles causes withdrawal of the valve; thus opening the passage between the siphon and mantle cavities.

It is interesting to note that in the intact animal, the cleaning reflex requires contraction of the incurrent siphonal valve to allow egress of the jet of water from the mantle cavity. Equally pertinent is the fact that the neurons controlling the posterior adductor muscle (the contraction of which is involved in the expulsion of water from the mantle cavity) are activated *only* by strong tactile stimulation (Mellon, 1967; Mellon and Prior, 1970). The

activity of these motoneurons (hence the posterior adductor muscle) is inhibited by weak tactile stimulation of the siphons. Therefore, a correlation exists between the responses of the motoneurons that activate the adductor muscle (involved in the explusion of water in the cleaning response) and the responses of the siphonal valve muscle which must be open to allow the exit of water.

The responses of the incurrent siphonal valve are in concert with the responses of the adductor muscle, both contracting in response to strong tactile stimulation.

On the basis of the foregoing observations, I suggest that the incurrent siphonal valve might temporarily entrap sand particles, thus preventing their entrance into the mantle cavity.

The siphonal valve could respond to sand grains falling on the siphons (presumably a weak tactile stimulus) by extending across the incurrent siphon cavity, entrapping the sand within the cavity. A subsequent contraction of the adductor muscles, synchronized with contraction (opening) of the siphonal valve muscle bundles, would expel a jet of water and the previously entrapped sand; the cleaning reflex.

Thus, the incurrent siphonal valve seems well suited for mediation of the "sand storage" suggested by Jacobson on the basis of behavioral observations.

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BOOK REVIEW

OYSTERS (TREATISE ON INVERTEBRATE PALEONTOLOGY). By H. B. Stenzel. 1971. Part N, Bivalvia, vol. 3, pp. 953-1224. 153 pls. in text. Geological Society of America, P. O. Box 1719, Boulder, Colo. 80302.

This excellent and well-illustrated systematic treatment of the subfamily Ostreina appeared three years ago but is still deserving of a review. Nearly half of the volume is a splendid treatment of the anatomy, distribution, ecology and phylogeny of the oysters. New genera and subgenera are proposed, including *Hyotissa* for *Mytilus hyotis* Linné, and *Neopycnodonte* for *Ostrea coehlear Poli.* Our Caribbean Coon Oyster, formerly *Ostrea frons* Linné, is now in the genus *Lopha* Röding and the subfamily Lophinae. The volume contains an index and errata and revisions to the earlier two bivalve volumes 1 and 2 of Part N.

R. Tucker Abbott
Delaware Museum of Natural History

SECOND LOCALITY RECORD FOR *MESODON LEATHERWOODI* PRATT

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Mesodon leatherwoodi Pratt was recently described from specimens collected at a single locality in western Travis County, Texas (Pratt, 1971). It is of interest to report the occurrence of *M. leatherwoodi* in the Pedernales Falls State Park, Blanco County, Texas which is approximately 13 miles upstream from the type locality. Four specimens were found near the Pedernales Falls within 1 m of each other at the base of a large rock on August 6, 1972. The collection site was above flood debris along the river suggesting that the snails were from the general area of the Falls, although, the shells may have been washed down from the oak-juniper community higher on the river bank.

The specimens have been deposited in the collection of the Fort Worth Museum of Science and History (catalog number 94V-3101). W. L. Pratt verified the identification of the specimens.

LITERATURE CITED

Pratt, W. Lloyd. 1971. *Mesodon leatherwoodi*, a new land snail from central Texas. The Veliger **13** (4): 342-343; 1 pl.

DEATH NOTICE

We regret to announce the death of John Quincy Burch, at Seal Beach, California, on August 7, 1974, at age 80. An obituary is planned for a future number of The Nautilus. Further information is found on page 220 of *American Malacologists*.

NEWS

Research on an index patterned after C. D. Sherborn's INDEX ANIMALIUM is underway at the National Museum of Natural History, Washington, D. C. 20560, U.S.A. The coverage is Mollusca only, and plans are to include original references for names of species and subsequent references to publications including illustrations. The period of chronological coverage begins in 1850, where Sherborn ended, and continues through 1870 to provide an overlap with the ZOOLOGICAL RECORD.

Persons having knowledge of or access to obscure pertinent references are invited to correspond with the compiler, Florence A. Ruhoff, Department of Invertebrate Zoology, Mollusks.

AMERICAN MALACOLOGISTS
1975 Supplement

The managing editorship and main office of the national register of amateur and professional malacologists have now been entirely transferred to Dr. R. Tucker Abbott, P. O. Box 4208, Greenville, Delaware, 19807. All correspondence, listings, and orders should be sent to the new address.

A supplement for 1975 is now being prepared and will be ready for mailing in early spring. The cost will be only $1.00, and it will contain address changes and a listing of the names, address and interests of new registrants. A special discount of 20% is now offered on the purchase of the 1974 hardbound, 494-page volume to those who send in for a free application form. The new reduced price is $10.00, plus 50 cents for postage and handling.

American Malacologists has proved to be very useful and interesting book for all those who correspond with other collectors or those who do research on the history of malacology.

BOOK REVIEW

THE SHELL MAKERS — Introducing Mollusks *By G. Alan Solem. xii + 289 pp., 136 figures (42 in color). 1974. John Wiley and Sons, Inc., 605 Third Avenue, New York, N. Y. 10016. Hardback, $9.95.*

There has long been a need for a good account of the evolutionary development of the Mollusca, and this book adequately fills that niche. There is a refreshingly large amount of information new to the zoological reader, much of which is illustrated by excellent drawings. The author is probably the world's leading expert on land mollusca and has the distinction of having pioneered in the use of the scanning electron microscope for studying mollusks.

The photographs and interpretations of the ultra-microscopic features of the radulae and shell sculpturing are significant advances in the field of mollusks. Other valuable parts of the book contain an account of the evolution of the shell-less pulmonates and a discussion of the adaptive thresholds in the development of the various classes of mollusks.

The book is well-written and not without humor. Some of the chapter headings are "On Becoming Sluggish", "The Slow and the Quick" (referring to chitons and cephalopods), and "To Scrape a Living." I heartily recommend this book, not only as background (and "foreground") reading for college courses in malacology and evolutionary biology, but also to amateur conchologists who admire shell makers.

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INFORMATION FOR SUBSCRIBERS

The *annual subscription* rate for *The Nautilus* is $7.00 for individuals and $12.00 for institutions (domestic or foreign). Subscriptions may begin in January. Send check or money order to "The Nautilus" to Mrs. Horace B. Baker, Business Manager, 11 Chelten Road, Havertown, Pa. 19083.

Back issues from volume 72 to date are obtainable from the Business Manager. Volumes 1 through 71 (if available) may be obtained in reprint or original form from Kraus Reprint Co., Route 100, Millwood, New York 10546.

Advertising rates may be obtained from the Business Manager or Editor.

CONTRIBUTORS

Manuscripts: Authors are requested to follow the recommendations of the *Style Manual for Biological Journals*, which may be purchased from the American Institute of Biological Sciences, 2000 "P" Street, N.W. Washington, D.C. 20036. Manuscripts should be typewritten and doublespaced; original and one copy are required, to facilitate reviews. Tables, numbered in arabic, should be on separate pages, with the title at the top. Legends to photographs should be typed on separate sheets. Explanatory terms and symbols within a drawing should be neatly printed, or they may be pencilled in on a translucent overlay, so that the printer may set them in 8 pt. type. There is a charge of 50 cents per word for this extra service. All authors or their institutions will be charged 50 cents per line of tabular material and taxonomic keys. The publishers reserve the right, seldom exercised, to charge $32 per printed page.

An *abstract* should accompany each paper.

Reprints and covers are available at cost to authors. When proof is returned to authors, information about ordering reprints will be given. They are obtained from the Economy Printing Co., Inc., R. D. 3, Box 169, Easton, Maryland 21601.

MOLLUSK VOUCHER SPECIMENS

It is becoming increasingly important for future research purposes that an identified sampling of species mentioned in publications be deposited in a permanent, accessible museum specializing in mollusks. This is particularly true of mollusks used in physiological, medical, parasitological, ecological, and experimental projects.

The Delaware Museum of Natural History has extensive, modern facilities and equipment for the housing and curating of voucher specimens. Material should be accompanied by the identification, locality data and its bibliographic reference. There is no charge for this permanent curating service, and catalog numbers, if desired, will be sent t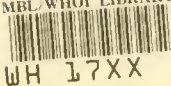o authors prior to publication.