

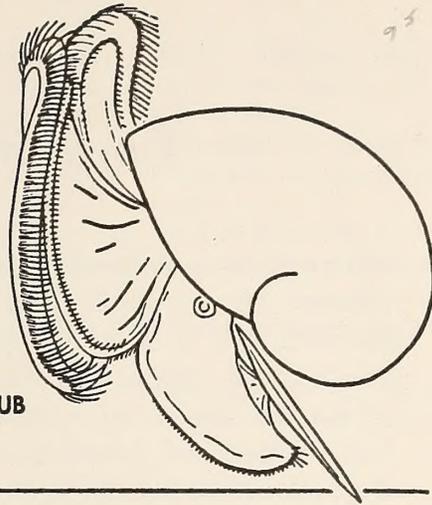


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THE VELIGER

A Quarterly published by
NORTHERN CALIFORNIA MALACOOLOGICAL CLUB
Berkeley, California



Volume 6

July 1, 1963 to April 1, 1964

Foreword to Volume Six

ANOTHER IMPORTANT STEP was taken with the beginning of the present volume: the transition from typewritten to typeset copy. Many new problems had to be solved and new skills had to be acquired. And as before, many individuals generously contributed their time and their advice. We are again indebted to Earl Gustafson, Charles Peckham, Louis Rengel and John Schoen of the University of California Printing Department for sharing with us their know-how and their experience. Mrs. Emily Reid, Staff Artist of the Department of Zoology, has continued to donate unstintingly of her time and her talent. Mrs. Jean Cate proof read every galley proof at least twice, both before and after the corrections were made.

New also is the fact that we have, at last, been able to send galley proofs to authors, except to those living overseas.

Mrs. Mary Larson has assumed the task of compiling a continuous cumulative index, relieving Dr. Phyllis Kutsky, who, moving out of this area, could no longer continue with this painstaking, demanding and time-consuming task.

Finally, the California Arts and Engravings Company of Berkeley has taken on the task of producing the offset masters for our color plates, the last color plate in the current volume (plate 18) being the first of their product.

To all persons, the few named and the many more unnamed, who have contributed in one way or another to the continued growth of our journal, go the warmest thanks of

Your Editor.

Berkeley, April 1, 1964.

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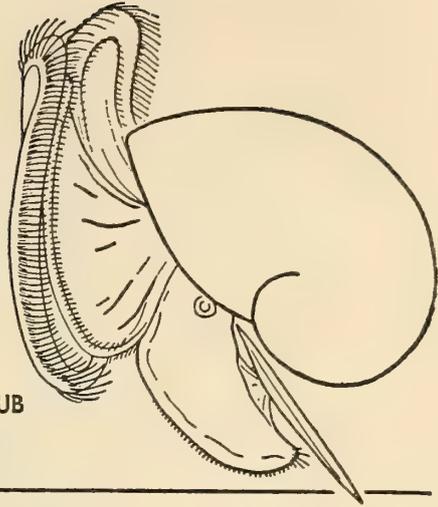
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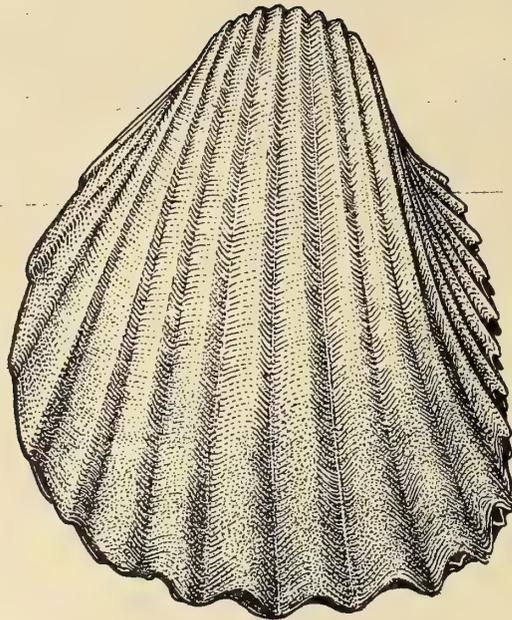
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Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION**, Subdivision, **SECTION**,
SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).
New Taxa

Food Recognition and Predation on Opisthobranchs by *Navanax inermis* (Gastropoda: Opisthobranchia)

BY

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Seattle 5, Washington

(Plate 1; 1 Text figure)

An adequate description of the ecological properties of a species should include its trophic relationships in terms of recognition of both predators and potential prey, and the quantitative and qualitative results of such behavior. Among higher organisms, gastropods offer many advantages in understanding these phenomena: they possess a variety of sensory mechanisms capable of detecting specific chemical stimuli (KOHNS, 1961), and many species are characterized by a dietary eclecticism (GRAHAM, 1955). The present paper describes the fundamental features of predation by the cephalaspidian *Navanax inermis* COOPER, 1862, on other opisthobranchs, especially the method of prey detection, and potential defensive adaptations of these prey species.

The work was done during the tenure of a Sverdrup Postdoctoral Fellowship at Scripps Institution of Oceanography, La Jolla, California, and probably would not have been completed without the taxonomic counsel of J. R. Lance, who identified most of the opisthobranchs. Thanks are also due R. Stohler, R. Rosenblatt, and T. S. Park for identifications of the prosobranchs, fishes, and amphipods, respectively; J. Lythgoe, P. B. Taylor, R. Ford, and B. Harrison for collection of many of the nudibranchs used in the feeding experiments; and A. J. Kohn for critically reading the manuscript.

DISTRIBUTION OF *NAVANAX*

Navanax inermis, hereinafter referred to as *Navanax*, ranges from Monterey Bay at least to Ensenada, Baja California (MACGINITIE and MACGINITIE, 1949). In my experience maximum size (ca. 20 cm or 300 gm wet weight) and abundance are reached in shallow protected bays where *Navanax* occurs from the tidal zone to depths of 15 to 25 feet. Although such bays must be considered the "typical" habitat, small individuals (5 to 6 cm length, up to 8 gm wet weight) were found regularly on rocky intertidal areas where positioning of

boulders results in areas relatively protected from severe surf action and surge. These sites, however, do not appear able to support permanent populations because seasonal shoreward movements of sand alter the bottom topography by filling in protective depressions and crevices. The oceanic subtidal distribution is enigmatic. Scuba divers at the Scripps Institution of Oceanography have rarely, if ever, taken *Navanax* in depths of 30 to 120 feet in the vicinity of La Jolla, although diving frequently. On the other hand, R. Ford, on an initial dive off the Coronado Islands, found one individual at 80 feet, and W. D. Clarke (pers. comm.) has observed *Navanax* in numbers in 30 to 50 feet off Santa Barbara. *Navanax*, then, should be considered a potential predator of acceptable organisms inhabiting bays and some oceanic environments from the intertidal zone to a depth of about 100 feet, and also of any more oceanic organisms washed into these areas.

FEEDING BEHAVIOR

When *Navanax* makes contact with a suitable prey species it is swallowed whole, being sucked into *Navanax*'s mouth often along with much water and debris. The latter are subsequently expelled through grooved channels in the buccal apparatus while fleshy finger-like protuberances help retain the prey. A sequence of the capture and ingestion of *Hermisenda crassicornis* is shown in Plate 1, figures 1 and 2. The prey is simply digested without the aid of trituration, and its jaws, radulae, and shell, if any, are defecated unaltered. (Incidentally, this provides a good preparation of delicate nudibranch jaws and radulae.) The field diet was determined from such unaltered remains.

The chemosensory acuity of many gastropods permits them to recognize and then locate prey by distance chemoreception (STEHOUWER, 1952; BRAAMS & GEELLEN, 1953; KOHN, 1959; BLAKE, 1960; COOK, 1962).

KOHN (1961) has drawn a distinction between this type of behavior and contact chemoreception in which prey recognition is based on taste or gustation. The observations reported below suggest that, on the basis of present knowledge, *Navanax* is unique among gastropods in relying entirely on contact chemoreception to locate acceptable prey.

It has been known for some time that *Navanax* feeds on other opisthobranchs, especially *Bulla* and *Haminoea* (JOHNSON & SNOOK, 1927; MACGINITIE & MACGINITIE, 1949; RICKETTS & CALVIN, 1952). Therefore, to emulate natural conditions 3 to 4 cm of clean sand were placed in aquaria and water added to a depth of five to ten cm. A *Bulla*, or occasionally *Haminoea* or *Hermisenda* was then tediously guided around the central portions of the container, being forced to avoid the walls. Because the cephalic shield of a moving *Bulla* is almost invariably just under the sand surface, sand grains or other small debris are bound in mucus, passed dorsally and posteriorly and eventually form a hollow tunnel marking the animal's past movements. In quiet bays these mucus tunnels formed by *Bulla*, *Haminoea* and *Aglaja* are conspicuous features of undisturbed bottoms. Upon completion of the experimental mucus tunnel, a *Navanax* would be released and observed, and the results mapped as in text figure 1. When encountering the mucus trail *Navanax* deviates from its former course and immediately begins following the trail. Two organs, called by MARCUS (1961, p. 66) the "inner fold of head shield" are kept in contact with the mucus trail in such a fashion that one, and usually both, are over it. If one of these presumed chemoreceptors loses contact with the trail, the predator's movements are appropriately corrected. In this manner the spoor is followed accurately.

The *Bulla* by appropriate guidance can be forced to leave a trail, such as in text figure 1, in which after some meandering, it approaches to within 2-3 cm of an older portion of the trail. *Navanax*, released at the trail's beginning, invariably bypassed its intended prey while following its trail, although the prey was within a short distance. In repetitions of this simple experiment, none of 9 *Navanax* deviated from the mucus trail. In addition, *Navanax* was not seen to orient to water currents flowing over *Bulla* or *Haminoea*, although apparatus similar to that used by STEHOUWER (1952) and KOHN (1959) was tried. The conclusion seems warranted that prey is located only after direct contact, or contact with its mucus trail; distance chemoreception does not appear to operate in obtaining food.

Navanax does not orient to low ridges or depressions in its environment, but moves over these in haphazard manner, either when it is or is not tracking prey. Also,

only opisthobranch mucus appears capable of eliciting the tracking response since trails formed by the prosobranch gastropods *Olivella biplicata*, *Nassarius tegula*, and *Conus californicus* were not followed. Ability to distinguish opisthobranch from prosobranch mucus, or failure to respond to the latter, has an obvious selective advantage in that trails of both varieties characterize environments in which *Navanax* seeks prey. If, as demonstrated below, mainly opisthobranchs are devoured, tracking prosobranchs will increase energy expenditures and decrease food-getting efficiency.

Upon contact with a trail, *Navanax* is just as likely to turn away from the prey as toward it. If the trail is followed away from the prey, a characteristic "searching" behavior is observed at its end. Once contact is lost, *Navanax* swings its head back and forth in small arcs, and eventually may even turn itself around. Since an individual responds to its own mucus, as well as the mucus of other *Navanax* individuals, such behavior obscures the original trail so that it may be lost. The success of corrective behavior in this situation is low.

Finally, some comments should be made on the relationship of size and behavior. Small individuals (2-12 cm length) almost invariably would track suitable prey, and their behavior could be demonstrated predictably. However, larger *Navanax* at times unaccountably failed to respond to fresh *Bulla* mucus, suggesting the presence of an unrecognized age or size specific behavioral pattern (such as mating behavior) superimposed on the food-getting requirements.

FOOD IN NATURE

In nature, *Navanax* feeds on opisthobranchs, and to a lesser extent on a variety of other invertebrates and fishes as represented by identifiable hard parts in *Navanax* fecal pellets. The species list (Table 1) has not been quantified because diet depends on, among other things, prey availability, and such a quantification would only indicate the author's choice of sampling areas. It should be emphasized, though, that on a dry weight basis, opisthobranchs constituted more than 95% of all food eaten.

In Table 1, ten of the 29 species of natural prey are not opisthobranchs but of these, only 2 prosobranch gastropods, *Cystiscus pyriformis* and *Barleeia* sp., and one fish, were eaten frequently. Neither of these prosobranchs as discussed below, were swallowed voluntarily by *Navanax* in the laboratory, suggesting that they probably were eaten accidentally in the field. The opportunity for this to happen exists naturally since *Barleeia* and *Cystiscus* along with *Bulla* abound on mats of vegetation over which *Navanax* hunts. These snails are probably engulfed in the following manner. When *Navanax* first encounters a trail of acceptable mucus, they will often "taste" it, swallowing in the process some of the local



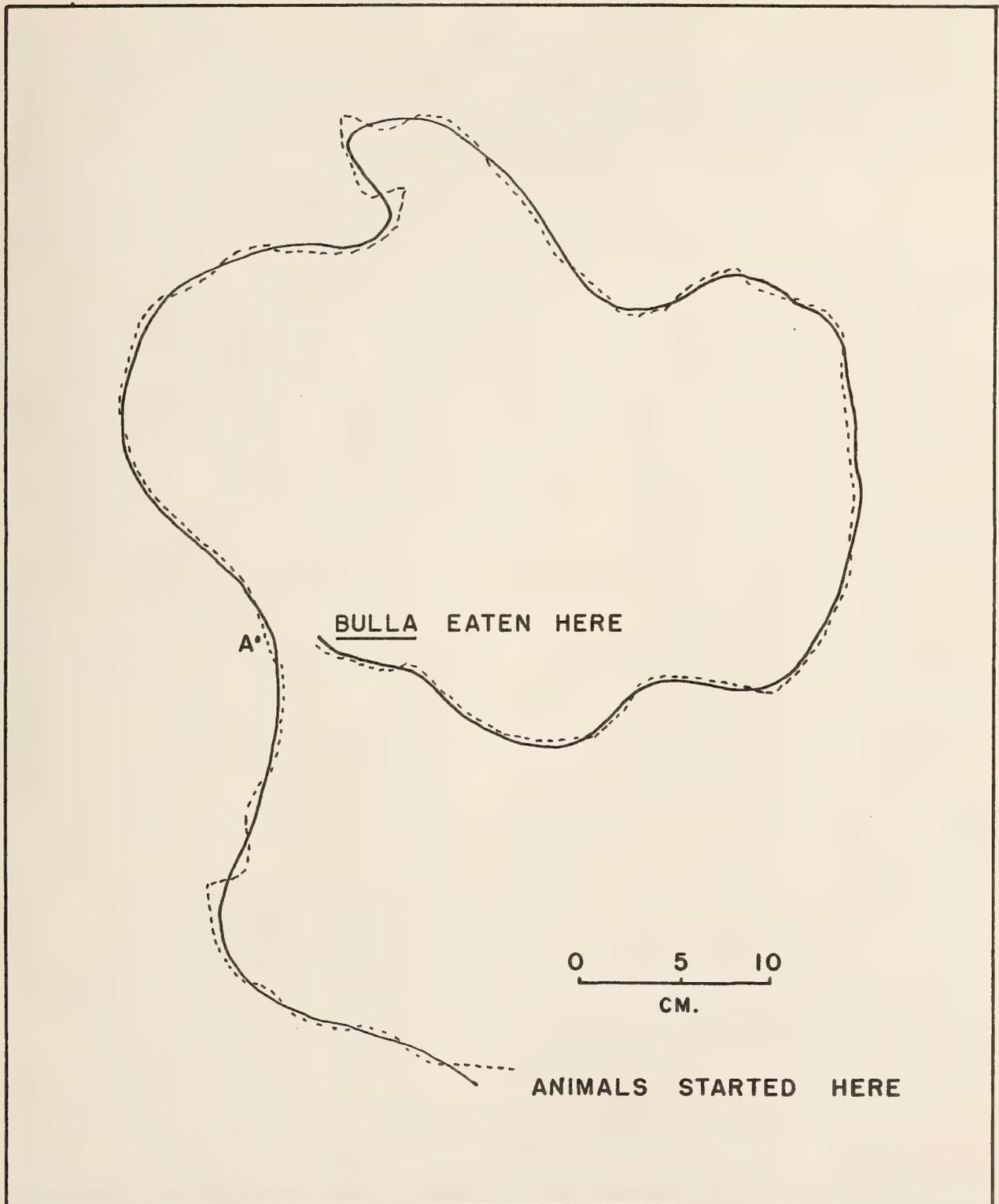
Figure 1



Figure 2

Navanax swallowing *Hermisenda crassicornis*.

Figure 1 indicates the initial writhing of certain prey species immediately after contact with *Navanax*. In Figure 2 the proboscis of *Navanax* is fully extended over the prey.



Text figure 1: A typical example of the ability of *Navanax* (-----) to follow the mucus-impregnated sand trail of *Bulla* (———). At point "A" the *Navanax*, although within two to three cm of its intended prey, will continue to follow the trail away from its prey.

Table 1

Tabulated observations on the field and laboratory diet of *Navanax*. In Column 1 the (*) indicates species eaten occasionally while (**) denotes prey species swallowed frequently. Columns 2, 3, and 4 report laboratory observations in which a variety of opisthobranchs were offered to *Navanax*. Columns 5 and 6 report data substantiating the division of some prey species into the categories "soft" and "hard" bodied.

	Field Diet	Laboratory Diet				Sample size 6
	occurrence 1	Number eaten 2	Number offered 3	% consumed 4	% water 5	
OPISTHOBRANCHIA						
Doridacea						
<i>Cadlina flavomaculata</i> MACFARLAND, 1905		2	2	100	70.3	1
<i>Cadlina marginata</i> MACFARLAND, 1905		0	3	0	81.3	2
<i>Glossodoris californiensis</i> BERGH, 1879		4	4	100	88.6	1
<i>Glossodoris macfarlandi</i> COCKERELL, 1902		1	4	25	89.6	1
<i>Rostanga pulchra</i> MACFARLAND, 1905		0	11	0	70.2	1
<i>Archidoris montereyensis</i> (COOPER, 1862)		0	1	0	85.5	3
<i>Anisodoris nobilis</i> (MACFARLAND, 1905)		0	2	0		
<i>Diaulula sandiegensis</i> (COOPER, 1862)		0	19	0	77.7	4
<i>Aegires albopunctatus</i> MACFARLAND, 1905		0	20	0	71.0	3
<i>Polycera atra</i> MACFARLAND, 1905	**	16	16	100	89.8	8
<i>Laila cockerelli</i> MACFARLAND, 1905		2	19	10.5	69.7	3
<i>Triopha carpenteri</i> (STEARNS, 1873)	*	4	4	100	91.1	1
<i>Triopha maculata</i> MACFARLAND, 1905	**	26	26	100	89.0	16
<i>Crimora coneja</i> MARCUS, 1961		2	2	100		
<i>Acanthodoris rhodoceras</i> COCKERELL & ELIOT, 1905	**	2	2	100	90.5	3
<i>Onchidoris hystericina</i> (BERGH, 1878)		0	4	0	74.6	1
<i>Hopkinsia rosacea</i> MACFARLAND, 1905		1	17	5.9	76.7	7
<i>Trapania velox</i> (COCKERELL, 1901)		1	1	100		
<i>Corambe pacifica</i> MACFARLAND & O'DONOGHUE, 1929		4	4	100		
<i>Dendrodoris albopunctata</i> (COOPER, 1863)	*	0	13	0	78.3	9
? <i>Thordisa</i>		0	10	0	78.9	1
unidentified mottled dorid		0	10	0	78.7	4
unidentified yellow dorid		0	2	0		
unidentified white dorid		0	1	0		
Dendronotacea						
<i>Tritonia festiva</i> (STEARNS, 1873)		1	1	100		
<i>Dendronotus frondosus</i> (ASCANIUS, 1774)	*	6	6	100		
<i>Melibe leonina</i> (GOULD, 1853)		2	2	100		
Arminacea						
<i>Antiopella barbarensis</i> (COOPER, 1863)		4	4	100	93.2	2
<i>Dirona albolineata</i> COCKERELL & ELIOT, 1905		2	3	66.7		
<i>Dirona picta</i> COCKERELL & ELIOT, 1905	**	8	8	100	92.1	3
Eolidacea						
<i>Flabellina iodinea</i> (COOPER, 1862)		1	22	4.5	90.3	8
<i>Capellinia rustya</i> MARCUS, 1961		17	17	100		
near <i>Caltriona</i>	*					
<i>Hermisenda crassicornis</i> (ESCHSCHOLTZ, 1831)	**	73	73	100	90.3	15
<i>Phidiana pugnax</i> LANCE, 1962		3	3	100		
<i>Tergipes</i> sp.		1	1	100		
<i>Facelina</i> sp.		1	1	100		
<i>Aeolidia papillosa</i> (LINNAEUS, 1761)		2	2	100		
<i>Spurilla chromosoma</i> (COCKERELL & ELIOT, 1905)	*					
unidentified eolid, Point Loma		1	1	100		

Table 1
[CONTINUED]

	Field Diet	Laboratory Diet				Sample size 6
	occurrence 1	Number eaten 2	Number offered 3	% consumed 4	% water 5	
Other OPISTHOBRANCHIA						
<i>Bulla gouldiana</i> PILSBRY, 1893	**	95	95	100		
<i>Haminoca virescens</i> (SOWERBY, 1833)	**	118	118	100		
<i>Aglaja</i> sp.	**	16	16	100		
<i>Navanax inermis</i> COOPER, 1862	**	13	13	100	89.0	27
<i>Chelidonura phocae</i> MARCUS, 1961		1	1	100		
red and white cephalaspidean		1	1	100		
<i>Aphysia californica</i> COOPER, 1863	*	2	2	100		
<i>Pleurobranchus californicus</i> DALL, 1900	*					
<i>Pleurobranchaea</i> sp.		0	6	0	93.7	2
<i>Acteon punctocaelatus</i> (CARPENTER, 1864)	*	1	13	7.7		
<i>Turbonilla</i> sp.	*					
<i>Retusa</i> sp.	*	1	3	33.3		
<i>Hermaeina smithi</i> MARCUS, 1961	*					
PROSOBRANCHIA						
<i>Barleeia</i> sp.	**					
<i>Cystiscus pyriformis</i> (CARPENTER, 1865)	**					
<i>Erato vitellina</i> HINDS, 1844	*					
<i>Mitrella carinata</i> (HINDS, 1844)	*					
ANNELIDA						
Nereididae	*					
ARTHROPODA						
Caprellidae	*					
Ischyroceridae	*					
Pleustidae	*					
<i>Spirontocaris</i> sp.	*					
VERTEBRATA						
Gobiidae	*					
<i>Porichthys myriaster</i> HUBBS & SCHULTZ, 1939	**					

substrate. These snails, then, may be taken during these "tastings," or during the actual ingestion of a selected prey species.

In collections of *Navanax* from the Flood Control Channel, Mission Bay, San Diego, *Barleeia*, an operculate snail, was often (as many as 17) found living in the fecal pellets, having survived the passage through *Navanax's* gut; rarely was a dead individual encountered. If *Barleeia* were offered to *Navanax* in the laboratory, they were not eaten, and, in fact, *Navanax* did not appear to recognize them as food. Therefore, *Barleeia* were counted and then rolled into strands of *Bulla* foot which slightly starved *Navanax* ingested readily. By varying the number of *Bulla* eaten prior to the swallowing of this package, the rate of passage through the gut could be altered.

Table 2 gives the percentage survival of *Barleeia* as a function of the time of passage, indicating this small snail readily survives the normal term of such treatment.

Navanax have also defecated up to 25 partially digested *Cystiscus* (a non-operculate prosobranch), which on the basis of laboratory observations do not appear to be eaten voluntarily either. Ten *Cystiscus* were confined for two days with each of 5 different *Navanax*, the equivalent of 20 *Cystiscus* days association with each predator. Only one was eaten, although the predators often went through the preliminary attack motions. On contact *Navanax* usually withdrew sharply, and on several occasions was seen to rapidly eject a previously swallowed *Cystiscus*. At the termination of this experiment all *Navanax* fed in the usual fashion on the nudibranchs *Antiopella* and

Hermisenda, suggesting that their feeding abilities were not impaired. Like the *Barleeia*, *Cystiscus*, and quite possibly all prosobranchs appearing in *Navanax* fecal pellets probably have been swallowed accidentally; nereid worms, amphipods, and shrimp probably enter in *Navanax*'s diet similarly.

Table 2

Percentage survival of *Barleeia* sp. after varying intervals of time in the digestive tract of *Navanax*

Hours in gut	Number used	% survival
18	113	100
22	56	96
40	64	77
70	26	46
94	2	50

The gobiid fish, and especially *Porichthys myriaster*, were found in fecal pellets occasionally from December, 1961 to February, 1962 but in 3 collections from the Flood Control Channel, 20 July to 4 August, 1962, *Porichthys* formed the bulk of the *Navanax* diet, with up to 13 fish, 20 to 30 mm in length, in each *Navanax*. These fish did not have the appearance of carrion; their eyes and photophores seemed fresh despite their recent exposure to *Navanax*'s digestive fluids. It is improbable that any item consumed in these numbers, simultaneously forming the bulk of the food ingested, is eaten accidentally. HUBBS (1920) mentions that *P. notatus*, a sluggish fish of retiring habits, migrates into shallow bays in spring where it buries itself just under the sand; in so doing, it or similar fishes become accessible to *Navanax*. The radical departure from the normal diet can not be explained at present, but it is the author's opinion that the piscivorous habit of *Navanax* is neither fortuitous behavior, nor represents the consumption of carrion. *Navanax* thus joins *Conus* (KOHN, 1956) as a piscivorous gastropod.

LABORATORY DIET

Navanax can be retained readily in the laboratory. Therefore, a wide variety of local opisthobranchs from shallow and deep water were offered to *Navanax* in plastic containers of about 500 cc capacity. Prey specimens were placed with small to medium sized (2 to 10 cm length) *Navanax*, and the ensuing events recorded. This is perhaps the most direct way of observing food preference, the judgment as "acceptable" or "not acceptable" being governed by whether a particular prey species was swallowed and then retained by the predator. These observations were made over a 6 to 7 month period, and involved 75 to 100 different *Navanax*; as such they probably represent a modal behavior for the species. The results, tabu-

lated by prey species in Table 1 and by higher categories in Table 3 confirm the field data that *Navanax* actively

Table 3

The breakdown by species within various higher categories of opisthobranchs, of those organisms either eaten or not eaten in the laboratory by *Navanax*

	Number eaten	Number not eaten
Eolidacea	8	1
Doridacea	9	15
Arminacea	3	0
Dendronotacea	3	0
Other opisthobranchs	7	3

preys on other opisthobranchs. This is then the first predator known to the author in which postlarval nudibranchs form an appreciable portion of the diet.

DEFENSIVE ADAPTATIONS OF THE OPISTHOBRANCH PREY

Table 3 indicates that not all opisthobranch groupings are eaten equally. Opisthobranchs have several defense mechanisms including nematocysts, acid secretions, other secretions, spicules, behavior, including swimming, and coloration (THOMPSON, 1960 a). These will now be examined with reference to those species consumed by *Navanax*. Where these can be shown to be an inefficient predation deterrent against *Navanax* one must assume that they prove effective against other kinds of predators.

Nematocysts: Although the possession of nematocysts by some eolids is well known (GROSVENOR, 1903; THOMPSON, 1960 a), they appear to be an ineffective deterrent. All eolids offered were readily consumed except *Flabellina* in which only 1 out of 22 specimens was eaten. In addition *Flabellina* proved to be the only eolid that could be maintained with *Navanax* in large, running water aquaria. Although *Flabellina* swims with ease, such evasive action would not prevent *Navanax* from consuming it if it were an "acceptable" food item. Its relative immunity must be laid to other causes, as yet unknown.

Acid Secretions: Only two "tectibranch" species (*Pleurobranchaea* sp., pH-1 and *Acteon punctocaelatus*, pH-3) and one nudibranch (unidentified mottled dorid, pH-1) were demonstrated (by touching their bodies with pH paper) to secrete acid, presumably similar to that described by THOMPSON & SLINN (1959). All the remaining species large enough to be tested proved to be neutral. None of the acid-secreters were eaten by *Navanax* in the laboratory, with one exception, and observations on the predator at the moment of prey contact, in which *Navanax* either withdraws abruptly or rolls its anterior end into

its body, suggest that acid secretion is extremely effective. *Navanax* has been observed to swallow, and then immediately regurgitate, *Acteon*, a shelled opisthobranch known to have toxin and acid secreting glands (FRETTER & GRAHAM, 1954). This delayed response supports THOMPSON'S (1960 b) belief that acid secretion is a discontinuous process, active release of acid being invoked only upon disturbance.

The similarity in behavior of *Navanax* on contact with both *Cystiscus* and *Acteon*, a known acid-secreter, suggests that the former also produces a noxious, probably acidic, secretion. However, both of these species are eaten by *Navanax* in nature (Table 1). It is likely that degree of prior stimulation of the prey, strength of the acid produced, or time since last feeding of the predator all influence the interaction. The presence of an external shell in *Acteon* and *Cystiscus* may also prove important, since this will increase the interval between contact by *Navanax* and release of acid, and hence increase the probability of being swallowed.

A single *Navanax* also defecated two shells of *Pleurobranchus californicus*. Little is known about this latter species, but by analogy with another member of the genus (THOMPSON & SLINN, 1959), it is apt to secrete strong acid. This observation suggests that the "trophic rogue" discussed below may not be limited in occurrence to the single specimen observed in the laboratory.

Spicules: THOMPSON (1960 a) has suggested that the spiculate texture of the dorid mantle may decrease the animal's attractiveness as fish food. Another explanation of the defensive value of these spicules is now proposed.

Navanax was offered 24 dorid species, which divide into 2 distinct groups on the basis of their dry weight to wet weight relationships (Table 1). These data were obtained by weighing a damp-dried animal (wet weight) and then oven drying that individual at 100°C ("dry" weight). Because dorid spicules are a hydrated amorphous calcareous gel (ODUM, 1951) a weight value comparable to that of other animals cannot be obtained at 100°C, and the present values are reported as "dry" weights. With two exceptions, all dorids in which about 90% of their wet weight is water were eaten, and conversely, those in which only 70-80% is water were not.

When *Navanax* feeds, the prey are sucked into the mouth. Larger prey individuals are ingested only if they can be molded to conform to a size *Navanax* can swallow. In this respect "soft" bodied dorids are similar to eolids, dendronotaceans, arminaceans, and some other opisthobranchs. On the other hand, spicules provide a certain body rigidity which prevents the "hard bodied" grouping from being treated in this manner. In addition, body rigidity, coupled with the broad foot of such dorids, makes them difficult to dislodge from flat surfaces, especially by a predator which can only ingest whole prey and possesses

no teeth, jaws, or similar structures.

However, the relationship between *Navanax* and its dorid prey is not this obvious. In the laboratory feeding experiments it was noted that the predators would often turn away, ignore, or make a minimal effort at swallowing "hard" bodied dorids even if the individual was small enough and had been placed on its dorsal surface. Such behavior, characterizing contact with *Aegires*, *Rostanga*, *Hopkinsia*, etc., suggests that other information is involved. The logical explanation is that some glandular secretion, distasteful or repellent to *Navanax*, has been emitted, and has been recognized by the predator. In this regard *Navanax* made no attempt to swallow most "hard" dorids, and the "soft" bodied nudibranchs *Flabellina* (90.3% water) and *Glossodoris macfarlandi* (89.6% water) enjoyed a certain immunity. The consumption of *Cadlina flavomaculata* (70.3% water) warrants further investigations.

Other Secretions: The heavily glandular surface epithelium and copious mucus secretions of many opisthobranchs are potential defense mechanisms (THOMPSON 1960 a), although their efficacy generally remains undemonstrated. An exception is the report of a seemingly volatile, neutral, poisonous secretion emitted along with much mucus by *Phyllidia varicosa* LAMARCK, 1801 (JOHANNES, 1963). The failure of *Navanax* to attack or eat *Flabellina* and *Glossodoris macfarlandi* suggests the presence of an effective non-acidic secretion although it must be noted that all non-spiculate, heavily glandular Arminacea and Dendronotacea species were eaten without hesitation.

Coloration and Behavior: Little information exists with respect to the efficiency of these categories of defense mechanism. *Navanax* has eyes, yet gives every appearance of being guided entirely by its chemosensory abilities and in fact seems oblivious to the striking coloration of some nudibranchs, consuming with equal relish the dull and the gaudy. Prey color is thus unlikely to effect this particular predator-prey interaction. Although most of the eolids wriggled violently in the presence of *Navanax*, (see Plate 1) such behavior seemed of little avail. In the field it may serve to dislodge them into currents capable of removing them from the immediate vicinity of this predator.

OTHER OBSERVATIONS

The general dominance of shelled opisthobranchs, especially *Bulla* and *Haminoea*, in *Navanax*'s diet indicates that these forms enjoy no special immunity. A shell may impart some protection when a particular prey individual is attacked by a *Navanax* too small to successfully engulf it. The rigidity due to the shell, then, functions in the same fashion and with similar results as the internal spicules.

The above records and observations probably indicate the usual course of, and limits of, predation by *Navanax* on other opisthobranchs. A single individual was discov-

ered, though, which did not respond in the usual fashion, and in its 15 days of captivity ate everything which, by the observer's prior experience, should have been avoided. This trophic rogue consumed the only individuals (Table 1) of *Flabellina*, *Acteon*, *Glossodoris macfarlandi*, and *Laila* observed to have been eaten. It appeared to be morphologically intact, and showed no signs of previous injury. Conceivably it represents an adaptational safety factor, insuring a third or fourth level consumer species, already characterized by a high degree of dietary selectivity, against a sudden disappearance of its preferred food species.

Finally, it should be emphasized that description of a species' normal diet, based solely on gut analyses from preserved material, without supplementary observations of living specimens, is not without its risks. Many species, including *Navanax*, capture prey by sucking or tearing at them, unavoidably engulfing some adventitious materials. The rôle of these in their predator's nutrition is unknown (though in the present case is known to be minimal). In addition, though gut analyses will be representative of what has been swallowed, they will not reflect accurately the species' preferred diet.

SUMMARY

The cephalaspidean *Navanax inermis* COOPER subsists primarily on other opisthobranchs which, after being selected, are swallowed whole. A smattering of small prosobranchs, shrimp, worms, and amphipods in its diet are probably engulfed accidentally. Fish, notably *Porichthys myriaster*, are also eaten, at times in such quantity that the act appears voluntary.

Navanax locates its prey by contact (not distance) chemoreception by following mucus-impregnated opisthobranch sand trails. It does not respond to prosobranch mucus. *Navanax* appears to be the first species known to prey heavily on postlarval nudibranchs, and only the second reported piscivorous gastropod.

Among potential nudibranch defense mechanisms, nematocysts, coloration, and behavior provide little protection from *Navanax*, whereas acid secretion especially, and other glandular secretions as well, may be extremely effective. Shelled forms enjoy no special immunity. The spicules of dorids, in making the nudibranch body more rigid, are an adequate defense mechanism, *Navanax* eats "soft" bodied (90% water) dorids such as *Polycera*, *Triopha* spp., *Acanthodoris*, *Trapania*, and *Glossodoris californiensis*, but not most "hard" bodied (70 to 80% water) ones. All but one eolid species, and all arminacean and dendronotacean species offered to *Navanax* in the laboratory were also consumed.

Literature Cited

- BLAKE, J. W.
1960. Oxygen consumption of bivalve prey and their attractiveness to the gastropod *Urosalpinx cinerea*. *Limn. Ocean.* 5: 273 - 280.
- BRAAMS, W. G., & H. F. M. GEELEN
1953. The preference of some nudibranchs for certain coelenterates. *Arch. Néerl. Zool.* 10: 241 - 262.
- COOK, EMILY F.
1962. A study of food choice of two opisthobranchs, *Rostanga pulchra* McFARLAND and *Archidoris montereyensis* (COOPER). *The Veliger* 4: 194 - 196; 4 textfigs.
- FRETTER, V., & A. GRAHAM.
1954. Observations on the opisthobranch mollusc *Acteon tornatilis* (L.) *Jour. Mar. Biol. Assoc. U. K.* 33: 565 to 585.
- GRAHAM, A.
1955. Molluscan diets. *Proc. Malac. Soc. London* 31: 144 - 159.
- GROSVENOR, G. H.
1903. On the nematocysts of eolids. *Proc. Roy. Soc. London* 72: 462 - 486.
- HUBBS, C. L.
1920. The bionomics of *Porichthys notatus*. *Am. Nat.* 54: 380 - 384.
- JOHANNES, R. E.
1963. A poison - secreting nudibranch (Mollusca: Opisthobranchia). *The Veliger* 5: 104 - 105.
- JOHNSON, M. E., & H. J. SNOOK
1927. Seashore animals of the Pacific Coast. The Macmillan Co., New York.
- KOHN, ALAN J.
1956. Piscivorous gastropods of the genus *Conus*. *Proc. Nat. Acad. Sci.* 42: 168 - 171.
1959. The ecology of *Conus* in Hawaii. *Ecol. Monogr.* 29: 47 - 90.
1961. Chemoreception in gastropod molluscs. *Am. Zool.* 1: 291 - 308.
- MACGINITIE, G. E., & NETTIE MACGINITIE
1949. Natural history of marine animals. McGraw-Hill Book Co., Inc. New York.
- MARCUS, ERNST
1961. Opisthobranch mollusks from California. *The Veliger* 3 (Supplement): 1 - 85; 10 pls.
- ODUM, H. T.
1951. Nudibranch spicules of amorphous calcium carbonate. *Science* 114: 395.
- RICKETTS, E. F., & J. CALVIN
1952. Between Pacific tides. Stanford Univ. Press, v - xiii; 3 - 502; 46 pls. Stanford, Calif.

STEHOUWER, H.

1952. The preference of the slug *Acolidia papillosa* (L.) for the sea anemone *Metridium senile* (L.). Arch. Néerl. Zool. 10: 161 - 170.

THOMPSON, T. E.

- 1960 a. Defensive adaptations in opisthobranchs. Jour. Mar. Biol. Assoc. U. K. 39: 123 - 134.

- 1960 b. Defensive acid-secretion in marine slugs and snails. The New Scientist 8: 414 - 416.

THOMPSON, T. E., & D. J. SLINN

1959. On the biology of the opisthobranch *Pleurobranchus membranaceus*. Jour. Mar. Biol. Assoc. U. K. 38: 507 to 524.

The Economics of *Dentalium*

BY

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(Plates 2, 3; 8 Text figures)

Dentalium shells, or tusk shells, served as money among the Indians of the United States and Canada, from Alaska to California and from the Pacific coast to the Dakota Territory (Fig. 1), until about the middle of the last century when contact with white traders resulted in cash, blankets and other trade goods replacing the *Dentalium* shells. There is nothing unusual in mollusc shells being used as currency among primitive peoples. Cowries were used over much of central Africa, the Indian Ocean, the Malay Archipelago and eastern Asia. Wampum of the aborigines of eastern Canada and the United States consisted of discs cut from mollusc shells (generally of bivalves) and the drilled-out columella of gastropod shells, threaded onto strings of sinew. The tribes of the southern half of California had similar strings of discs cut from *Saxidomus* and *Mytilus* shells and they also used *Olivella*. But the difference between all these other forms of shell money and *Dentalium* is that the raw material can be obtained intertidally whereas *Dentalium* shells are found washed ashore only infrequently and, as it transpires, damaged shells found on the beach had very little value in the Indians' eyes.

How did the Indians get their *Dentalium*, particularly as in my experience, the animal occurs only in relatively deep water? This problem has intrigued me for some years and I have made an intermittent and rather amateurish attempt to find the solution, though not with very great success. A number of the early accounts by anthropologists do not make zoological sense, while the more recent authorities appear to be slightly dubious about the

details of the whole thing. We are left with a most unsatisfactory state of affairs, and I have written what I have managed to find out so far, incomplete though it is, in the hope that someone will clear up the outstanding difficulties for me.

THE *DENTALIUM* OF THE INDIANS

Only three species of *Dentalium* appear to have been in use as money:

Dentalium pretiosum SOWERBY, 1860 (also referred to as *D. pretiosus* NUTTALL and *D. indianorum*). This is the only species that was ever in common use as currency among the north-western tribes. However, since species of *Dentalium* are difficult to identify, some of the earlier records refer, probably erroneously, to *D. entalis* LINNAEUS. BAIRD (1864) claimed that there was no material difference between north Pacific and north Atlantic species of *Dentalium* and referred them all to *D. entalis*, but this view has not been sustained and eleven species of *Dentalium*, one of *Siphonodentalium* and even of *Cadulus* are now recognized from the Pacific coast of north America from Alaska to Mexico (DALL, 1921). WHYMPER (1868) referred to the use of *D. entalis* by Indians at Fort Yukon in Alaska in 1867, but this is evidently another example of the failure to recognize the distinctness of the Pacific species.

Dentalium neohexagonum PILSBRY & SHARP, 1897 (also referred to as *D. hexagonum*). Strings of *Dentalium* found in old graves excavated on San Miguel Island (off the coast of southern California) and at San Luis



Figure 1: Regions of the United States and Canada in which *Dentalium* shells were formerly in use as currency and ornaments.

Obispo, California, include this species as well as *D. pretiosum* (STEARNS 1889). This appears to be the only recorded use of *D. neohexagonum*.

Dentalium entalis LINNAEUS (also referred to as *Entalis vulgaris*). This is the common north Atlantic species (HENDERSON, 1920); it does not occur in the Pacific and was never collected by the Indians. Early white traders among the Hidatsa and Gros Ventre Indians, which by 1850 inhabited eastern Montana and the northwestern part of the Dakota Territory, discovered *Dentalium* shells to be so highly prized by the Indians that they found it advisable to obtain supplies of shells for trading purposes. The shells used by the traders were imported from the east coast and were those of *D. entalis*. They were eventually introduced in such numbers that the currency became debased. STEARNS (1889) records that in 1866, "ten of these (imported) shells of inferior size, costing the traders only a cent apiece, would buy a superior buffalo robe," formerly, however, "only two or three of the same quality were paid for a robe." STEARNS was of the opinion that a great many of the *Dentalium* in circulation "in recent years" (i.e. before 1889) were of the north Atlantic species. Indeed, the tribes of the upper Missouri and Yellowstone rivers to whom STEARNS refers, were under the impression that all *Dentalium* shells came from the Great Lakes or the Atlantic coast and called them "Iroquois shells," though this may be a corruption of the Chinook "hyaqua" by which the currency was generally known throughout the area of its use. The Hidatsa and Gros Ventre Indians were members of the Salish linguistic group which extended to the shores of the Pacific, and there seems little doubt that the original trade routes for the shells were from the west.

THE NATURAL OCCURRENCE OF *DENTALIUM*

Dentalium is a scaphopod mollusc that lives partly buried in muddy sand below tide level and often at a considerable depth. The shell is conical and open at both ends. The reduced head and the conical foot can be protruded from the wider end which is buried, the mouth surrounded by extensible capitula for feeding, the foot with its lateral lobes for burrowing (MORTON, 1959). A respiratory current of water is pumped in and out of the hole at the narrower end of the shell which projects slightly about the surface of the substratum (YONGE, 1937).

Of the three species of *Dentalium* (Fig. 2) in use in North America as currency, *D. entalis* was imported by white traders who presumably dredged it off the New England coast; it need concern us no further.

Dentalium neohexagonum occurs off the coast of central and southern California, Mexico and central America

from Monterey to Guacomayo (DALL, 1921). Off Monterey it is abundant and occurs in sand at depths between 9 and 40 fms (KEEN, 1937; SMITH & GORDON, 1948). According to Stearns (1889) it is as common at San Diego as *D. pretiosum* is in Puget Sound. This species and *Cadulus fusiformis* PILSBRY & SHARP, 1898 which seems never to have been used by Indians, are the only two common scaphopods off the Californian coast and neither occurs in water shallower than nine or ten fathoms. *Dentalium rectius* CARPENTER 1864, which is also reasonably common off Monterey, is a deep-water form and has not been found in less than 35 fms of water (SMITH & GORDON, 1948).

Dentalium pretiosum occurs from Alaska to San Diego (DALL, 1921, KEEN, 1937), but is rare in the southern half of its range (SMITH & GORDON, 1948). The southern form of this species differs from that in Puget Sound and that in circulation among the Indians, in that it is more curved, longer, narrower and altogether more fragile (SMITH & GORDON, 1948). At Monterey, this species is not usually found in less than 20 fathoms, although further north it may occur in shallower water. LORD (1864) records that in some sheltered bays on the west coast of Vancouver Island, it occurs in as little as 5 fathoms water, and it is general experience that cold-water, arctic species tend to live in deeper and hence colder water in the more southerly parts of their range (EKMAN, 1953). This is true of *D. pretiosum* on the Pacific coast and also of *D. entalis* which is the common shallow water species of the New England coast north of Cape Cod, but occurs on the continental slope at considerably greater depth off southern New England and the Virginia Capes (HENDERSON, 1920).

JOHNSON & SNOOK'S (1927) claim that *Dentalium* shells are "frequently" to be found on the shore between tide marks, and ROGERS' (1908) remark, apropos the Indians, that "the industrious beachcomber might soon become a man of means" appear to be exaggerated. *Dentalium* lives in fine, muddy sand, a deposit which is only found in relatively undisturbed waters. When the mollusc dies, the shell remains embedded in the sand and only the most exceptional changes in the water currents or uncommonly severe storms wash it ashore. In any case, such shells would have been of slight use to the Indians; only perfect shells achieved a high price and those few washed ashore are damaged and have lost their lustre as a result of wave-pounding and grinding. QUIGGIN'S (1949) comment that the live shells which have to be dredged are better coloured than dead shells which are washed ashore, is, of course, mistaken. *Dentalium* shells are white and in any case have the same color when in use as currency whether they had been collected alive or dead.



Figure 2: Distribution of *Dentalium pretiosum*, *D. neohexagonum*, and *D. entalis* off the American coasts.

THE COLLECTION OF *DENTALIUM*

Almost all the *Dentalium* in circulation appear to have been collected by the Nootka Indians (Fig. 3) of Vancouver Island (LORD, 1864; JENNESS, 1934), where the animals are accessible in relatively shallow water. Two sites where *Dentalium* could be collected were known to, and used by the Indians. These were both on the west side of Vancouver Island, one at Cahquos (Fig. 4), north-west of Tachu Point, and the other in Barkley Sound. The shells are also said to be washed ashore on Long Beach near Ucluetet, also in Nootka territory, and the Haida and Oregon Indians claim to have collected some

empty shells on their beaches (DRUCKER, 1951). Considering the very large number of *Dentalium* in circulation in north-western America, and the relative scarcity and poor quality of shells that could be found on the shore, it is clear that the *Dentalium* fisheries on Vancouver Island must have been effectively and intensively exploited over a long period of time.

Not all the Nootkan tribes fished for *Dentalium*. Use of the northern *Dentalium* grounds at Cahquos was reserved for certain chiefs of only the Chickliset, Kyoquot, Ehetisat and Neuchatelet Indians (Fig. 4), the four most northerly of the Nootkan groups. Of these, the chief of the Olaktcieth, a Neuchatelet tribe, appears to have been

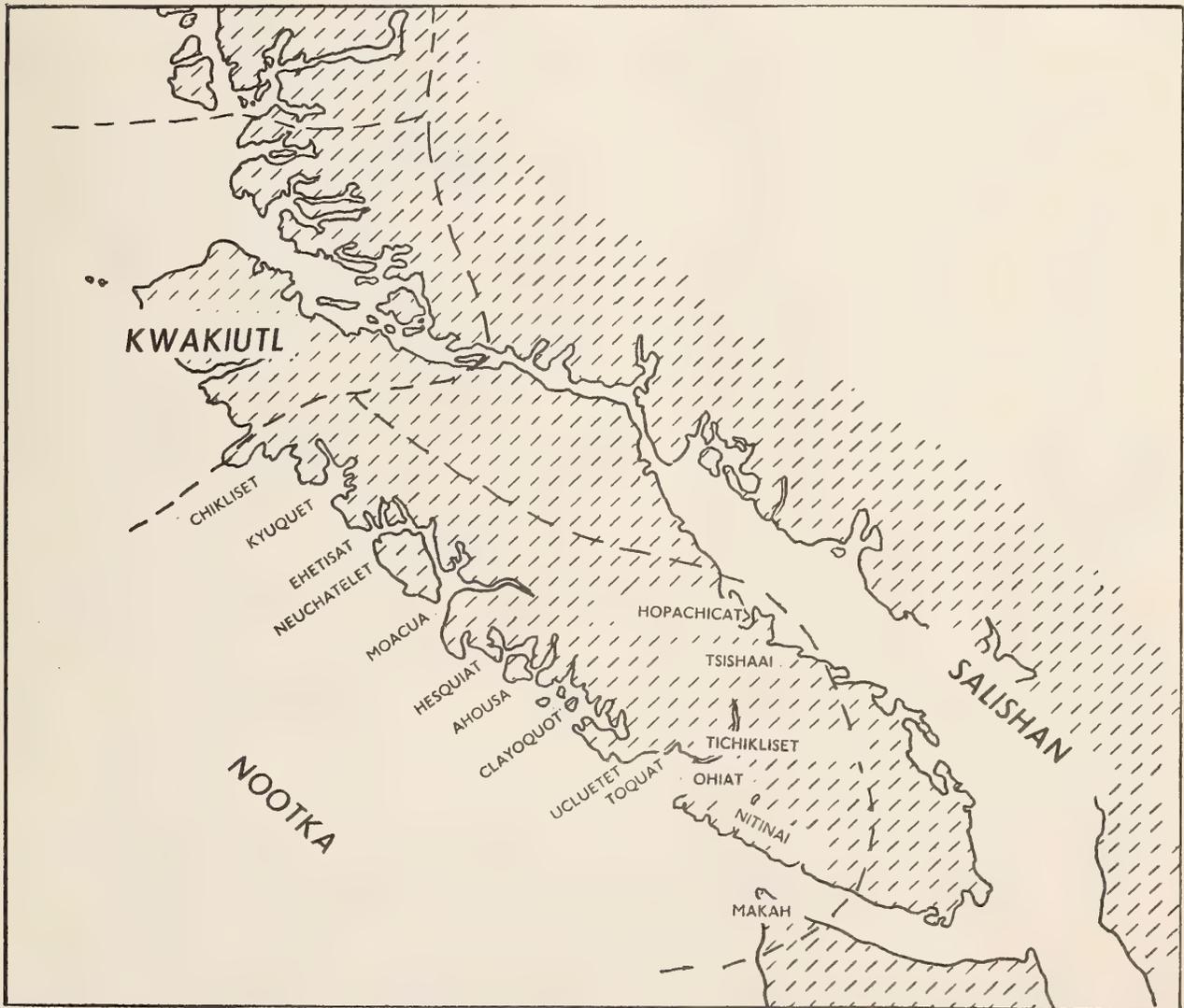


Figure 3: Tribal groupings of the Nootka Indians of Vancouver Island (after DRUCKER, 1951).

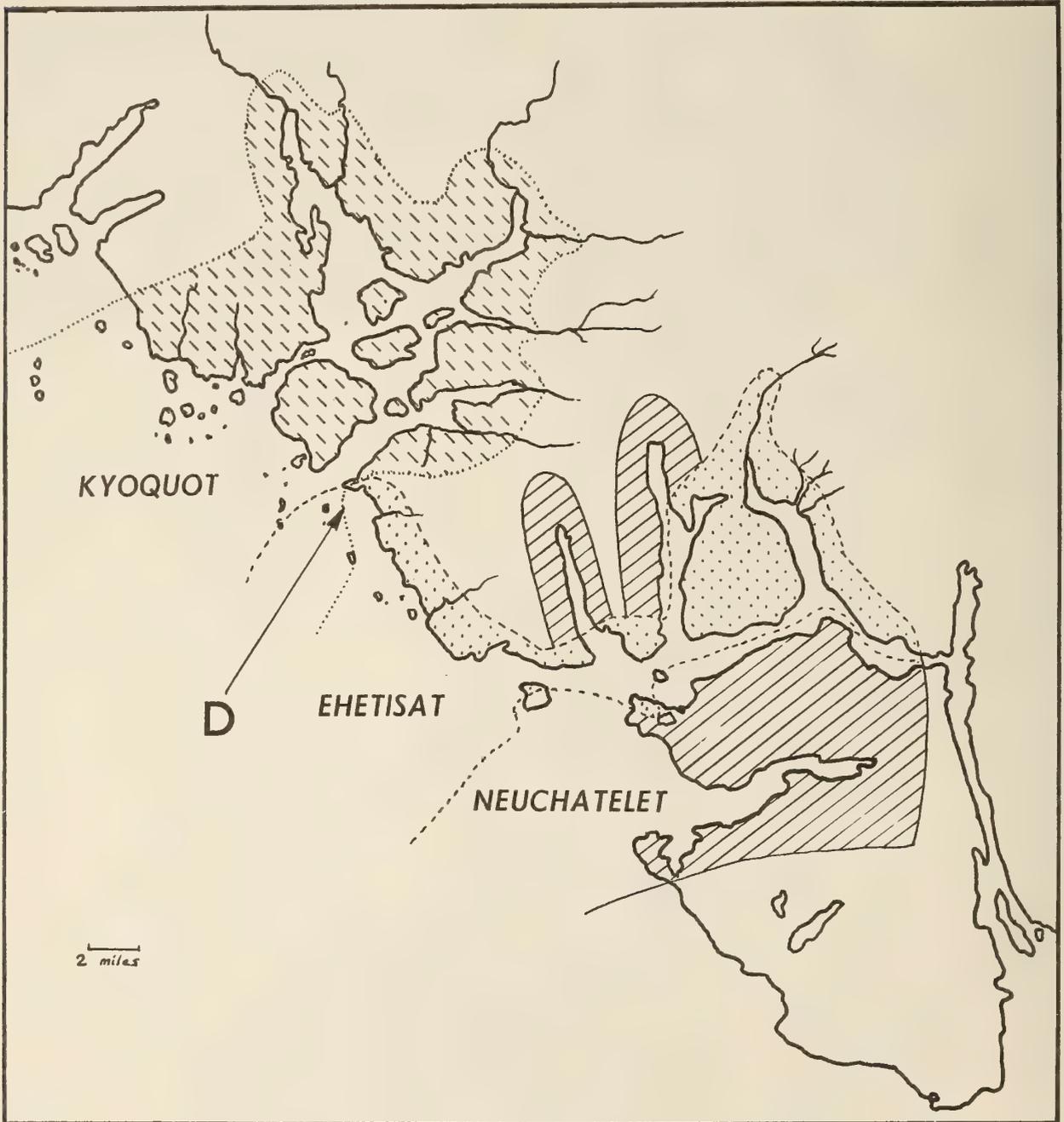


Figure 4: Territories of the Kyoquot, Ehetisat, and Neuchatelet confederations on Vancouver Island. The *Dentalium* fishery at Cahquos is indicated by the arrow. (after DRUCKER, 1951.)⁸

the principal owner in recent times (i.e. since about 1850) and until the fishery ceased to be exploited. Ownership and fishing rights changed hands several times. At one time, the Cahquos fishery was owned by the Qwiwonas, a tribe of the Kyoquot confederation. They were tradi-

tionally the first men to be created after "the transformation of the world" and had certain priority of status and were owners of all the Kyoquot ocean frontage as well as the *Dentalium* fishery. It may be questioned whether their status and supposed priority of creation did not

spring from their wealth as owners of one of the two known sites where *Dentalium* might be collected. Such a reversal of cause and effect is not unknown in other peoples even today. Whatever the origins of the Quiwonas, they gave away their territorial rights as part of the dowry to the Tacisath, another Kyoquot tribe who, in turn, passed them to yet another tribe. However, both the Quiwonas and the Tacisath retained the right to fish for *Dentalium* at Cahquos even after these transfers of other rights. Other groups in the area presumably gained fishing rights at Cahquos because of the proximity of their settlements to the *Dentalium* grounds.

Fishing rights, most property rights and, indeed, the nominal ownership of all food produced by human labour, were vested in the chiefs who nominated a certain number of men to collect *Dentalium*. Salvage, including *Dentalium* shells, caught accidentally or found stranded on the beach belonged to the chief but, according to a Nootkan informant of DRUCKER (1951), articles of little value were generally given to the finder. Thus he might be permitted to keep a few *Dentalium*, "but if one found many, they had to be given to the chief."

Even though *Dentalium* occurs in relatively shallow water off the west coast of Vancouver Island, the task of collecting animals in 20 or 30 feet of water is not an easy one. However the Nootka were skillful boatmen in the violent seas of this coast. They were whalers and a whaling party of three to ten dug-out canoes, each about 30 feet long and manned by eight men, might spend three or four days at sea (STIRLING, 1955). They fished for *Dentalium* from boats and evolved several spears for the purpose, which differed in detail, though probably not in principle, from each other.

1. A specimen in the Provincial Museum, Victoria, B. C., was collected by Dr. C. F. Newcombe in 1911 at Kyoquot (text figure 5, left; Plate 2). It is 5 feet 8 inches long with a tapered shaft of ash or some similar wood and has a bundle of yellow cedar prongs attached to one end. The prongs are protected by six tapered boards. Two stone weights are securely lashed to the base of the shaft with braided cedar-bark rope and a long rope is tied to the spear near the stones.

This is probably the type of apparatus used in the manner described by Jewett (1896). It was lowered to the sea-bed in 50 or 60 fathoms of water, raised a few feet and dropped on the bottom several times, and then hauled to the surface in the hope that a few *Dentalium* shells had become wedged between the prongs of the spear.

2. Another spear in the Provincial Museum and collected by Dr. Newcombe in 1914 at Nootka, is 6 feet long and has an untapered shaft of cedar (Fig. 5, right). The prongs are a good deal longer than in the previous spear and are of hardwood splints. The prongs are protected by four spear-shaped boards and are lashed together with cedar-

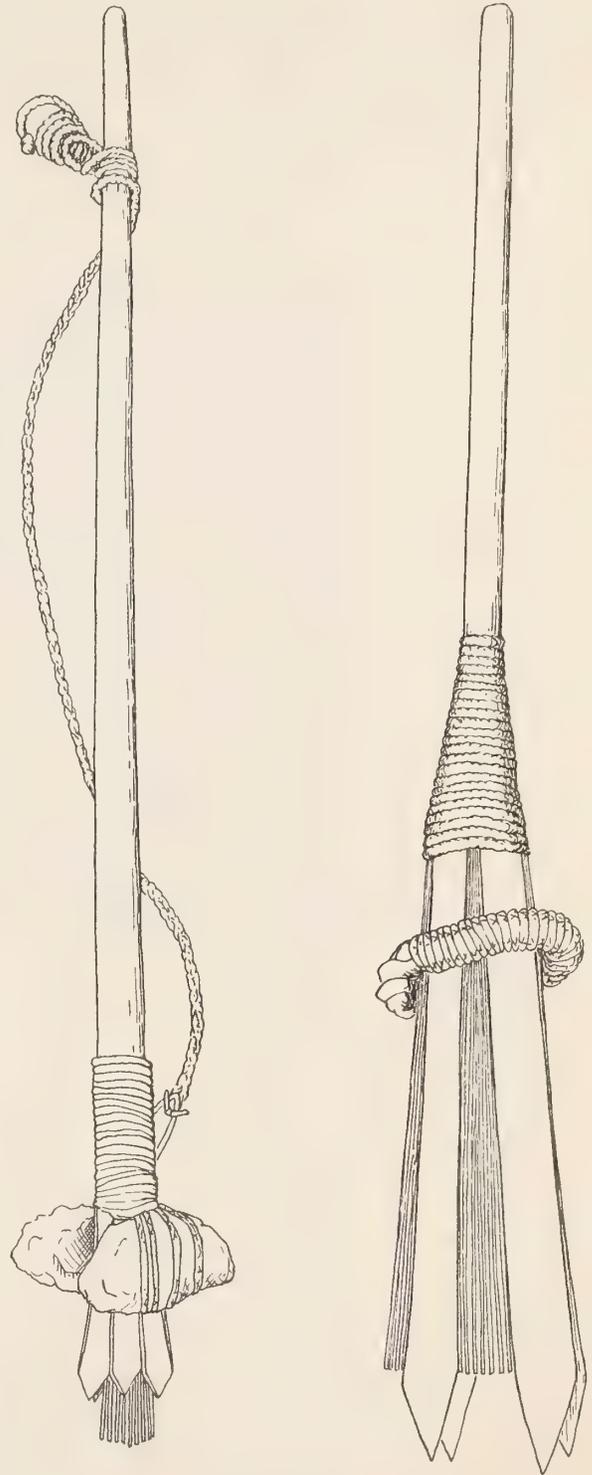


Figure 5: Two types of Nootkan *Dentalium* spear (types 1 and 2 in the text). (Based on drawings supplied by the Provincial Museum, Victoria, B.C.)

bark rope. There is a woven cedar-bark grommet around the splints and this can slide almost to the end of them.

This spear was used in a similar manner to the former, except that it was held in the hand and jabbed against the seabed. Obviously it could only be used in relatively shallow water, although additional lengths could be lashed to the shaft until the spear touched bottom (see below). According to a note in the Victoria Provincial Museum catalogue, "the rope grommet slipped down over the prongs as the spear was withdrawn after striking the bottom, so compressing the prongs," but this seems unlikely. More probably, as Dr. Wilson Duff (*in litt.*) suggests, the grommet was used to keep the prongs compressed when the spear was not in use, to prevent them splaying and so becoming useless for catching *Dentalium*. It is also possible, though perhaps less likely, that the grommet could be adjusted to give the required compression on the prongs during use.

3. DRUCKER (1951) described a variant of the previous spear. The implement is similar to the former except that the grommet is replaced by a wooden board with a round hole in it and a stone weight lashed to each end of the board. This fitted over the broom and slid down over the prongs when it was jabbed in the sand, compressing the prongs around any *Dentalium* which may have been caught. A heavily weighted board would behave in this way whereas a rope grommet would not. DRUCKER states that additional lengths were lashed to the shaft to give the required length.

4. LORD (1864) described a fourth type of *Dentalium* spear. It had a long deal shaft to the end of which a strip of wood was fixed transversely and a number of bone pegs driven into it so that it resembled "a long comb with the teeth very wide apart." This, it is said, was stabbed into the sand two or three times and then drawn to the surface with *Dentalium* impaled on the bone prongs. LORD believed that *Dentalium* lived buried in the sand with the wide end of its shell pointing upwards. If this were so, it would be easy to understand how the spear might work, but as *Dentalium* in fact lives the other way up, it is not clear if LORD's account is a mistaken one of a variety of one of the foregoing spears, or if the description is correct but the implement was used in a different way or even for another purpose. As it is, it sounds unlikely that many *Dentalium* could have been collected with it.

5. ROGERS (1908) writes of the Indians collecting *Dentalium* shells by combing the bottom with a long fine-toothed rake. It is not clear if this is an independent observation or is an abbreviated quotation from another author. Apart from the implication that the pegs were close together, this account may refer to a similar implement to that described by LORD. According to Miss ROGERS, the operation was conducted from a canoe, but it is difficult to imagine that this could have been as ef-

fective a technique for gathering *Dentalium* as the better authenticated methods.

THE USES AND VALUE OF *DENTALIUM*

Among the Nootka, wealth was measured in territorial holdings, privileges, titles, etc., and *Dentalium* shells were used only as ornaments (Fig. 6). Both sexes wore shells as ear pendants and, more commonly among the women, as nose ornaments, though the nasal septum of both boys and girls was pierced. The women also wore *Dentalium* necklaces and an important use of the shells was as the

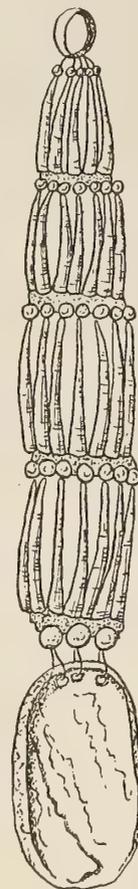


Figure 6: *Dentalium* and *Haliotis* shell ornament.
(After STEARNS, 1889.)

hair ornaments which pubescent girls wore, for one or two months in the case of commoners, or eight to ten months for a chief's daughter. The hair ornaments were the property of the chief and he hired them out for use, though a man with a succession of daughters might apparently compound the hire charges and buy the shells outright.



The end of the *Dentalium* spear illustrated in Figure 5 (left).
The *Dentalium* are unlikely to have been caught in the
manner suggested in the photograph.
(No. 2231 in the Provincial Museum, Victoria, B. C.)

Dentalium was never used by the Nootka as currency; indeed they did not attach precise monetary values to anything. Luxury articles might be given at potlatches but there was no fixed scale of values in *Dentalium* shells or blankets as in the other coastal tribes. After Captain Cook's visit to Nootka territory in 1778, the Nootka came into contact with white traders who exchanged steel knives, copper kettles and blankets for sea-otter furs. The furs were carried to China and traded for tea, which was then sold in Boston where the knives, etc., came from. This three-way trade flourished until the sea-otter became virtually extinct. In the mid 19th century Nootkans were employed on whalers working from American and Canadian ports and as a result of this prolonged contact with whites, their customs gradually changed. Cash, cotton blankets, gowns and cloth predominated as gifts at potlatches and *Dentalium* shells declined in importance and were used solely as ornaments. The *Dentalium* fishery waned and went out of use.

Other Indian groups from Puget Sound to Alaska appear, like Nootka, to have used *Dentalium* shells as ornaments (Plate 3) and as a sign of wealth, though LORD (1864) records that earlier in the 19th century they had reckoned monetary values in *Dentalium*. Outside this area, where the shells were naturally scarcer, they had a precise monetary value. Since coastal tribes traded with tribes of the interior for nephrite (jadeite), a stone which could be polished and given an edge and was used for adzes, chisels, etc., for native copper, furs and skins, and the horns of mountain sheep and goats (MARTIN, QUIMBY & COLLIER, 1947), it is likely that the practice of evaluating articles in terms of *Dentalium* shells evolved among the coastal Indians as a result of their contact with peoples outside the area.

Among tribes in Washington and north-western Oregon, the standard measure of length was the fathom—the extent of the outstretched arms—and a fathom line of 40 shells represented the highest monetary unit (GIBBS, 1873). At the time when GIBBS was writing, such a string was worth five dollars, though formerly it would have purchased a slave. A fathom line made up of more than 40 shells had a correspondingly smaller value depending upon the number of shells needed to complete it.

The Chinook and Klikitat appear to have been largely responsible for trading the shells with tribes further inland and to the south. Naturally the recipient had to be content with fewer and rather more inferior shells than tribes near Puget Sound, and monetary values soared. We have already seen that the Hidatsa in the Dakota territory valued only two or three shells as equivalent to a buffalo robe as late as the 1850's or 1860's, and used *Dentalium* so extensively as currency that white traders were forced to import their own supply of shells (STEARNS, 1889). But it was in northern California, on the southern fringe

of the *Dentalium* belt, that the shells acquired the highest and most precise monetary value.

Even in early times native Californians appear to have had a highly developed financial sense. According to DRUCKER (1951) an elaborate system of currency and money values was evolved in north-western California "where the people haggled and split hairs over microscopic variations in the few dentalia that reached them." Actually the number of shells may not have been so small. According to POWERS (quoted in STEARNS, 1889) immense quantities were at one time in circulation and there must have been a continual influx of shells to replace the wastage caused by sacrifices on the deaths of wealthy men and, among the tribes of the coast range, by propitiatory sacrifices of wealth. POWERS estimated that "in early days" (presumably the first half of the 19th century) every Indian in the state possessed an average of one hundred dollars worth of *Dentalium* shells.

Strings of shells (Figs. 7, 8) were evaluated slightly

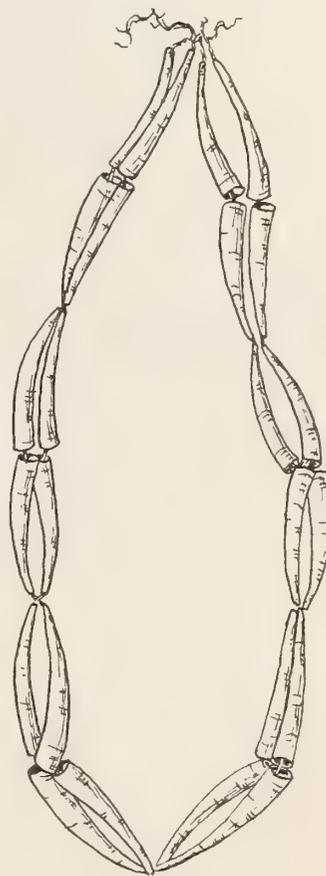


Figure 7: String of shell-money (allicochick) from the west coast of North America. (After STEARNS, 1889.)

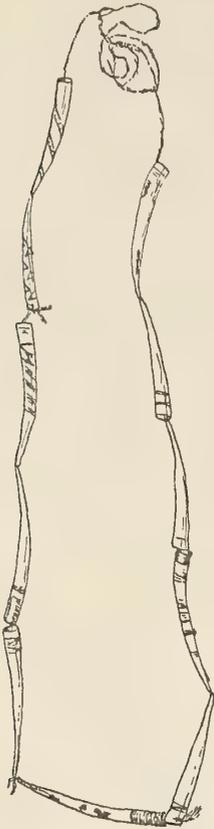


Figure 8: Californian shell-money, of *Dentalium* shells decorated with scratched patterns.
(After QUIGGIN, 1949.)

differently by Californian Indians from those of Washington and Oregon. The Korok used a fathom line of shells, but this was made up of both long and short shells, and they also used shorter strings of shells, worth between twenty-five cents and two dollars according to length. The Hupa living in the Trinity River valley used a string of 5 shells as the unit of currency. Nearly all the men had a series of lines tattooed on the inner side of the left arm against which shell-money could be measured. A string extending from the thumb to the top line was worth twenty-five dollars in gold, or five dollars a shell, but very few strings reached this high value; most were worth about ten dollars a string (STEARNS, 1889).

A number of tribes had an elaborate scale of fines in *Dentalium* strings for various offenses. Thus among the Patawat and Hupa, murder was compounded by payment of shells—ten strings of ten shells each if the victim was a man, four strings if it was a woman. Wives, too, had a precise monetary value in some tribes. Among the Hupa a market value, ranging between 3 and 10 strings, was set upon girls after the puberty celebrations, which her pro-

spective husband had to pay. The gradual disappearance of *Dentalium* from circulation in the latter half of the century had important sociological consequences in some areas. Young male Yurok had to pay a price in shell money to the father of the bride, and she then lived in her husband's cabin and was his slave. Sometimes he might pay half the sum and be "half married," i.e. live in her hut and be her slave, until he could accumulate the balance of the purchase price — clearly the origin of time payments. After the arrival of the whites, however, shell-money became much scarcer and it became more and more difficult for a young man to collect the necessary sum — the old men still accepting payment only in shell-money — on which POWERS comments that "since the advent of the Americans, the honorable state of matrimony has fallen sadly into desuetude." One doubts, though, that this was the prime cause of the near extinction of the Californian tribes.

PROBLEMS

Although I now know where the *Dentalium* came from and how they were collected, there are still a number of outstanding mysteries. Obviously, an enormous number of shells must have been in circulation, yet nearly all of them came from one or two sites and were fished by selected members of only four tribes of Nootka Indians. One might have thought that it would have been a full-time job to supply the western half of the continent with currency, yet clearly it was not; the *Dentalium* fishing season was limited and periods of fair weather must also have been devoted to food collection. Such was the demand for shells that these should have been wealthy tribes, but probably, like most primary producers, they were not. The Nootka were a relatively isolated people, largely self-sufficient and, to judge from DRUCKER's (1951) account of them, they did not engage in trade with neighbouring peoples to any very great extent. How, then, were such large numbers of *Dentalium* shells put into circulation?

I still have a lurking suspicion that I know only half the story, but perhaps after reading this, someone will write and tell me how the gaps in this account can be filled. I hope they do.

ACKNOWLEDGMENTS

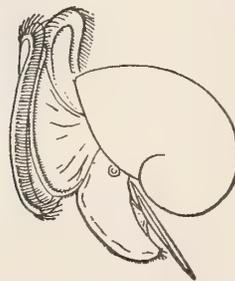
I am particularly grateful to correspondents who have supplied me with information. They include Dr. Wilson Duff, Anthropologist at Victoria Provincial Museum, Dr. Paul Illg, of the Department of Zoology, University of Washington, Seattle, and Dr. R. W. Pillsbury, of the Department of Zoology, University of British Columbia, Vancouver. I am also grateful to the Directors of the Provincial Museum, Victoria, B. C., and the Portland (Oregon) Art Museum for permission to use the photographs of the *Dentalium* spear and Tlingit shark helmet, respectively, shown in Plates 2 and 3.



Tlingit shark helmet of carved and painted wood, with a fringe of *Dentalium* and bead ornament.
(No. 48.3.419 in the Rasmussen Collection in the Portland Art Museum.)

Literature Cited

- BAIRD, W.
1864. A species of shell belonging to the family Dentaliidae. Proc. Zool. Soc. London; vol. for 1864: 136.
- DALL, WILLIAM HEALEY
1921. Summary of the marine shell-bearing mollusks of the north-west coast of America from San Diego, California, to the Polar Sea, mostly contained in the collection of the U. S. National Museum. Smithson. Inst., U. S. Nat. Mus. Bull. 112: pp. 1-217; pls. 1-22.
- DRUCKER, P.
1951. The northern and central Nootkan tribes. Smithson. Inst., Bureau Amer. Ethnol., Bull. 144.
- EKMAN, S.
1953. The Zoogeography of the Sea. London.
- GIBBS, S.
1873. Tribes of western Washington and north-western Oregon.
- HENDERSON, J. B.
1920. A monograph of the east American scaphopod mollusks. Smithson. Inst., U. S. Nat. Mus. Bull. 111.
- JENNESS, D.
1934. The Indians of Canada. Nat. Mus., Canada, Bull. 65.
- JEWETT, J.
1896. The adventures of John Jewett (ed. R. Brown). London.
- JOHNSON, MYRTLE E., & H. J. SNOOK
1927. Seashore animals of the Pacific Coast. The Macmillan Co., New York.
- KEEN, A. MYRA
1937. An abridged check list and bibliography of west North American mollusca. Stanford Univ. Press, Stanford, Calif. pp. 1-88.
- LORD, J. K.
1864. Notes on the use of (a species of shell belonging to the family Dentaliidae) by the natives of Vancouver Island and British Columbia. Proc. Zool. Soc. London, vol. for 1864: 137.
- MARTIN, P. S., G. I. QUIMBY, & D. COLLIER
1947. Indians before Columbus. Chicago.
- MORTON, J. E.
1959. The habits and feeding organs of *Dentalium entalis*. Jour Mar. Biol. Assoc., U. K., 38: 225.
- QUIGGIN, A. H.
1949. A survey of primitive money: The beginning of currency. London.
- ROGERS, JULIA ELLEN
1908. Shells. (The Nature Library, vol. 15) vii-xxii; 3-503; pls. 1-87.
- SMITH, ALLYN G., & MACKENZIE GORDON, JR.
1948. The marine mollusks and brachiopods of Monterey Bay, California, and vicinity. Proc. Calif. Acad. Sci., 4th. Ser., 26 (8): 147-245; pls. 3-4; textfigs. 1-4.
- STEARNS, ROBERT EDWARDS CARTER
1889. Ethno-conchology: a study in primitive money. Smithson. Inst., U. S. Nat. Mus., Rept. for 1887: 297.
- STIRLING, M. W.
1955. Indians of the Americas. Washington.
- WHYMPER, F.
1868. Travel and adventure in the Territory of Alaska. London.
- YONGE, C. M.
1937. Circulation of water in the mantle cavity of *Dentalium entalis*. Proc. Malacol. Soc. London, 22: 333.



On the Identities of
Trivia buttoni and *Trivia galapagensis* MELVILL, 1900
 (Mollusca : Gastropoda)

BY

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(Plate 4)

Discovery of the holotype of *Cypraea (Trivia) buttoni* MELVILL, 1900 and a set of three specimens labeled "types" of *Cypraea (Trivia) galapagensis* MELVILL, 1900 in the collection of the late Fred L. Button,—purchased by Chicago Natural History Museum in 1960,—prompted an attempt to determine their relationships. This was only partly successful, since requisite type material could not always be located, but a refiguring of the holotype of *Trivia buttoni* and a good paratype of *T. galapagensis* does allow clarification of some confusing issues and proposed new synonymies permit a modest reduction in the "23 or more species of *Trivia* that have been reported from the Eastern Pacific" (CAMPBELL, 1961:25).

The most recent review of the trivias (ALLAN, 1956) is almost a verbatim compilation from SCHILDER (1932). The latter considered *Trivia buttoni* to be a distinct species with a subspecies, *T. b. panamensis* DALL, 1902. *Trivia galapagensis* was treated as a subspecies of *T. sanguinea* GRAY, 1832. Otherwise there has been little mention in the literature of either species. BUTTON (1902:256 and 1908:11) pointed out that the type of *T. galapagensis* was worn and that in fresh individuals the ribs extend over the dorsum. HOWARD & SPHON (1960:42) in their key of Panamic *Trivia* differentiate *T. galapagensis* by its smooth dorsum, relying on MELVILL's misleading description and overlooking BUTTON's later comments.

We have, at present, practically no knowledge on the extent of variation within species of *Trivia* and minimal information on the geographic range of the species. The present paper does nothing to remedy this unfortunate situation, being necessarily restricted to a consideration of type materials. Much of the trouble dates from the original work done on Galapagos *Trivia* by GRAY (1832), based on materials collected by Hugh Cuming. Little or no question has arisen concerning the identity of *T. maugeri* and *T. pacifica*, but much confusion and doubt has ex-

isted concerning *T. fusca*, *T. rubescens* and *T. sanguinea* (for example, see BUTTON, 1902: 255 to 256). It might be added here that the record of *T. rubescens* from Wreck Bay, Chatham Island, Galapagos, given by SCHWENDEL (1938: 2) is incorrect. The specimens (now Chicago Natural History Museum number 27521) are of *T. pacifica*.

At my request, Mr. S. P. Dance of the Mollusca Department of the British Museum (Natural History) attempted to locate the types of *Trivia fusca*, *T. rubescens* and *T. sanguinea* in order to compare them with photographs of the best specimen of *T. galapagensis* and also to compare any material of *T. acutidentata* GASKOIN, 1836 and *T. paucilirata* SOWERBY, 1870 with photographs of *T. buttoni*. I am deeply indebted to Mr. Dance for his help in locating the specimens and for his advice concerning the relationships of the several forms. I am also indebted to Dr. Joseph Rosewater of the United States National Museum for the loan of a paratype of *Trivia panamensis* DALL, 1902, and to Dr. Myra Keen of Stanford University for information on paratypes of *T. galapagensis*.

On the basis of the information supplied by Mr. Dance, study of the original literature, and specimen comparisons, I would propose the following synonymies, relegating both of MELVILL's species to the status of junior synonyms.

Trivia (Dolichupis) paucilirata (SOWERBY, 1870)

(Plate 4, figures 1 to 3)

Cypraea paucilirata SOWERBY, 1870, Thes. Conch.,
Cypraea, pp. 49, 53, pl. 36, fig. 502; pl. 37, fig.
 526—locality unknown.

Cypraea (Trivia) buttoni MELVILL, 1900, Ann. Mag.
 Nat. Hist., (7), 6:209-210, 2 figs.—locality un-
 known.

Trivia panamensis DALL, 1902, Nautilus, 16 (4), pp.
 43-44 - Albatross Station 2798, 18 fms., Panama



Figure 1



Figure 2



Figure 3



Figure 4



Figure 5



Figure 6

Figures 1, 2, and 3: *Trivia (Dolichupis) paucilirata* (SOWERBY). Holotype of *Trivia buttoni* MELVILL, 1900. Chicago Natural History Museum number 116972.

Figures 4, 5, and 6: *Trivia (Pusula) rufescens* (GRAY, 1832). Paratype of *Trivia galapagensis* MELVILL, 1900. Chicago Natural History Museum number 116974.

Bay, Panama; DALL, 1908, Bull. Mus. Comp. Zool., 43 (6), p. 324, pl. 12, figs. 7, 9, 12.

The type of *Trivia paucilirata* is in the British Museum (Natural History) and, judging from photographs, does not differ significantly from *T. buttoni*, except that it is larger in size. The latter species seems to be based on a worn specimen. A paratype of *T. panamensis* (United States National Museum number 652 351) was compared directly with the type of *T. buttoni* (Chicago Natural History Museum number 116 972). In character and spacing of the sculpture, form of the aperture, and degree of protrusion of the beaks they are identical. Differences in size and proportion are minor, probably falling within expected range of normal variation. Comparative measurements are:

	Height	Length	H. L.	Width	W. L.
Type of <i>Trivia buttoni</i>	3.73	6.01	0.620	4.32	0.718
Paratype of <i>T. panamensis</i>	3.08	4.58	0.672	3.46	0.757

For convenient reference, the type of *T. buttoni* is here refigured.

SCHILDER (1932: 100) placed *Trivia paucilirata* in the synonymy of *T. acutidentata* GASKOIN, 1836, although SCHILDER & TOMLIN (1931) were not fully convinced of their identity. The type of *T. acutidentata* was broken before it could be figured and no topotypic material has been collected. The concept of *T. acutidentata* held by SCHILDER & TOMLIN is of a shell with narrower aperture, more crowded ribs and less produced beaks than the type of *T. buttoni*. Even if they are correct in their revival of the name *acutidentata*, it is very doubtful that it and *T. paucilirata* are the same species because of the differences cited above. The only other reference to *T. acutidentata* (BUTTON, 1906) is based on a worn shell from the Galapagos (Chicago Natural History Museum 96 037) that is 8.1 mm long, 4.8 mm high and 5.7 mm wide. The ribs are continuous across the dorsum, narrow, and not beaded. The beaks are strongly protruded. The shape and sculpture are quite different from that in the shell figured by SCHILDER & TOMLIN (1931) and I would unhesitatingly state that they belong to different species. Until adequate series of specimens are available from this area, it will be impossible to determine whether BUTTON or SCHILDER & TOMLIN are correct in their interpretation of GASKOIN's name.

Trivia (Pusula) rufescens (GRAY, 1832)

Plate 4; Figures 4 to 6

Cypraea rufescens GRAY, 1832, in SOWERBY'S Conch.

Illus., *Cypraea*, p. 12, fig. 31—no locality.

Cypraea sanguinea GRAY, 1832, in SOWERBY'S Conch.

Illus., *Cypraea*, p. 12, fig. 31—Panama and Mexico; SOWERBY, 1870, Thes. Conch., *Cypraea*, p. 48, pl. 327 (36), figs. 483-486.

Cypraea fusca GRAY, 1832, in SOWERBY'S Conch. Illus., *Cypraea*, p. 13, fig. 37—Galapagos and Bay of Guayaquil.

Cypraea rubescens [sic] SOWERBY, 1870, Thes. Conch. *Cypraea*, p. 50, pl. 327 (36), figs. 506, 507, pl. 328 (37), fig. 520.

Cypraea (Trivia) galapagensis MELVILL, 1900, Ann. Mag. Nat. Hist. (7) 6: 208 to 209, 2 figs.—Albemarle Id., Galapagos.

Pusula (Ciotrivia) occidentalis SCHILDER, 1931, Zool. Anz., 96 (3-4), p. 72, fig. 6—Mexico to Galapagos; SCHILDER, 1932, Foss. Cat. I, 55: 98 (as synonym of *fusca*).

Trivia (Pusula) sanguinea circumdata SCHILDER, 1931, Arch. f. Mollusk., 71 (1), p. 43, fig. 4—locality unknown; SCHILDER, 1931, Zool. Anz. 96 (3-4) p. 72—Gulf of California and Santa Elena.

The above references deal only with the primary descriptions and correctly identified figures in SOWERBY'S *Thesaurus*. SOWERBY'S figures of *Trivia fusca*, for example, are not the same as the original. SOWERBY figured a smaller, more slender shell, and this morph has been subsequently called *fusca*, not only by TRYON, but probably in the secondary literature. Possibly it is a dwarf form of *T. rufescens*, but determination of its status is beyond the scope of this paper. If found to be distinct, then probably it will require a new name.

While there are no labeled types in the British Museum (Natural History) of *Trivia rufescens*, *T. fusca* and *T. sanguinea*, Mr. Dance did locate material that can be considered authentically identified and could be formalized as types of *T. rufescens* and *T. sanguinea*. Until such time as there is sufficient material available for a modern systematic revision of the West American *Trivia*, I much prefer not to formalize type designations that might later create systematic problems. The present paper attempts only to indicate probable synonymies of early names, the fact that both of MELVILL'S species are synonyms, and to point out the misinterpretation of *T. fusca*.

British Museum specimens from the collections of Cuming, Gaskoin, and Taylor are labeled *Trivia rufescens* and were annotated by E. A. SMITH "*rubescens* [sic] GRAY=*fusca* GRAY." Two specimens of *T. sanguinea* from the GRAY collection exactly match the type photographs of *T. galapagensis* and one exactly matches a Cuming collection specimen of *T. rufescens*. There is no labeled material of *T. fusca* in the British Museum collection, but the original figures show no basis for separating *T. sanguinea* and *T. fusca*, while *T. rufescens* differs primarily in being lighter in color, a probable result of fading coloration in a dead specimen. If allowance is

made for size and color variation, it seems very probable that *T. rufescens* (length .45"), *T. sanguinea* (length .45") and *fusca* (length .33") are variants of the same species.

Some problems exist concerning the location of the type of *Trivia galapagensis* MELVILL. Stanford University and the Fred Button collection each contain sets of three specimens of this species. The Stanford specimens were labeled, probably by BUTTON, "*Trivia galapagensis* MELVILL n. sp. 1900 rare. Galapagos Is. (SNODGRASS, 1899)." The smallest of the three is the exact size given by MELVILL for the largest set of dimensions, but it is not the figured specimen. The three specimens in the Button collection do not match the cited dimensions, but one of them is unquestionably the figured specimen and has been selected as lectotype (Chicago Natural History Museum 116973). The other two paratypes are Chicago Natural History Museum 116974. The measurements of the three Chicago Natural History Museum specimens are:

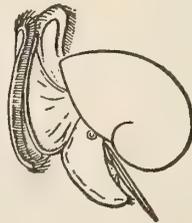
	Height	Length	H/L	Width	W/L
Type	5.23	8.11	0.646	6.02	0.742
Paratype	4.77	7.13	0.670	5.62	0.788
Paratype	6.15	10.45	0.588	7.45	0.713

The Stanford specimens probably can be considered as paratypes.

The two names proposed by SCHILDER (1931) are probably superfluous, since the illustrations of both seem to fall well within the range of variation of *Trivia rufescens* and do not appear to have a geographic basis.

Literature Cited

- ALLAN, JOYCE
1956. Cowry shells of world seas. Georgian House, Melbourne. i-x; pp. 1-170; pls. 1-15.
- BUTTON, FRED
1902. West American Cypraeidae. Jour. of Conch. 10 (8): 254-258.
1906. Note on *Trivia acutidentata* GASK. The Nautilus 19 (11): 132.
1908. Note on *Trivia galapagensis* MELVILL. The Nautilus 22 (1): 11.
- CAMPBELL, BRUCE
1961. Four new Panamic gastropods. The Veliger 4 (1): 25-28; plt. 5.
- DALL, WILLIAM HEALEY
1902. New species of Pacific Coast shells. The Nautilus 16 (4): 43-44.
1908. Report on the scientific results of the expedition to the Eastern Tropical Pacific. . . . XIV. The Mollusca and Brachiopoda. Bull. Mus. Comp. Zool., Harvard 43(6): 205-487; 22 pls.
- HOWARD, FAYE B., & GALE G. SPHON, JR.
1960. A new Panamic species of *Trivia*. The Veliger 3 (2): 41-43; plt. 7.
- MELVILL, JAMES COSMO
1900. Descriptions of two species of *Cypraea*, both of the subgenus *Trivia* GRAY. Ann. Mag. Nat. Hist., (7) 6: 207-210; 4 figs.
- SCHILDER, FRANZ ALFRED
1931. Beiträge zur Kenntnis der Cypraeacea (Moll. Gastr.) - IV. Zool. Anz., 96 (3-4): 65-72.
1931. Zwei neue *Trivia* (Cypraeacea: Eratoidae). Arch. für Mollusk., 63 (1): 42-44; plt. 3.
1932. Cypraeacea. In Fossilium Catalogus I: Animalia, part 55: 276 pp.
- SCHILDER, FRANZ ALFRED, & JOHN R. le B. TOMLIN
1931. Rediscovery of a rare cowry. Proc. Malac. Soc. London 19 (6): 274-275; figs.
- SCHWENDEL, JEANNE S.
1938. Zoological results of the George Vanderbilt South Pacific Expedition, 1937. Part I, — Galapagos Mollusca. Proc. Acad. Nat. Sci., Philadelphia 90: 1-3; 3 figs.
- SOWERBY, GEORGE BRETtingham (first of name)
1832-1841. Conchological Illustrations.
- SOWERBY, GEORGE BRETtingham (2nd of name)
1870. *Cypraea*. In Thes. Conch., 4: 58 pp.; 37 pls.



Revision of Dall's Hawaiian Mitrids With Descriptions of Three New Species

(Mollusca : Gastropoda)

BY

JEAN M. CATE

Conchological Club of Southern California, Los Angeles 7

(Plates 5 to 8; 1 map)

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INTRODUCTION

During the 1920's William Healey Dall was working on a manuscript dealing with the marine mollusks of Hawaii. Some years after his death in 1927, Paul Bartsch and Harald Rehder completed the pelecypod section of this work, and in 1938 the Bernice P. Bishop Museum published the "Manual of Recent and Fossil Marine Pelecypods of the Hawaiian Islands," co-authored by Dall, Bartsch and Rehder. The gastropod section, however, was never published, and those working with Hawaiian species have been handicapped by the lack of this sorely needed

reference.

Through the courtesy of Dr. Harald A. Rehder of the United States National Museum and Dr. W. P. Popenoe of the University of California at Los Angeles, I have had the opportunity of studying the material in Mitridae on which Dall based part of his manuscript. Dr. Rehder, who intends to revise and complete the Dall paper, has very kindly allowed me the privilege of completing the necessary research on the supposed new species of *Mitra*.

The need for a great deal of revision in Dall's work can readily be seen from the results of my study with this relatively small portion of it; with a total of 28 species, 24 bear *nomina nuda*, 23 are synonymous, one is not a mitrid, and one is indeterminate, leaving only three that are potentially valid species. No more than 21 recognizably different forms are to be found among the 28 proposed, Dall unaccountably having applied two to three new names to the same species in four separate instances. The validated species will be newly described and figured here; the invalid names will be listed with their valid counterparts and synonyms, and those species will be illustrated and discussed under their correct names. An index of all species mentioned in this paper will be found on page 42.

There is need for further revision among the subgenera of the Mitridae. In order to expedite the present work and to avoid, as far as possible, assigning any of the species involved to an incorrect taxon, I have conservatively made assignments of the various species only on a generic level; i. e., to *Mitra*, *Vexillum*, *Pusia*, or *Imbricaria*. At a later date these species may then be included in more appropriate subgenera without a major revision of the group.

Imbricaria virgo, *Mitra ancillides*, *Vexillum millecostatum* and *V. rubrum* have been ascribed by several workers to William Swainson, but from a study of the introductory remarks accompanying the original paper in which these and 22 other species were described, I believe

Broderip should be considered the author. The account given by Broderip when he read his paper before the Zoological Society of London includes the following statement: "The species of the genus *Mitra*, Lam., which I am about to describe had been sent by Mr. Cuming, in whose cabinet they are, to Mr. Swainson, whose intimate acquaintance with this family renders him so particularly competent to the task of describing them. They were named by him, and he also made notes respecting them before returning them. In the following account of them I have retained Mr. Swainson's name in every instance but one: and whenever he has made any written observations I have quoted them."

From the foregoing remarks, it appears to me that Broderip furnished the validating descriptions for the shells, using Swainson's manuscript names; I have accordingly attributed these species to Broderip.

I should like to call attention to a change in my citation of *Mitra tiarella* A. ADAMS. In earlier papers (CATE, 1962a, 1962b) I have used for this species the date 1851, which appears on the flyleaf of that portion of the Proceedings of the Zoological Society of London in which this and 51 other mitrid species were described. It also has been habitually cited thus by other authors in the past. However, it has recently come to my attention that this particular paper was not in fact published until 1853; accordingly, I have amended my citation to read *Mitra tiarella* A. ADAMS, 1853.

In the same manner, dates have been changed for five other species cited in this paper: *Mitra ancillides* BRODERIP, 1836, *Vexillum millicostatum* (BRODERIP, 1836), *V. rubrum* (BRODERIP, 1836) and *Imbricaria virgo* (BRODERIP, 1836) have formerly been cited in the literature as having been published in 1835. The date of *Vexillum exquisitum* (GARRETT) has been changed from 1872 to 1873. My authority for these changes is DUNCAN (1937).

The practice of actually circulating a publication on any date other than that appearing on its printed pages has caused a great deal of the existing confusion in conchological nomenclature; with a gap of two years, as in the case of *Mitra tiarella*, the priority of any species in that paper is open to question. Although this procedure is not sanctioned by the International Code (Article 21), it is unfortunately still being practiced in some of our modern publications.

Perhaps it should be explained that I have not seen a copy of Dall's original manuscript, nor even a verified listing of the mitrid species it contains. I have worked entirely from the shells in the collection of the U. S. National Museum that are marked with his unpublished names, and as a check against these I have also employed a list compiled by Mr. E. H. Bryan, Jr., of the Bishop Museum. There may be a few that have escaped my attention, but to the best of my knowledge I have included

all the mitrid species Dall meant to publish in his work on the Hawaiian gastropods.

I have discussed a few species in my paper that Dall may not have intended to include in his manuscript; two of these involve apparently unpublished Dall names that I have encountered in studying various large collections, but which were not contained in his type material at USNM nor in Mr. Bryan's checklist. It seems appropriate to deal with them in connection with Dall's other Hawaiian species, even though they may possibly not have been in the manuscript originally. I have deleted one species he intended to include, as Dr. Rehder concurred with me that it is not a mitrid and thus does not come within the scope of this paper. These additions and deletions will be noted in the discussions of the respective species.

While this paper is primarily concerned with the work of W. H. Dall, it is impossible to ignore the parallel efforts of his contemporary worker, Henry A. Pilsbry of the Academy of Natural Sciences of Philadelphia. Covering approximately the same geographical area, their conchological activities necessarily included a good deal of similar material; the result was that in 1920 Pilsbry published certain new species that would also have been described by Dall if his manuscript had been completed. Both men erred in considering the Hawaiian fauna largely endemic, consequently overlooking the fact that much of it had already been described. Both Dall and Pilsbry therefore lost several of their "new" species to synonymy; Dall further lost some of his through Pilsbry's prior publication.

It should be assumed that there is a logical explanation for the many problems of synonymy encountered in the papers on Hawaiian miters by both men. The Hawaiian fauna was outside the fields of endeavor in which they are acknowledged to have done their best work, Dall's forte having been the mollusks of North America and Pilsbry's the land snails. Dall's Hawaiian work was done during the later years of his productivity and just a few years before his death at the age of 82. We do not know that he intended to publish the present manuscript without a considerable amount of additional research and revision; it is quite possible that one of the reasons it was never published is that he considered it little more than the first draft of a proposed work. If he had been able to revise and complete it he would most likely have corrected many errors and discrepancies. I believe we should view Dall's manuscript as objectively as possible. The species he recognized as new and which are herein described as valid should be considered his contribution to the knowledge of the Hawaiian mitrid fauna. It is not my intention to present my findings as a critique of either Dall or Pilsbry, but rather as an outline of what I consider the present status of the species discussed. Any emphasis on the invalid species is merely for the purpose of placing them in their proper systematic positions in the Mitridae.

An incomplete list of 22 of the unpublished names appeared twice in the Hawaiian Shell News (1956, 1959). Regrettably, most of Dall's manuscript names thereby became *nomina nuda* through this publication of the names without descriptions or figures. In the ensuing years there has been much conjecture as to what these species might be, and some of the invalid names have been used in both institutional and private collections despite their unavailability.

Dall was himself indirectly responsible for three of his unpublished names becoming *nomina nuda* prior to the listings in the Hawaiian Shell News. Charles F. Mant sent a large group of shells from the Kewalo dredgings to the U. S. National Museum for identification and later published a list of the names furnished him by Dall (The Nautilus, 1923). On this list 23 mitrid names appear, three of which (*kewaloensis*, *lipara*, and *mitata*) are among the species in the Dall manuscript. It is ironic that two of these should have been among the five that were inadvertently omitted from the checklists later published in the Hawaiian Shell News; in other words, if Dall had not given his MS names (without labelling them accordingly) to Mant, who innocently published them as valid, the names *kewaloensis* and *lipara* would not have become nude names. From a total of 28, then, only four names remained taxonomically available through not having been cited previously; when my research was begun *pellucida*, *propetusa*, *stephana* and *melacis* were still potentially valid names, but they have all subsequently proved to be synonyms of earlier-named species.

Several of Pilsbry's Hawaiian mitrid names were also included in Mant's list in The Nautilus. No reference was made to Pilsbry as the author of those species, and Mant further cited them in an erroneous and misleading manner—unintentionally, to be sure, but incorrectly, nevertheless. It is curious that Dall did not change the labels on the USNM specimens which by that time should have borne the Pilsbry names; we know he was familiar with them because he cited them in identifying Mant's material. This is likewise true of other species on the list; for one example, Dall recognized *Mitra peasei* DOHRN, 1860 among the Mant shells, and a note in the Thaenum catalog mentions that in 1920 Dall identified certain specimens in that collection as *M. peasei*, but his MS name *Mitra missa* remained on a single dead specimen that is unquestionably the same species. As Mant's list does not cite authorities or dates and has at least one spelling error, its usefulness as a reference to Hawaiian miters is considerably reduced, there being no way to verify the identifications of those particular shells.

It is certain that Dall and Pilsbry were working concurrently, though independently, with identical material; I discovered this interesting coincidence while working with the *Mitra* collection and catalog of Mr. Ditlev

Thaanum, who has very graciously loaned these to me for use in my present study. Mr. Thaenum was diligent in sending generous, well-labelled samples from his extensive collecting to the more important museums, and as he was one of the pioneer collectors in the Pacific area, a large number of the shells he collected were either new to science or rare enough to be generally unknown in most collections. Mr. Thaenum evidently divided his material into at least three approximately equal parts, sending one set to the United States National Museum, one to the Academy of Natural Sciences of Philadelphia, and retaining one in his own collection. As a result, with the loaned Thaenum specimens at hand, the USNM material on which part of the Dall manuscript was based, and excellent photographs of Pilsbry's Hawaiian types in the ANSP collection (furnished in 1961 through the courtesy of Stanford University while the Pilsbry shells were on loan to that institution), I have been able almost literally to reconstruct several of the entire original lots collected by Thaenum; this circumstance has provided nearly three times as many specimens for those species as I would otherwise have had available for study purposes. In more than one instance the larger series has made it possible to solve certain problems about a species that might not have been apparent with fewer specimens. It was easy to match up the various parts of each original lot through identical information on the individual labels from the three collections—including depth, location, frequently a station number, and most importantly, the Thaenum catalog number which is repeated on the USNM labels in addition to the museum's own number. Since more than half of both Pilsbry's and Dall's new mitrid species were originally collected by either D. B. Langford (whose shells are now in the Thaenum Collection) or by Thaenum himself, the importance of this coincidence cannot be overemphasized. A few of the specimens among the Dall material were collected by the U. S. Fish Commission, and the rest were donated by private collectors whose names will be noted at the appropriate places.

The duplication of work by the two independent authors accounts for four of the Dall manuscript names being synonyms, as Pilsbry's names were published while Dall was still working on his paper. It does not, however, account for the large amount of synonymy seen in the works of these two men, each of whom, respectively, had access to the largest and finest reference collections and libraries in this country.

I do not know Dall's reasons for choosing the particular names he intended to use for his new species, except in the case of two or three patronymics. It is therefore my intention to validate two of his proposed names (*kewaloensis* and *pailoloana*) which seem especially euphonious as well as appropriate. For the third (*batista* or *eruda*) I have selected a new name with a typically Hawaiian con-

notation in order to ensure the association of that species with its place of origin. The three new species will be described first, with the others following in systematic order. The literature cited under each species includes only the more important citations or those furnishing additional illustrations, and it is not intended as a complete bibliographical reference. All direct quotations represent the original descriptions and pertinent remarks made by the authors of the valid species.

None of the species contained in this paper has been recorded among the fossils from Hawaii.

ACKNOWLEDGMENT

It gives me a great deal of pleasure to acknowledge the assistance of several members of the Hawaiian Malacological Society in bringing the records up to date for the species within the scope of this paper. Working from life-sized (or larger) photographs, these collectors promptly and willingly checked their collections and records, furnishing recent first-hand information on many of the species discussed here. Some of the species were unknown to them, and these will be noted accordingly, to point out the extreme rarity of occurrence in those instances. My gratitude is expressed to the following participants in this project: Dr. C. M. Burgess, Mr. Ellis Cross, Dr. Alison Kay, Mr. Reginald Gage, Mrs. Elizabeth Harrison, Mr. Robert Lee, Dr. Thomas Richert, Professor Jens M. Ostergaard, Mr. Ditlev Thaanum and Mr. Clifton S. Weaver. I should also like to thank the Santa Barbara Museum of Natural History and Prof. Jens M.

Ostergaard for lending specimens from their collections.

Others who have helped immeasurably in various ways are Dr. Harald Rehder, Dr. W. P. Popenoe, Dr. Myra Keen, Dr. Rudolf Stohler and especially Crawford Cate, whose constant encouragement has been a real source of inspiration.

The map of the Hawaiian Islands was adapted by Mrs. Emily Reid from The Hawaiian Chain, by E. H. BRYAN, Jr. (1954; B. P. Bishop Museum Press, Honolulu). Unless otherwise credited, the photographs are by Takeo Susuki.

Vexillum kewaloensis J. CATE, spec. nov.

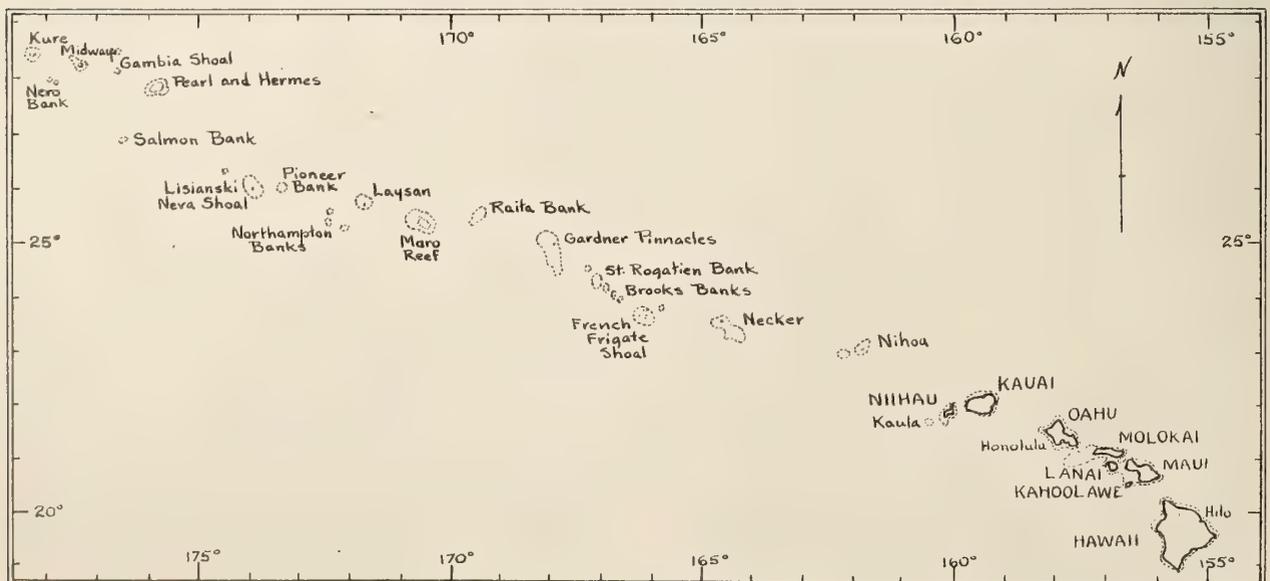
(See figures 1 to 5, Plate 5)

Mitra kewaloensis DALL MS (*nomen nudum*)

Shell small (approximately 11.5 mm long), smooth, shining. Protoconch lacking; teleoconch with about eight convex whorls, longitudinally ribbed (about 20 smooth, whitish ribs on the last whorl); interstices faintly transversely grooved. Neck of shell constricted, ribs becoming tuberculate instead of smooth at this point. Columella with four strong oblique folds; lip smooth, finely lirate within, parietal ridge present.

Color pale pinkish russet (probably a deeper red-brown in living animals); extremities and columellar folds creamy white; ribs whitish. Animal unknown.

The type locality of *Vexillum kewaloensis* is Kewalo, Oahu, Hawaii (21° 18' North Latitude, 157° 51' West Longitude). So far as is presently known, its range is from



Kewalo to Laysan Island.

Derivation of the name *kewaloensis* is from the type locality, Kewalo Basin, a marine yacht harbor at Honolulu.

The holotype is in the U. S. National Museum (No. 333316) (figure 1, Plate 5). Hypotype 1, from Laysan Island, is USNM 217083. There are four paratypes in the collection of Jens M. Ostergaard (figures 2 to 5, Plate 5), who very kindly loaned his specimens for this study, and one in my own collection. (See Table 1.)

I have not seen additional specimens, nor was this species known to the Hawaiian collectors (with one exception) from the unidentified photograph I submitted to them. Dr. Alison Kay made the following notation regarding this particular photograph: "Apparently *M. kewaloensis* DALL MSS.—'Kewalo'—C. F. Mant. But there are several specimens in Bishop Museum from 'Honolulu Harbor dredgings' labelled variously. A lot of variation among them, too." I believe there may be more than one species in this group mentioned by Dr. Kay; completely faded, white specimens of a related unknown species not covered in this paper are difficult to distinguish from *Vexillum kewaloensis* without a close scrutiny. DALL's manuscript name has evidently been used in the Bishop Museum collection.

Further study and additional material may tend to show that *Vexillum kewaloensis* is allied with the small subgenus *Idiochila* PILSBRY, 1920—a group established for *V. (I.) turben kanaka* PILSBRY, 1920 (= *V. (I.) turben* [REEVE, 1844]). *Vexillum kewaloensis* is much more slender and fusiform than *V. turben*, which is swollen

and bulbous at the periphery and has more distinct interstitial sculpture (almost approaching a cancellate appearance); in addition, *V. kewaloensis* has a smooth, shining surface, whereas *V. turben* is dull.

Vexillum kewaloensis has several morphological characteristics in common with *V. georgii* (MELVILL & SYKES, 1899), but differs from that species in that it has strongly nodulose spiral cords on the neck of the shell, whereas this area is fairly smooth in *V. georgii*; *V. kewaloensis* appears to be devoid of surface ornament, while *V. georgii* has a narrow whitish spiral band below the sutures; there is pronounced interstitial sculpture present in *V. kewaloensis* that is absent in *V. georgii*; further, *V. kewaloensis* has a more delicate appearance and the color may be different. However, since *V. kewaloensis* is now known only from subfossil specimens, it is impossible at this time to ascertain whether the shells of living animals are as dark a color as that of *V. georgii*, which is nearly black.

An earlier named species, *Vexillum aubryana* (HERVIER, 1897) may be conspecific with *V. georgii*; its type figure and description indicate several features that are similar to that species. Both of these little-known forms will need further study before a decision may be made as to whether they comprise one species or two, and whether *V. kewaloensis* may belong in the synonymy of either. However, all three are of such rare occurrence and from such widespread type localities (Andaman Islands, New Caledonia, and Hawaii, respectively) that it seems reasonable to assume, on the basis of evidence available at the present time, that they are all separate species.

Table 1

Data for all known specimens of *Vexillum kewaloensis* J. CATE, spec. nov.

(Measurements in millimeters)					
Specimen	Collection	Locality	Collector	Length	Width
Holotype	USNM 333316	Kewalo, Oahu	C.F. Mant	12.0	4.5
Hypotype 1	USNM 217083	Laysan Island	W.H. Golisch	9.6	4.3
Hypotype 2	Ostergaard Coll.	Honolulu	J.M. Ostergaard (1915)	10.5	4.3
Hypotype 3	Ostergaard Coll.	Honolulu	J.M. Ostergaard (1915)	10.6	4.7
Hypotype 4	Ostergaard Coll.	Honolulu	J.M. Ostergaard (1915)	11.6	4.5
Hypotype 5	Ostergaard Coll.	Honolulu	J.M. Ostergaard (1915)	11.8	4.5
Paratype 1	J. Cate Coll.	Kewalo dredgings	Morris Schick (1929)	11.5	4.6

Vexillum moana J. CATE, spec. nov.

(See figures 6 to 10, Plate 5)

Mitra batista DALL MS (*nomen nudum*)

Mitra eruda DALL MS (*nomen nudum*)

Shell small (approximately 15 mm in adult specimens), oblong-ovate, spire somewhat turriculate, longer than the last whorl. Protoconch conical, homostrophic, deviated, consisting of about 2½ whorls. Telcoconch in adult specimens consists of about nine convex whorls; shoulders somewhat rounded and ornamented with strong continuous spiral sculpture, nodulose on the summits of the axial ribs. Axial sculpture of raised equidistant collabral costae (about 19 on the penultimate whorl). Lip simple, weakly lirate within, lirae faintly granulose. Four sharp oblique folds on the columella.

Color of the shell dark brown in living animals, with spire, columella, neck and rib-tubercles pure white. A wide, smooth, shiny brown zone surrounds the shell below the periphery, this band devoid of ornament except for infrequent small white tubercles on the axial ribs, evenly spaced in the center of the brown zone and occurring with greater frequency abapically, giving the appearance of a row of tiny pearls along the axial ribs. Nodulose white spiral cords reappear on the neck of the shell. Small, uneven brownish patches between the axial ribs, on the shoulders.

Most known specimens are subfossil, with the resulting typical paler color (see figs. 6 and 7, Plate 5). The animal of the species is unknown.

The type locality of *Vexillum moana* is Waikiki, Oahu, Hawaii (21° 18' North Latitude, 157° 51' West Longitude).

The name *moana* is an Hawaiian word meaning "deep

sea" — an appropriate designation for a species known at this time only from a depth of at least 100 feet.

The holotype and several juvenile paratypes are in the U. S. National Museum; hypotypes are in the collections of the Santa Barbara Museum of Natural History, Ditlev Thaanum (Honolulu) and J. Cate (Los Angeles) as listed in Table 2.

It is hoped that publication of the figures accompanying this paper will bring other specimens of this apparently rare species to our attention, with the data necessary to define its range. At the present time *Vexillum moana* is presumed to range from the south shore of Oahu to Okinawa.

Vexillum moana is known to me from only three or four adult specimens and nine microscopic juveniles; of these, the holotype is the only live-collected specimen. The type (chosen by DALL as the type of *Mitra batista*) is considerably smaller than the other adult specimens in the type lot, but it was selected as holotype because it alone shows the true color of a living specimen instead of the typical faded orange tone of subfossil specimens, as seen in the accompanying color reproductions on Plate 5.

Six paratypes are minute juvenile specimens (all from Thaanum lot 8397) that were designated by DALL as the type lot of *Mitra eruda*; evidently the much smaller size led him to regard it as a different species. Three identical specimens (with the same lot number) remain in the Thaanum Collection.

The three hypotypes, all relatively large subfossil adult shells of about equal size, are from various localities other than the type locality (see Table 2). The only apparent difference between the hypotypes and the holotype is their larger size. Although Hypotype 1 was in the general collection at USNM, it was not included by DALL as a part

Table 2

Data for all known specimens of

Specimen	Collection	Locality and
Holotype	USNM 338665	Dredged off Waikiki in 33 to 50 fathoms, D. Thaanum No. 8397
Paratypes 4 to 7	USNM 333027	Dredged off Waikiki in 33 to 50 fathoms, D. Thaanum No. 8397
Paratypes 8 to 10	Thaanum No. 8397	Dredged off Waikiki (Map 34, loc. 8) in 200 to 300 feet,
Hypotype 1	USNM 542590	Midway; J. G. Crafts leg.
Hypotype 2	SBMNH 00721	Okinawa; Morton L. Vance, Jr., leg.
Hypotype 3	Cate No. M 2843	Dredged in 45 feet, entrance to Pearl Harbor, Oahu;

of his originally selected type material; however, I recognized it as the same species and therefore have included it in the type lot of *Vexillum moana*. Its museum label is written in pencil: "*Mitra ?affinis* REEVE".

Vexillum moana is quite different from all the better-known forms of *Vexillum*; however, the type figure of *Mitra* (*Costellaria*) *pagodula* HERVIER (1897, Pl. 9, fig. 6), bears a certain resemblance to it that must not be overlooked. I have not seen an example of *M. pagodula*, but from HERVIER's description I would say that it is distinct from *Vexillum moana* in the following ways: it has a higher, more angled spire, more sloping and less rounded shoulders; it has a heavier, porcellaneous texture; it lacks the white nodules on the ribs within the brown zone; it has a wider aperture and a less convex outline. The type locality of *Mitra pagodula* is New Caledonia.

The survey I conducted among collectors in Hawaii brought forth the information that two or three additional specimens of *Vexillum moana* (determined from my unidentified photograph by Drs. Burgess and Richert) were collected by the Pele I and II Expeditions in 1959 and 1962, dredged in 18 to 20 fathoms on a sand and coral substrate in the area off Ewa, Makua, Kewalo Basin and Waikiki, Oahu. Mr. Ellis Cross also reported having collected a dead specimen while diving in 100 feet of water on coral rubble off Diamond Head, Oahu, in May 1962. I have not seen any of these latter specimens, but their reported collecting localities all fall within approximately 35 nautical miles of the type locality.

Vexillum pailoloanum, J. CATE, spec. nov.

(See figures 11 to 13, Plate 6)

Mitra pailoloana DALL MS (*nomen nudum*)

Mitra languida DALL MS (*nomen nudum*)

Shell of moderate size (approximately 30 mm in length, 11 mm in greatest diameter), fusiform, whorls moderately inflated. Nuclear whorls missing in all type specimens, about six whorls remaining. Spire whorls longitudinally ribbed (about 20 low, rounded ribs on antepenultimate whorls), ribs more or less obsolete on last whorl in adult specimens. Weak transverse spiral striae present throughout, strongest below the periphery. Aperture wide, outer lip simple, canal a little recurved toward the dorsum, columella usually with three strong folds.

Color a dull sandy straw-beige throughout (faint indication of a darker brown peripheral band present in a subadult specimen only); columella and aperture white, shining. Two specimens with weak columellar folds and less attenuate canals. The animal is unknown.

The type locality of *Vexillum pailoloanum* is the Pailolo Channel, between Maui and Molokai, Hawaiian Islands (21° 15' North Latitude, 156° 30' West Longitude).

In color and surface ornament, *Vexillum pailoloanum* somewhat resembles *Strigatella stricta* (REEVE, 1844), but it is a much thinner, lighter-weight species and has none of the characters typical of *Strigatella* such as the heavy, thickened outer lip. Furthermore, its columellar folds are fewer in number, it has the characteristic vexillid ribs and the shell is more elongate; in general shape the shell of *V. pailoloanum* is more typical of *Volutomitra* than of *Strigatella*.

The holotype (USNM 173 008), three paratypes and three hypotypes are in the United States National Museum (see Table 3). I have seen no other specimens of this species, though Dr. T. Richert reported one dead specimen, dredged in rubble in 30 fathoms off Pearl Harbor by the Pele I Expedition, 1959. There may be additional specimens at the Bishop Museum; Dr. Alison Kay's com-

Table 2

Vexillum moana J. CATE, spec. nov.

(Measurements in millimeters)			
Collector	Length	Width	
	6.1	2.7	DALL's type of <i>Mitra batista</i>
largest:	4.7	2.0	DALL's types of <i>Mitra eruda</i>
smallest:	2.8	1.3	
D. B. Langford, coll., 1917 approximately the same as	Paratypes 1 to 7 above		<i>Mitra</i> sp.
	15.4	6.8	" <i>Mitra ?affinis</i> REEVE"
	15.1	6.7	unidentified
Morris Schick leg., 1929	15.4	6.2	unidentified

Table 3

Data on *Vexillum pailoloanum* J. CATE, spec. nov.

Specimen	Museum No.	DALL'S Designation	Depth in fathoms	Station No.	Locality
Holotype	USNM 173008	"Fig'd type" <i>Mitra pailoloana</i>	256 to 283	3865	Pailolo Channel
Paratype 1	USNM 335349	<i>Mitra pailoloana</i>	256 to 283	3865	Pailolo Channel
Paratype 2	USNM 173007	"Fig'd type" <i>Mitra languida</i> ^{1 2}	256 to 283	3865	Pailolo Channel
Paratype 3	USNM 335266	<i>Mitra languida</i> ²	256 to 283	3865	Pailolo Channel
Hypotype 1	USNM 172992	"Fig'd type" <i>Mitra languida</i> ¹	259 to 266	3839	S. Coast Molokai Island
Hypotype 2	USNM 335263	<i>Mitra languida</i>	352 to 357	4123	S.W. Coast Oahu Island
Hypotype 3	USNM 335264	<i>Mitra languida</i>	294 to 330	3917	S. Coast Oahu Island

All specimens were collected by the U.S. Fish Commission

¹ Note two lots with identical notation.² Aberrant form.

ments on my photograph of USNM 172 992 are as follows: "There are at least three 'species' which are similar to the photograph — differ in columellar plaits and color but may be beach specimens." I know no further particulars about those shells, though it is possible some of them may have been collected by the U. S. Fish Commission at the same time as the type lot.

The groups of shells called *Mitra pailoloana* and *M. languida* presented several unusual problems; of seven specimens from four different dredging stations, Dall had labelled two *M. pailoloana* and five *M. languida*. Of the latter five, however, three specimens are identical with his type of *M. pailoloana*, while the other two seem somewhat different. I therefore rearranged the groups, using the name *pailoloana* for the larger series of five shells. The two remaining specimens (appropriately called *M. languida*) possess such extremely weak columellar folds that I experienced some doubt of their being mitrids; moreover, they have a shorter posterior canal than the usual *Mitra* or *Vexillum*. Data on the shells (see Table 3) showed that two specimens from each group had evidently

been collected in the same dredge haul, as the depth record and station number were identical on each of four different lots. However, since I have so far been unable to locate another generic group to which the second form might more appropriately be assigned, I have concluded that Dall's *Mitra languida* may possibly be an aberrant form of *M. pailoloana*, its deviation from the others being due perhaps to the great depth at which the mollusks were collected, their known benthic range lying between 1500 and 2000 feet.

Two important considerations influenced my line of reasoning; first, that both "species" were probably taken in the same dredge haul, and second, that the two forms strongly resemble one another except for the two morphological characters already mentioned as atypical of mitrids in general. Until additional material of both forms can be collected and further studied, I propose placing *Mitra languida* in the synonymy of *M. pailoloana* (= *Vexillum pailoloanum*) though I realize there are several possibilities that may eventually change this assignment.

Explanation of Plate 5

Vexillum kewaloensis J. CATE, spec. nov.

Figure 1: Holotype, USNM 333 316 (x 2); Figures 2 to 5: Hypotypes 4, 3, 5, and 2, respectively, ex J. M. Ostergaard Coll. (x 3)

Vexillum moana J. CATE, spec. nov.

Figures 6 and 7: Hypotype 3, ex Cate Coll. (x 3¼)
Figure 8: Hypotype 1, USNM 542 590 (x 2) Figure 9: Holotype, USNM 338 665 (x 4) Figure 10: one of seven minute paratypes, in lot numbered USNM 333 027 (x 4)

All photographs on this plate by T. Susuki.



Figure 1



Figure 2

Figure 3



Figure 4

Figure 5



Figure 6



Figure 7



Figure 8



Figure 9



Figure 10

Mitra climacella DALL MS (*nomen nudum*)

This species is not a mitrid, and therefore has been omitted from the group Dall intended to include among his new species of *Mitra* from Hawaii. In addition to the type lot at the United States National Museum, there is one lot also at the Museum of Comparative Zoology, Harvard University. Other specimens bearing this name may exist in other collections, hence its inclusion here to call attention to its invalid name.

Mitra iota DALL MS (*nomen nudum*)

(See figure 14, Plate 6)

I do not consider that there is enough material available at the present time to justify validating *Mitra iota*. Dall's holotype is USNM 173200, from Station 3846 off the south coast of Molokai Island, dredged in 60 to 64 fathoms by the U. S. Fish Commission. It is a single, totally bleached minute shell that does not retain enough of the characters of a living animal to make possible a positive determination as to whether or not it is conspecific with an already described one. To a certain degree it resembles *Mitra cerithina* MELVILL, 1888, possibly a juvenile specimen of *Mitra bronni* DUNKER, 1861, or even, perhaps, a very young *Vexillum kewaloensis* (see page 26 ff.), but in my opinion no decision should be made on this species without a larger, more representative series for careful study.

Pusia alveolus (REEVE, 1845)

(See figures 15 to 18, Plate 6)

Mitra olgae DALL MS (*nomen nudum*)*Mitra stearnsiana* DALL MS (*nomen nudum*)*Mitra propetusa* DALL MS

1845. *Mitra alveolus* REEVE, Conch. Icon. 10, Pl. 32, sp. 334
1874. *Mitra alveolus* REEVE, SOWERBY, G. B., Thes. Conch. 4:330; Pl. 22, fig. 477 (not 476)
1882. *Turricula (Pusia) alveolus* (REEVE), TRYON, G. W., Jr., Man. Conch. 4:184; Pl. 55, fig. 586
1933. *Mitra (Pusia) alveolus* (REEVE), Dautzenberg and Bouge, Journ. de Conchyl. 77:153. Not figured.

{Ed. Note: The quotations of the original descriptions are set indented instead of in quotation marks.}

The Chess-board Mitre. Shell shortly ovate, sutures of the spire deeply impressed; longitudinally finely plicately ribbed, transversely grooved at the base; whorls jet black round the lower part, white above, tessellated with black; columella four-plaited. Hab. —?

Dall's types are as follows:

Mitra olgae (= *Pusia alveolus* [REEVE]); USNM 339851 (TYPE); Waimea, Oahu; Olga Smith coll. (one specimen). USNM 338700, Laysan Id. (worn); Golisch

coll. (22 specimens).

Mitra stearnsiana (= *Pusia alveolus* [REEVE]); USNM 335444 (TYPE and Fig'd. type), Honolulu; F. Stearns coll. (two specimens in separate vials).

Mitra propetusa (= *Pusia alveolus* [REEVE]); USNM 333345 Hilo, Hawaii; F. Stearns coll. (two specimens in separate vials).

I can see no differences among the three "species" proposed by DALL as new, and all three agree closely with typical *Pusia alveolus* (REEVE). All of Dall's specimens are subfossil, some worn smooth and others merely faded in color, though fairly well preserved otherwise. I have seen one freshly-collected live-taken specimen (dredged in 100 feet off the south shore of Oahu, Pele I Expedition, April 1959) that is a little larger than any others I have encountered, a very dark brown shell (nearly black) with a white band below the sutures and occasional white flame-like spots that extend from the white band to the suture next above. Other specimens in the Thaanum Collection are smaller and somewhat faded, though undoubtedly the same species; these are labelled *Mitra tusa* REEVE, but after studying Reeve's type figures of both species I believe they more closely resemble *Pusia alveolus*. This misidentification may have been based on an incorrect figure designation in the Sowerby monograph; Dall apparently also misidentified this species, considering at least one of his new forms similar to *M. tusa*, the name *propetusa* meaning "close to *tusa*".

Pusia alveolus is not common in Hawaii, being represented in private collections there by not more than about a dozen specimens. It has been collected in depths from four feet to 20 fathoms, in sand and coral rubble. Dr. Alison Kay reports specimens of *P. alveolus* in the Bishop Museum from all islands from Laysan to Hawaii; records in the Thaanum catalog substantiate the occurrence of the species even farther northward, at Midway Atoll. It is known elsewhere in the Pacific, from Lord Hood's Island, French Oceania; Lifu, New Caledonia; from Mindoro and Palawan in the Philippines, and from Japan.

Pusia patriarchalis (LAMARCK, 1811)

(See figures 19 and 20, Plate 6)

Mitra depressa DALL MS (*nomen nudum*)

1797. ——— Encyclopédie Méthodique, Pl. 374, figs. 1a, 1b
1811. *Mitra patriarchalis* LAMARCK; Ann. Mus. Nat. Hist., 16: 216, no. 55; not figured.
1844. *Mitra patriarchalis* LAMARCK, REEVE, L., Conch. Icon. 10, figs. 146a, 146b
1874. *Mitra patriarchalis* LAMARCK, SOWERBY, G. B. Thes. Conch. 4: sp. 322, figs. 505, 506
1882. *Turricula patriarchalis* (LAMARCK), TRYON, G. W., Jr., Man. Conch. 5: 191; Pl. 56, fig. 621

M. Ovata, transversè striata, fulva s. spadicea; anfractibus supernè angulatis, plicatis, nodulosis, albo fasciatis; basi granosâ; columellâ quadruplicatâ. Mus. n. 51, Encycl., pl. 374, f. 1a, b. Specimen junius. Chemn. Conch. 10, t. 150, f. 1425, 1426.

Habite l'Océan indien. Quoique petite, cette mitre est fort jolie et à caractères bien prononcés. Sa moitié supérieure ressemble à une thiare blanche, étagée, et couronnée de tubercles. Le fond rouge-brun de cette coquille ne se montre que comme une large zone sous la dernière rangée de tubercles, et au-dessous l'on retrouve une zone blanche qui recouvre la base granuleuse de la coquille; quatre plis à la columelle. Longueur, 2 centimètres. Mon Cabinet. *Nota.* Les sutures sont distinctement crénelées.

Dall's type specimen of *Mitra depressa* (= *Pusia patriarchalis* (LAMARCK)) (USNM 339 838) is a single, badly beachworn specimen. It was collected at Waimea, Oahu by Olga Smith; its condition is so poor as to suggest deformity, but this condition is possibly due to wave-action and erosion.

Pusia patriarchalis is rare in Hawaii, and the few specimens to be seen in local collections were mostly collected on the beaches and reefs after severe storms, suggesting the possibility of a deep-water habitat as yet undiscovered. Only about a dozen specimens have been collected around Oahu, according to the information sent me in response to my questionnaire; of these, probably less than half were collected alive. The species is more common at Okinawa, the Philippine Islands, and Australia's Great Barrier Reef. As quoted above, its type locality is the Indian Ocean.

The name *Pusia patriarchalis* has been mistakenly applied, in Hawaii, to *P. tuberosa* (REEVE, 1845), following the misidentification of that species in TINKER (1958, p. 156). *Pusia tuberosa* is a more common species in Hawaii than *P. patriarchalis*; it will be illustrated and discussed in a subsequent paper.

Vexillum collinsoni (A. ADAMS, 1864)

(See figure 21, Plate 6)

Mitra polycymata DALL MS (*nomen nudum*)

1864. *Costellaria collinsoni* A. ADAMS, Journ. Linn. Soc. 7: 200. Not figured.
1874. *Mitra collinsoni* ADAMS, SOWERBY, G. B., Thes. Conch. 4, sp. 482; figs. 621, 622
1882. *Turricula (Costellaria) collinsoni* A. ADAMS, TRYON, G. W., Jr., Man. Conch. 4: 172; Pl. 51, figs. 458, 460, 461
1961. *Mitropifex collinsoni* (A. ADAMS), HABE, Col. Illust. Shells of Japan, Pl. 34, fig. 6; p. 69, no. 6

C. testa turriformi, castanea, fascia fulva transversa in medio anfractuum ornata, spira elata conoidali quam apertura longiore; anfractibus 9, planis, longitudinaliter costatis, costis mediocribus, dis-

tantibus, interstitiis transversim valde sulcatis; apertura angusta, labio plicis tribus obliquis instructo, labro intus lirato ad marginem laevi. Hab. Kino-O-Sima.

I have named this pretty species after John Collinson, Master R. N., my frequent companion in my Japanese wanderings, and a most assiduous and able collector.

Dall's type of *Mitra polycymata* (= *Vexillum collinsoni* A. ADAMS) is a faded but well preserved specimen (US NM 173 005), dredged in 128 to 138 fathoms at Station 3858 in the Pailolo Channel, Hawaiian Islands, by the U. S. Fish Commission. The earlier figures of *V. collinsoni* by SOWERBY and TRYON are not adequate illustrations, but the color reproduction in HABE (1961) depicts the species well, giving a clear indication of the characteristically sinuous ribs which serve to separate *V. collinsoni* from its most closely related forms.

For the most part, the Hawaiian collectors who took part in my survey of the "Dall species" were unfamiliar with *Vexillum collinsoni*. One faded specimen was noted from the beach at Paumalu, Oahu in 1960; the only other specimens known seem to have come from the Pele I Expedition, dredged in 20 to 45 fathoms in Kechi Lagoon and off Ewa, Oahu. The only type of substrate mentioned is "rubble". A few live-collected shells from the Keehi Lagoon station are on loan to me at the present time for identification; these show a deep rusty-red color with beige-white bands, whereas the Dall specimen and one or two of the Pele I shells have faded to a yellow-orange color.

The data for the few specimens known at the present time seem to indicate a deep-water habitat for *Vexillum collinsoni*. Its geographic range is apparently from Hawaii to as far west as Japan; at the present time I know of no other verified record for this species.

Vexillum comptum (A. ADAMS, 1853)

(See figure 22, Plate 6)

Mitra farda DALL MS (*nomen nudum*)

1853. *Mitra compta* A. ADAMS. Proc. Zool. Soc. London, pt. 19, p. 134. Not figured.
1870. *Mitra corbicula* SOWERBY. Proc. Zool. Soc. London, p. 258. Not figured.
1874. *Mitra compta* A. ADAMS, SOWERBY, G. B. Thes. Conch. 4, sp. 445, fig. 540.
1874. *Mitra corbicula* SOWERBY. Thes. Conch. 4, sp. 444, fig. 538.
1882. *Turricula (Costellaria) corbicula* SOWERBY, TRYON, G. W. Jr., Man. Conch. 4: 172; Pl. 51, fig. 457.

M. testâ ovato-fusiformi; spirâ aperturâ longiore; anfractibus subrotundis, supernè angulatis, sordidè albâ, longitudinaliter plicatâ; transversim lirata, liris

apud plicis nodulosis; interstitiis valdè et regulariter clathratis, anfractu ultimo anticè angustato et reflexo; columellâ plicis quinque instructâ; labro internè sulcato, margine crenulato. Hab. China Seas.

This species, remarkable for the strong cancellations between the longitudinal plicae, was brought home in H. M. S. Samarang.

Dall's type of *Mitra farda* (= *Vexillum comptum* (A. ADAMS)) is a rather faded specimen (USNM 338 010) collected by Thaenum at Keaukaha, Hawaii (Thaenum No. 7828c). Other lots of the same species in the Thaenum Collection (7828, 7828c, d, e) were collected in depths of from 12 to 30 fathoms, off Waikiki and Waialua Bay, Oahu, between 1916 and 1938.

Vexillum comptum is a relatively little-known species; Sowerby's figure of it may be the only one so identified until now. Tryon incorrectly made *V. comptum* a synonym of *V. militaris* (REEVE, 1845). There are other very similar species that I have considered in studying *V. comptum*; for one example, *Mitra modesta* REEVE, 1845, also known from Hawaii, has identical surface ornament, but a more obese and convex outline.

Except for the presence of a few irregularly spaced small brown spots on the periphery, *Mitra corbicula* SOWERBY, 1870 seems otherwise identical with *Vexillum comptum*. After studying about a dozen specimens from Hawaii, I now believe the brown spots typical of *M. corbicula* are merely worn off or faded from the specimens referable to *Vexillum comptum*. A specimen on loan to me for identification from the C. S. Weaver Collection is one I had tentatively called *Mitra corbicula*; it was dredged in 45 fathoms in Keehi Lagoon, Oahu, by the Pele I Expedition. This specimen has several small brown spots just above the sutures and on the periphery of the last whorl; there is also a faint indication of two or three narrow pink bands on the body whorl. A single specimen in the Thaenum Collection that must have been collected with Dall's type of *Mitra farda* (it is the only other specimen from Keaukaha) shows a faint trace of the brown spots, and another shell from off Waikiki shows a hint of pink at the base. Otherwise, all except Mr. Weaver's shell appear either dead and bleached, or covered with a dirty coating that obscures any pattern. It is a possibility that the brown spots may not always be present, even in living specimens. For all these reasons I believe these two forms are conspecific, and I have therefore placed Sowerby's name *Mitra corbicula* in the synonymy of the earlier name, *Vexillum comptum*.

Pending further study, it seems best not to cite a geographical range for this species at the present time. *Mitra corbicula* has been recorded from Mauritius and New Caledonia; the type locality of *Vexillum comptum*, "China Seas", is rather vague, though we may assume that it came from somewhere along the route of the Voyage of

the Samarang, which covered a good deal of the Philippine area and extended southward into the Sulu Sea. Even though we know of several verified collecting stations in Hawaii, it would be inadvisable to cite the Hawaiian Islands as a new type locality until we know the approximate center of the species' range.

Only one of the Hawaiian collectors who answered my questionnaire recognized this species from its photograph; Mr. Ellis Cross reports having collected four living specimens in 90 feet of water in a sand pocket under a coral slab off Barber's Point, Oahu in January 1962.

Adult specimens of *Vexillum comptum* range in size from about 15 to 20 mm long, and from six to seven mm in diameter.

Vexillum exquisitum (GARRETT, 1873)

(See figure 23, Plate 6)

Mitra mitata DALL MS (*nomen nudum*)

1873. *Mitra exquisita* GARRETT. Proc. Zool. Soc. London, p. 839. Not figured.

1875. *Mitra suavis* SOUVERBIE. Journ. Conchyl. 23: 285; Pl. 13, fig. 3.

1922. *Mitra (Pusia) suavis* SOUVERBIE, DAUTZENBERG & BOUGE, Journ. Conchyl. 67: 244. Not figured.

Shell small, oblong, subfusiform, glassy, hyaline, pinkish red, with two transverse brown lines enclosing a white band, the band and one line continued up the spire; spire rather short, turreted, subacute, little more than half the length of the shell; whorls 9 (3 of which are embryonal), plano-convex, shouldered above, the last rounded, much contracted and granulated at the base, which is produced in a short slightly twisted canal; longitudinally ribbed, ribs closely set, rather large, angular, slightly nodulose above, 12 to 13 in number, interstices transversely impressly striated; aperture narrow; outer lip rather thin, notched above, and slightly sinuous; columella with four folds.

Length 5 mill., diam. 3½ mill.

Hab. Paumotu, Tahiti, Cook's, Samoa, and Viti Islands (coll. Garrett). It belongs to the same group as *M. recurva* and *mirifica*. Notwithstanding its wide range, it is a rare species. Under stones on reefs.

Dall's type of *Mitra mitata* (= *Vexillum exquisitum* (GARRETT)) is a single, bleached specimen (USNM 333 369) from Kewalo, Oahu; C. F. Mant, leg. This shell is so badly faded that it appears totally white except for an indication of two narrow brown spiral lines at the periphery. When collected alive, *V. exquisitum* is a very attractive minute species, bright rose color with a white spiral zone between the narrow chestnut bands. It is evidently one of the rarest mitrids in Hawaii, as none of the present-day collectors who helped me with the modern records had ever seen a specimen of it. I was unable to

ascertain before this manuscript went to press whether any may exist in the Bishop Museum Collection.

A few specimens in the Thaanum Collection are labelled *Mitra suavis* SOUVERBIE, but these have been incorrectly identified and are, in fact, *Vexillum rubrum* (BRODERIP, 1836) (*M. rhodochroa* HERVIER, 1897). These two species are very similar and have confused nearly every monographer of the Mitridae; I have therefore purposely omitted the references of Reeve, Sowerby, and Tryon in this paper. Both species will be illustrated and discussed in a later study; for the purpose of brevity I will mention only the most important differences between them: *Vexillum exquisitum* has distinctive nodules at the upper ends of the ribs that are lacking in *V. rubrum*; *V. rubrum* has also a much more convex and inflated shape than *V. exquisitum*.

The validity of Garrett's name for this species has been questioned; DAUTZENBERG & BOUGE (1922) placed it in the synonymy of *Mitra suavis* SOUVERBIE because Garrett did not publish an illustration with his description, and further assigned it to an incorrect subgenus. However, I believe the Dautzenberg and Bouge assignment to *Pusia* is also incorrect, and since with Garrett's excellent description it is possible, even without a figure, to distinguish between the two very similar species discussed above, the restoration of the earlier name *Vexillum exquisitum* seems fully justified.

Unfortunately, Garrett did not cite a type locality for *Vexillum exquisitum*, though he mentioned five widely

separated localities in the central Pacific where he had personally collected it. Therefore Souverbie's citation of Lifu, New Caledonia, will necessarily remain the type locality even though this is probably close to the extreme southern end of the range of the species. One of Garrett's localities would have been more suitable, being nearer to its apparent center of distribution.

The known range of this species at the present time is from Lifu, New Caledonia to Oshima-Osumi, Japan; Dall's Hawaiian specimen serves to extend the range eastward approximately 60 degrees of longitude and northward (from Tahiti) approximately 40 degrees of latitude.

Souverbie remarked that all six of the specimens he used in describing *Mitra suavis* had the lower edges of the outer lips broken off, as is also the case with Dall's specimen. *Vexillum exquisitum* probably should be assigned to the small subgenus *Idiochila*, which was established by PILSBRY in 1920 for *Vexillum turben* (REEVE). The tendency to have a weak outer lip is only one of several morphological characters typical of *Idiochila* that seem applicable to this species.

Vexillum micra PILSBRY, 1920

(See figures 24 to 26, Plate 6)

Mitra elima DALL MS (*nomen nudum*)

1920. *Vexillum micra* PILSBRY, H. A., Proc. Acad. Sci. Phila., 72: 317. Not figured.

1962b. *Vexillum micra* PILSBRY, CATE, The Veliger 4 (3): 147; Pl. 34, fig. 6 (type figure).

Explanation of Plate 6

Vexillum pailoloanum J. CATE, spcc. nov.

Figure 11: Holotype, USNM 173 008 (x 2) Figure 12: Paratype 2, USNM 173 007 (x 2) Figure 13: Hypotype 1, USNM 172 992 (x 1)

Figure 14: *Mitra iota* DALL MS (*nomen nudum*); USNM 173 200 (x 4)

Pusia alveolus (REEVE)

Figure 15: type of *Mitra olgae* DALL MS, USNM 339 851 (x 3)

Figure 16: type of *Mitra propetusa* DALL MS, USNM 333 345 (x 4)

Figure 17: type of *Mitra stearnsiana* DALL MS, USNM 335 444 (x 3)

Figure 18: typical specimen of *Pusia alveolus* (REEVE) ex Cate Coll. (x 3)

Pusia patriarchalis (LAMARCK)

Figure 19: type of *Mitra depressa* DALL MS,

USNM 339 838 (x 2)

Figure 20: typical specimen of *Pusia patriarchalis* (LAMARCK), ex Cate Coll. (x 2)

Figure 21: *Vexillum collinsoni* (A. ADAMS) — type of *Mitra polycymata* DALL MS, USNM 173 005 (x 2)

Figure 22: *Vexillum comptum* (A. ADAMS) — type of *Mitra farda* DALL MS, USNM 338 010 (x 2)

Figure 23: *Vexillum exquisitum* (GARRETT) — type of *Mitra mitata* DALL MS, USNM 333 369 (x 3)

Vexillum micra PILSBRY

Figure 24: type of *Mitra elima* DALL MS, USNM 338 081 (x 4)

Figures 25 and 26: types of *Vexillum micra* PILSBRY, Acad. Nat. Sci. Phila. 116 986 (Stanford University photograph, x 4)

All photos on this plate by T. Susuki, except as noted.



Figure 11



Figure 12



Figure 13



Figure 14



Figure 15



Figure 16



Figure 17



Figure 18



Figure 19



Figure 20



Figure 21



Figure 22



Figure 23



Figure 24



Figure 25 Figure 26

The shell is fusiform, vinaceous tawny with a band at the periphery and another on the base of burnt umber. Sculpture of many vertical rounded ribs, about 30 on the last whorl, the intervals with wide, low spiral cords separated by impressed lines, of which there are 4 on the penult whorl; base with spiral cords. Aperture colored like the outside. Columella with four plaits. The embryonic shell is long-conic, of about $3\frac{1}{2}$ smooth whorls. Length 6.5, diameter 2.7, aperture 3 mm.; $5\frac{1}{2}$ post-embryonic whorls. Off Waikiki, Oahu, in 25 - 50 fms. D. B. Langford. One specimen is a little stouter and lacks the lower brown band.

Dall's type lot of *Mitra elima* (= *Vexillum micra* PILSBRY) consists of six specimens in two vials, one of these marked TYPE. USNM 338 081 ex Thaanum Coll. 5252; off Waikiki, Oahu, in 33 to 50 fathoms.

One lot (No. 5252), consisting of two specimens of this tiny, rare species, was found among unidentified material in the Thaanum Collection loaned to me. Since catalog numbers and locality data agree with the information on the USNM label for Dall's *Mitra elima*, there is little doubt that these are all identical material. There is also a very strong probability that Pilsbry's type lot of *Vexillum micra* likewise came from Thaanum Lot 5252, as its data are very similar though the original lot number has evidently not been recorded on the label of the Academy of Natural Sciences of Philadelphia. One additional lot (5252a) is recorded in Thaanum's catalog; these shells were dredged in 1935 by Thaanum and Langford in 20 to 30 fathoms off Waikiki. I have not seen lot 5252a.

In early January 1963, Mr. Clifton Weaver sent me for identification a small mitre that he had collected alive at a depth of approximately 55 feet, under coral in sand at Mokolea Rock, Kailua Bay, on the windward side of Oahu — the opposite shore from the type locality of *Vexillum micra*. He pointed out certain obvious resemblances to *V. micra* in the early whorls of his specimen, which is, however, considerably larger than any of the other known shells of that species. I now believe, after a thorough study of all the specimens, that Mr. Weaver's shell may be the only known adult specimen of *V. micra*, and the first to be collected alive. It differs from the others only in being larger and more attenuate, and, of course, has a darker color which is to be expected in a living example. This shell is chocolate brown with a narrow white band a short distance below the sutures. It measures 9.2 mm in length, 3.5 mm in greatest diameter, and its aperture is 4.2 mm long. It has a total of eight whorls — two and a half more than the holotype. It is very finely nodulosely lirate within the inner lip — a character either lacking or difficult to discern in the minute, faded specimens of the other lots.

Vexillum millecostatum (BRODERIP, 1836)

(See figures 27 to 29, Plate 7)

Mitra lipara DALL MS (*nomen nudum*)

1836. *Tiara millecostata* BRODERIP, W. J., Proc. Zool. Soc. London, p. 195. Not figured.
1844. *Mitra millecostata* SWAINSON (BRODERIP) REEVE, L. Conch. Icon. 10, sp. 301
1860. *Mitra picea* PEASE, W. H., Proc. Zool. Soc. London, p. 146. Not figured.
1874. *Mitra millecostata* SWAINSON, SOWERBY, G. B., Thes. Conch. 4: 22; sp. 480
1880. *Turricula millecostata* SWAINSON, GARRETT, A., Jour. Conch. 3: 51
1882. *Turricula (Pusia) millecostata* SWAINSON, TRYON, G. W., Jr., Man. Conch. 4: 185; Pl. 55, fig. 588
1933. *Mitra (Pusia) millecostata* SWAINSON, DAUTZENBERG & BOUGE, Journ. de Conchyl. 77: 175. Not figured.

Tiara testa subovata, longitudinaliter creberrime costata, basi cancellata, nigro-castanea, apice albido; columella triplicata: long. $\frac{1}{2}$, lat. $\frac{1}{4}$ poll.

Hab. ad Insulam Annaan. Found on the reefs in shallow water.

The close-set longitudinal ribs and cancellated base give this shell, which may not have attained its full growth, the aspect of a *Cancellaria*.

Dall's holotype of *Mitra lipara* (= *Vexillum millecostatum* (BRODERIP)) is USNM 333 370, a single subfossil specimen from the Kewalo dredger dump, collected by C. F. Mant.

Although I have not seen the types of either *Mitra picea* or *Vexillum millecostatum*, after studying the figures of those species in Sowerby, Reeve and Tryon it is my belief that they are conspecific, but considered different by the various authors chiefly because of the normal color change caused by fading in dead shells. I admit the possibility of an error on my part, particularly since DAUTZENBERG & BOUGE (1933) record both species from the Tuamotus; however, to me *V. millecostatum* seems to be a variable species, with more or less decussate sculpture on the last whorl, depending upon the conditions under which it lives. Live-collected specimens in the Thaanum Collection show considerable variability in form which includes the various minor differences seen in the illustrations mentioned. Some are short and obese, others are rather elongate; some light-colored shells show a well-defined spiral band at the shoulders, while this character is hardly noticeable in the darker specimens; and the decussate sculpture is more pronounced in some than in others. At any rate, Dall's *Mitra lipara* is evidently a synonym of either *Vexillum millecostatum* or of *Mitra picea*, or possibly of both.

Until I may have the opportunity to study the types of both species, I shall consider *V. millicostatum* the valid name for all three, since it has priority.

Vexillum millicostatum is evidently uncommon in Hawaii; none of the collectors I polled recognized it from my photograph, though I have seen several Kewalo dredger specimens in the Ostergaard Collection, and there is a considerable number of live-collected ones in the Thaanum Collection, dredged by Thaanum and Dranga in 1936 at depths of eight to 20 feet off Waikiki, Waimanalo, and Maunaloa Bay, Oahu; and Lahaina, Maui. It has been recorded throughout the central Pacific: Tuamotus; Mindanao, Philippines; and Hawaii.

This species may be unknown to the general collector because of its small size and the relative unavailability of descriptive literature to help identify it. An average adult specimen measures 6.8 mm in length, 3.5 mm in greatest diameter, and 4.2 mm in length of aperture.

Vexillum thaanumi PILSBRY, 1920

(See figures 30, 31, Plate 7)

Mitra stephana DALL ?MS

1920. *Vexillum thaanumi* PILSBRY, H. A., Proc. Acad. Sci. Phila., 72: 316; Pl. 12, fig. 31

1962b. *Vexillum thaanumi* PILSBRY, CATE, JEAN M., *The Veliger* 4 (3): 147; Pl. 34, fig. 4; Pl. 35, fig. e

The shell is fusiform, rather slender, white, with a cinnamon band below the periphery. At the periphery there are narrow vinaceous or brownish spots between the ribs, surmounted by a continuous, cinnamon line. On the penult whorl this line is median.

Sculpture of vertical ribs weakening towards the base, the intervals with short impressed lines in a spiral direction; on the last whorl there are 11 ribs and about 19 spirals, exclusive of those on the siphonal fasciole. On the penult whorl there are 10 or 11 impressions in an interval.

The aperture is slightly pink tinted within, lirate in the throat. Five columellar plaits, the lower one very small.

Length 25.3, diameter 8, aperture 12 mm.; 10 whorls.

Off Waikiki, Oahu, in 200 - 300 feet. D. B. Langford.

I do not know the whereabouts of any specimen designated by Dall as type for *Mitra stephana*, and as I have not seen his original manuscript for the Hawaiian gastropod paper, I do not know whether he intended to describe *M. stephana* there. I have seen this name employed only once, on a label at the Museum of Comparative Zoology (Harvard University); this label was evidently hand written by Dall, and accompanied a specimen of *Vexillum thaanumi*. Dr. Ruth Turner at MCZ and Dr. Joseph Rosewater at USNM both helped me in an exhaustive

search of Dall's publications; no published reference to the name *Mitra stephana* nor any figure of the species could be found. I have therefore included it here on the assumption that Dall may have intended to publish it with his other new Hawaiian species. Unless a valid description published prior to Pilsbry's 1920 paper can be found, Dall's name *M. stephana* must be considered a synonym of *Vexillum thaanumi*; they are unquestionably conspecific.

This is one of the apparently endemic species of *Vexillum* in Hawaii, as well as one of the most beautiful. As it seems normally to be a deep-water species, it is of rather rare occurrence except in dredged material. It was taken in some quantity by the Pele I Expedition on a sand or sand and coral-rubble substrate, usually at a depth of about 100 to 150 feet. The Thaanum records for *Vexillum thaanumi* indicate its occurrence at various depths from 25 feet to 30 fathoms, at several localities around Oahu and off West Maui.

The holotype of *Vexillum thaanumi* is in the collection of the Academy of Natural Sciences of Philadelphia.

Vexillum xenium PILSBRY, 1920

(See figures 32 to 34, Plate 7)

Mitra agria DALL MS (*nomen nudum*)

1920. *Vexillum xenium* PILSBRY, H. A., Proc. Acad. Sci. Phila., 72: 317; Pl. 12, fig. 25

1962b. *Vexillum xenium* PILSBRY, CATE, JEAN M. *The Veliger* 4 (3): 147; Pl. 34, fig. 5; Pl. 35, fig. b

The shell is fusiform, white with a chestnut band traversed by several paler spiral lines, below the periphery, two or three paler interrupted lines above it on the summits of the ribs only, and a few widely spaced blackish-brown spots below the suture, on the ends of some of the ribs. The first three whorls are also deep brown. Sculpture of smooth, longitudinal ribs, 22 on the last whorl, equal to their interstices, the latter marked with short impressions in spiral series, 6 on the penult whorl in each interval; base spirally grooved over ribs and intervals forming about 4 spiral series of tubercles. Two obliquely spiral cords are more prominent just above the siphonal fasciole. Aperture shorter than the spire, the throat with 9 thin beaded lirac. Columella with 5 thin plaits.

Length 18, diameter 7.5, aperture 8.4 mm., 10 whorls.

Off Waikiki, Oahu, 25 - 50 fms. D. B. Langford.

Dall's type for *Mitra agria* (= *Vexillum xenium* PILSBRY) is USNM 173 197, a single small, dead specimen collected by the U. S. Fish Commission at Station 3846 off the south coast of Molokai Island, in 64 fathoms. It appears to be possibly a juvenile specimen of *Vexillum xenium*, having identical sculpture and columellar folds,

and a similar outline. It is, however, evidently a younger specimen than any of the few typical *V. xenium* I have seen; it measures only 10.2 mm in length, whereas the type of *V. xenium* is 18 mm long and a specimen in my collection is 24.2 mm in length. The sculpture of Dall's proposed *M. agria* is a little sharper than that of *V. xenium*, but this could be explained by its being a younger, less-worn example.

At the present time I consider *Mitra agria* to be a juvenile stage of *Vexillum xenium*; at any rate, only one specimen is not sufficient material to justify validating Dall's proposed new species unless it were more strikingly different from all other known forms. However, this decision is open to review if larger quantities of material are collected, making possible a more thorough study and comparison of the species.

Mitra alba (PEASE, 1867)
(See figures 35, 36, Plate 7)

Mitra pellucida DALL MS

1867. *Thala alba* PEASE, Am. Journ. Conch. 3: 215; Pl. 15, fig. 8
1880. *Mutya alba* (PEASE), GARRETT, Journ. Conch. 3: 12
1882. *Mitra (Aidone) alba* (PEASE), TRYON, G. W. JR., Man. Conch. 4: 129; Pl. 51, fig. 471

Shell elongate, slender, fusiform, rather thin and translucent, transversely striate, decussate with very fine longitudinal striae; aperture slightly effuse at the base, somewhat contracted and thickened in the middle; columella with four plaits; color white. Length 7½ mm., diam. 2 mm. Hab. Paumotus.

The type locality is here restricted to Huahine, Society Islands (approximately 17° 00' South Latitude, 151° 00' West Longitude); this is the first recorded locality for the species, according to DAUTZENBERG & BOUGE (1933).

Dall's type specimens for *Mitra pellucida* (= *M. alba* (PEASE)) are USNM 333 483; two specimens, one labelled TYPE, ex Thaanum Collection No. 8712; Palmyra Island.

This species has a rather wide range, but appears to be rare nevertheless. It has been recorded from the Tuamotus as well as the Society Islands, and northward through the Palmyra area to as far as Oahu. It has, perhaps, been overlooked because of its lack of color and its small size (an average adult specimen measures about five millimeters in length); even in the Thaanum Collection, where it is represented from four different localities, there are less than a dozen specimens, mostly dredged as dead shells in depths of from ten to fifteen feet. Dr. Alison Kay reports beach specimens of *Mitra alba* in the Bishop Museum Collection from Waianae, Paumalu and Kailua, Oahu; Hoopuloa, Hawaii; Moomumi, Molokai; and Lahaina, Maui.

Today we would probably not consider Palmyra Island as part of the Hawaiian chain of islands, but until Hawaii attained statehood in 1960, Palmyra was part of Honolulu County, hence the inclusion of a species from that distant island in a paper dealing with Hawaiian mollusks.

Mitra ancillides BRODERIP, 1836
(See figures 37, 38, Plate 7)

Mitra golischi DALL MS (*nomen nudum*)

1836. *Mitra ancillides* BRODERIP, W. J., Proc. Zool. Soc. London, p. 193. Not figured.
1845. *Mitra ancillides* SWAINSON, REEVE, L., Conch. Icon. 10, sp. 319
1874. *Mitra ancillides* SWAINSON, SOWERBY, G. B., Thes. Conch. 4: 225; sp. 100
1882. *Mitroidea ancillides* (SWAINSON), TRYON, G. W., Jr., Man. Conch. 4: 162; Pl. 47, fig. 374

Mitra testâ turritâ, minutissimè transversim striatâ, totâ pallidè flavâ; columellâ quinqueplicatâ: long. 5, lat. 2 poll. Hab. ad Insulam Annaan. Found on the reefs.

There are three lots in the U. S. National Museum Collection labelled *Mitra golischi* DALL (= *M. ancillides* BRODERIP); the locality of the type specimen (USNM 333 028) is cited merely as "Sandwich Islands." This specimen was collected by W. H. Golisch. A second lot of seven specimens (USNM 486 076) was collected at Kwajalein Atoll in the Marshall Islands, and a single specimen (USNM 606 719) was collected by Bartsch at Sand Island, Midway. This latter shell is slightly different from the others, and is undoubtedly a specimen of *Mitra ostergaardi* PILSBRY, 1920. All nine are subfossil specimens, but Dall's type and the seven from Kwajalein are slender, attenuate, and though broken, they show an indication of the recurved posterior canal typical of the Reeve and Sowerby figures of *Mitra ancillides* BRODERIP, whereas *M. ostergaardi* is more obese and has a shorter canal. With these exceptions, all the remaining morphological characters of the two latter species seem to be identical, which suggests the possibility that *M. ostergaardi* may represent an extreme form of *M. ancillides* at the eastern end of its range. However, *M. ancillides* is a rare species, and as I have seen neither the holotype nor any live-collected specimens in any collection, I hesitate to suggest placing *M. ostergaardi* in synonymy with it at this time.

The locality citation for Dall's species is so vague that one cannot be certain it was collected within the limits of the Hawaiian chain of islands as we think of that geographical entity today (see map). Further, since none of the present-day Hawaiian collectors who have viewed a photograph of the type figure of *Mitra ancillides* is familiar with that slender form, I believe that at present Dall's proposed new species, *M. golischi*, should be placed in synonymy with *M. ancillides*, and may be considered

separable from typical *M. ostergaardi*.

The type locality of *Mitra ancillides* is the island of Anaa in the Tuamotu group, French Oceania.

Mitra nigricans PEASE, 1865

(See figures 39 to 41, Plate 7)

Mitra alcida DALL MS (*nomen nudum*)

Mitra diamantina DALL MS (*nomen nudum*)

1865. *Mitra nigricans* PEASE, Proc. Zool. Soc. London, p. 514. Not figured.

1867. *Strigatella nigricans* (PEASE); PEASE, Am. Journ. Conch. 3 (3): 215. Not figured.

1882. *Strigatella nigricans* (PEASE), TRYON, G. W., Jr., Man. Conch. 4: 153. Not figured.

Shell fusiform, elongate, smooth, finely transversely striate, striae somewhat remote, punctured; covered with a thin epidermis; spire slender, elongate, acute; lip simple; columella with four plaits; black, encircled by a narrow chestnut band, aperture lead color. Length 20 mm., Diam. 7 mm. Sandwich Islands.

The type locality is here restricted to Waikiki, Oahu 21° 16' North Latitude, 158° 50' West Longitude).

Dall's type specimen for *Mitra alcida* (= *M. nigricans* PEASE) is USNM 190 430, from U. S. Fish Commission Station 4032; 27 to 29 fathoms, Penguin Banks, South Coast, Oahu. On the museum label the MS name and the word TYPE have been scratched out, but no correction or explanation has been made. The lot consists of one dead, decollate specimen.

Dall's type specimen for *Mitra diamantina* (= *M. nig-*

ricans PEASE) is USNM 338 074, from three to five fathoms off Diamond Head, Oahu, ex Thaanum Collection No. 2638. It is a little larger and has somewhat more convex whorls than the type of *M. alcida*, but is otherwise similar in every respect. The only specimen in this lot is a dead shell with a broken lip. I believe the slight amount of variation seen in this specimen is within the normal range of variability, not sufficient to justify a separate species name.

Mitra nigricans rather resembles a small *M. tiarella* A. ADAMS, 1853; it is, however, consistently smaller (the largest typical adult specimen I have seen is only 15.3 mm long) and smoother, its spiral punctations being almost invisible without a magnifying glass; it has a smooth lip instead of a crenulated one, and there are no sutural crenations. It does not have the typical characteristics of a *Strigatella*, and I believe Pease assigned it to that genus in error — two years after he described the species.

The typical habitat of *Mitra nigricans* appears to be under coral heads in from ten to 30 feet of water, although it has been collected alive in only two feet of water in a reef pocket in seaweed at Ala Moana Reef and dredged in 300 feet in Keehi Lagoon by the Pele I Expedition. It is not a common species in Hawaii, but it is reported from several Oahu stations: Waikiki, Waialua Bay, Manana Island, Rabbit Island, Nanakuli, Kahe Point; and from two stations on Maui: Honokowai, Lahaina; Kaopaipu. A total of approximately 40 specimens are known from these areas.

I know of no locality records for this species outside the Hawaiian Islands; it may be an endemic form. Its known

Explanation of Plate 7

Vexillum millecostatum (BRODERIP)

Figure 27: type of *Mitra lipara* DALL MS, USNM 333 370 (x 2)

Figures 28 and 29: typical specimen of *Vexillum millecostatum* (BRODERIP), ex Thaanum Coll. (x 3)

Figures 30 and 31: *Vexillum thaanumi* PILSBRY (*Mitra stephana* DALL MS); typical specimens, ex Cate Coll. (Victor Duran photo, x 2)

Figure 32: ?*Vexillum xenium* PILSBRY (juv.) (type of *Mitra agria* DALL MS, USNM 173 197, x 2)

Figures 33 and 34: types of *Vexillum xenium* PILSBRY, Acad. Nat. Sci. Phila. 116 983 (Stanford University photograph, x 2)

Mitra alba (PEASE)

Figure 35: type of *Mitra pellucida* DALL MS

USNM 333 483 (x 3.5)

Figure 36: typical specimen of *Mitra alba* (PEASE), ex Cate Coll. (x 3.5)

Mitra ancillides BRODERIP

Figure 37: type of *Mitra golischi* DALL MS, USNM 333 028 (x 2)

Figure 38: type figure of *Mitra ancillides* BRODERIP, ex REEVE, species 319 (natural size)

Mitra nigricans PEASE

Figure 39: type of *Mitra alcida* DALL MS, USNM 190 430 (x 3)

Figure 40: type of *Mitra diamantina* DALL MS, USNM 338 074 (x 3)

Figure 41: typical specimen of *Mitra nigricans* PEASE, ex Thaanum Coll. (x 3)

All photos on this plate by T. Susuki, except as noted.



Figure 27



Figure 28



Figure 29



Figure 30

Figure 31



Figure 32



Figure 33



Figure 34



Figure 35



Figure 36



Figure 37



Figure 38



Figure 39



Figure 40

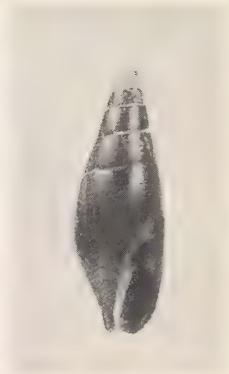


Figure 41

range at the present time is from Maui to Waialua Bay, northwest Oahu.

Mitra ostergaardi PILSBRY, 1920

(See figures 42 to 44, Plate 8)

Mitra pararhodia DALL MS (*nomen nudum*)

1920. *Mitra ostergaardi* PILSBRY, H. A., Proc. Acad. Sci. Phila., 72: 314; Pl. 12, fig. 22

1962b. *Mitra ostergaardi* PILSBRY, CATE, JEAN M., The Veliger 4 (3): 143; Pl. 33, fig. 3; Pl. 35, fig. c

The shell is fusiform with conic spire, somewhat flattened periphery, somewhat convexly tapering base, slightly concave below; ochraceous-buff to nearly as dark as ochraceous-orange, the spire usually a little paler. Sculpture of widely-spaced spiral series of small punctures, six on back of penult whorl, the intervals very minutely, superficially striate spirally; towards the base having punctured spiral grooves. Under the suture the whorls are a little prominent and finely, irregularly crenate.

The aperture is flesh-tinted within; narrow, but slightly wider below; lip contracted above. Five plaits. Length 43, diameter 15, length aperture 22.3 mm. (summit broken). Honolulu Harbor, in the dredger dump. J. M. Ostergaard.

The color is altered, as in nearly all shells from the "dump", in life it will be found to be much darker in color. It is closely related to *M. thaaniumiana* [= *M. coffea* SCHUBERT & WAGNER], but the last whorl is decidedly more cylindrical, and there are fewer spiral puncture lines.

Two of the three specimens show a very faint pale line at the shoulder. Some young shells which are perhaps this species have a distinct whitish line at the shoulder. They have 4 columellar plaits.

The type selected by Dall for *Mitra pararhodia* (= *M. ostergaardi* PILSBRY) is USNM 338 035, one specimen collected by Thaenum (No. 8361) in 25 to 50 fathoms off Waikiki, Oahu.

This may have been the only specimen Thaenum had at the time he sent it to Dall, as there is no similar number in the Thaenum catalog. *Mitra ostergaardi* is uncommon in Hawaii, and appears to range no farther than from Midway south to Oahu.

Mitra ostergaardi seems to be most frequently collected at depths of from 20 to 60 feet, usually associated with coral heads. Collecting stations around Oahu include Makua, Kahe Park, Nanakuli, Mekahe, Keau, Waikiki, Rabbit Island, Kailua Bay, Barber's Point. About 50 specimens are reportedly in collections in Hawaii.

Further discussion of this species may be found in J. CATE (1962 b).

The holotype is at the Academy of Natural Sciences of Philadelphia.

Mitra peasei DOHRN, 1860

(See figures 45 to 47, Plate 8)

Mitra missa DALL MS (*nomen nudum*)

1860. *Mitra peasei* DOHRN, Proc. Zool. Soc. London, pt. 28: 366. Not figured.

1874. *Mitra peasei* DOHRN, SOWERBY, G. B., Thes. Conch 4, sp. 106, fig. 76

1920. *Mitra langfordi* PILSBRY, H. A., Proc. Acad. Sci. Phila. 72: 315; Pl. 12, fig. 20

1962b. *Mitra peasei* DOHRN, CATE, JEAN M., The Veliger 4 (3): 144; Pl. 34, fig. 1

Mitra peasei. Testa subulato-fusiformis, hyalino-albida, spiraliter obsolete crebricostata, subtilissime longitudinaliter striata; sutura simplex; anfr. 8 planiusculi, ultimus paulo ventrosior, subrecurvus; apertura fusiformis; columella 5-plicata. Long. 37, lat. 11; ap. long. 20, lat. 5 mill. Hab. Australia.

Dall's type of *Mitra missa* (= *M. peasei* DOHRN) is a dead and worn specimen (USNM 173 212), dredged by the U. S. Fish Commission in 28 to 43 fathoms at Station 3876 in the Auau Channel, Hawaiian Islands. Though imperfect, enough of the shell remains to make possible a positive identification as *M. peasei*.

Since one or two of the Hawaiian collectors responding to my questionnaire did not agree with my identification of this species and a few others appeared uncertain, it seems best to disregard their comments in this case, as possibly applying to a different form. At least one of the collectors considered that the photograph of Dall's species might more accurately have been identified as *Mitra emersoni* PILSBRY, 1920, but the photograph alone does not furnish a sharp enough definition of the sculpture for an accurate determination; under magnification Dall's shell can be matched without doubt to *M. peasei*. While *M. emersoni* and *M. peasei* are very similar in many ways, there are decided differences in the interstitial sculpture of the two species (See CATE, 1962 b).

From other records I can confirm that *Mitra peasei* was dredged in relative abundance on a sand and coral substrate in from 80 to 200 feet off the south shore of Oahu by the Pele I Expedition in 1959. It is also collected in somewhat shallower water by divers, but rather infrequently.

TRYON (1882) erroneously placed *Mitra peasei* in the synonymy of *M. isabella* SWAINSON.

Mitra tiarella A. ADAMS, 1853

(See figure 48, Plate 8)

Mitra crassula DALL MS (*nomen nudum*)

1853. *Mitra tiarella* A. ADAMS, Proc. Zool. Soc. London, p. 133. Not figured.

1874. *Mitra tiarella* A. ADAMS, SOWERBY, G. B., Thes. Conch. 4, Pl. 5, fig. 56; Pl. 12, figs. 215, 217

1920. *Mitra lugubris honoluluensis* PILSBRY, H. A., Proc. Acad. Nat. Sci. Phila. 72: 314; Pl. 12, fig. 16
- 1962a. *Mitra tiarella* A. ADAMS, CATE, JEAN M., The Veliger 4 (3): 133; Pl. 29, fig. 3
- 1962b. *Mitra tiarella* A. ADAMS, CATE, JEAN M., The Veliger 4 (3): 143; Pl. 33, fig. 4

M. testâ oblongo-ovatâ, fuscâ, nodulis albis, ad suturas coronatâ, longitudinaliter subplicatâ, transversim lirâtâ, interstitiis valdè punctatis; columellâ plicis quatuor; labro margine crenulato. Hab. Island of Ticao, sandy mud, 6 fathoms.

This small, brown-coloured species is beautifully crowned, in adult specimens, with a diadem of white nodules at the suture of the whorls.

Dall's type of *Mitra crassula* (= *M. tiarella* A. ADAMS) is USNM 339 899, collected by W. D. Gifford from dredgings at the entrance to Honolulu Harbor. It is a single subfossil specimen, unquestionably identical with *M. tiarella*. Since this species has been rather thoroughly discussed in J. CATE (1962 a, 1962 b) with respect to its appearance and to several incorrect references in the literature, I need not repeat the discussions here.

A somewhat uncommon species in Hawaii, *Mitra tiarella* is represented in collections there by approximately 40 specimens collected in sand, though occasionally under coral and sometimes on flat reefs. Its benthic range is from two to 60 feet.

Records I have myself verified indicate that *Mitra tiarella* is known from Japan, the Ryukyu Islands and the southern Philippines. Other records need further substantiation, since the species has long been variously misidentified.

Mitra ticaonica REEVE, 1844

(See figures 49 to 51, Plate 8)

Mitra pupiformis DALL MS (*nomen nudum*)

1844. *Mitra ticaonica* REEVE, L., Proc. Zool. Soc. London, p. 183. Not figured.
1844. *Mitra ticaonica* REEVE, L., Conch. Icon. 10, Pl. 23, sp. 181
1874. *Mitra ticaonica* REEVE, SOWERBY, G. B., Thes. Conch. 4: 281; Pl. 15, figs. 252, 254
1920. *Mitra ticaonica vagans* PILSBRY, H. A., Proc. Acad. Nat. Sci. Phila., 72: 314; Pl. 12, figs. 14, 15
- 1962b. *Mitra ticaonica* REEVE, CATE, JEAN M., The Veliger 4 (3): 144; Pl. 33, fig. 5

The Ticao Mitre. Shell ovate, thick, solid, spire short, sutures deep; whorls transversely faintly grooved throughout, rather smooth next the sutures; bay brown, interior of the aperture bright purple brown; columella four-plaited. Hab. Island of Ticao, Philippines (found on the reefs at low water); Cuming.

A very characteristic species with a dark purple-brown richly enameled mouth.

Dall proposed the name *Mitra pupiformis* (= *M. ticaonica* REEVE) for this species, using for his holotype USNM 338 028; the lot consists of two vials containing one specimen and six specimens, respectively. These are from the Thaanum Collection (No. 808a), from the reef at Honokowai, Maui. Another lot (USNM 338 029) contains one specimen from the Thaanum Collection (No. 808b), from four to twelve fathoms off Kaanapali, Maui.

Present-day collectors in Hawaii consider this species common on all shores with reefs; it is taken intertidally

Explanation of Plate 8

Mitra ostergaardi PILSBRY

Figure 42: type of *Mitra pararhodia* DALL MS, USNM 338 035 (x 1)

Figures 43 and 44: holotype of *Mitra ostergaardi* PILSBRY; Acad. Nat. Sci. Phila. 46 770 (Stanford University photograph, x 2)

Mitra peasei DOHRN

Figure 45: type of *Mitra missa* DALL MS, USNM 173 212 (x 1)

Figures 46 and 47: typical *Mitra peasei* DOHRN; Acad. Nat. Sci. Phila. 46 805 (Stanford University photograph, twice natural size)

Figure 48: *Mitra tiarella* A. ADAMS (type of *Mitra crassula* DALL MS, USNM 339 899, x 2)

Mitra ticaonica REEVE

Figure 49: type of *Mitra pupiformis* DALL MS, USNM 338 028 (x 2)

Figures 50 and 51: types of *Mitra ticaonica vagans* PILSBRY (= *Mitra ticaonica* REEVE). Acad. Nat. Sci. Phila. 46 790 (Stanford University photograph, x 2)

Mitra waikikiensis PILSBRY

Figure 52: type of *Mitra colpophila* DALL MS, USNM 337 991 (x 2)

Figures 53 and 54: types of *Mitra waikikiensis* PILSBRY. Acad. Nat. Sci. Phila. 46 788 (Stanford University photograph, x 3/2)

Figures 55 and 56: *Imbricaria conovula* QUOY & GAIMARD (*Imbricaria melacis* DALL MS) (x 2)

All photos on this plate by T. Susuki, except as noted.



Figure 42



Figure 43



Figure 44



Figure 45



Figure 46



Figure 47



Figure 49



Figure 48



Figure 50



Figure 51



Figure 52



Figure 53



Figure 54



Figure 55



Figure 56

or as deep as 30 feet, in coral and in seaweed on inshore reefs.

Mitra ticaonica is a fairly common species throughout the Pacific, and is recorded from the Philippines, Samoa and Fiji, among other localities.

Mitra waikikiensis PILSBRY, 1920

(See figures 52 to 54, Plate 8)

Mitra colpophila DALL MS (*nomen nudum*)

1920. *Mitra waikikiensis* PILSBRY, H. A., Proc. Acad. Sci. Phila., 72: 316; Pl. 12, fig. 17

1962b. *Mitra waikikiensis* PILSBRY, CATE, JEAN M., The Veliger 4 (3): 145; Pl. 34, fig. 3; Pl. 35, fig. a

The shell is fusiform, pale brown with ill-defined peripheral and basal bands and white tubercles. Sculpture of spiral cords (eleven on the last whorl behind the lip) and lower longitudinal ribs, producing tubercles where they cross the cords. Aperture white. Columella with three plaits, the upper large, the lower quite small.

Length 12.5, diameter 4.8, length of aperture 6.7 mm.

Length 11.6, diameter 4.5, length of aperture 6.3 mm.

Off Waikiki, Oahu, in 35-50 fathoms. D. B. Langford.

Dall's specimens labelled *Mitra colpophila* (= *M. waikikiensis* PILSBRY) are as follows:

USNM 337 991 (TYPE) Thaanum Coll. 8328a; 4-12 fathoms off Mala Bay, Maui

USNM 337 992 1 spec. Thaanum Coll. 8328b; 4-12 fathoms off Mt. Lihau, Maui

USNM 337 999 2 specs. Thaanum Coll. 8328; 54-83 fathoms off Waikiki, Oahu

Mitra waikikiensis is rather rare in Hawaii except for dredged specimens. It is typically a small form, though eight very large shells were dredged in 1959 (Pele I Expedition) in Keehi Lagoon, Oahu; these are twice as large as the types, and somewhat resemble Reeve's figure of *Mitra loricata*, a species I have not seen.

Mitra waikikiensis is probably endemic to the Hawaiian Islands, its known range at the present time being from Mala Bay, Maui to Keehi Lagoon, Oahu. Several Hawaiian collectors judged it "abundant at 100 to 300 feet in sand, all about Oahu."

Further discussion of this species may be found in J. CATE (1962 b).

The holotype is at the Academy of Natural Sciences of Philadelphia.

Imbricaria conovula (QUOY & GAIMARD, 1833)

(See figures 55, 56, Plate 8)

Imbricaria melacis DALL ?MS

1833. *Mitra conovula* QUOY & GAIMARD, Voy. Astro-labc, Zoologic 2:655; Pl. 45b, figs. 18-22

1836. *Conoelix virgo* BRODERIP, Proc. Zool. Soc. London, p. 197. Not figured.

1922. *Imbricaria punctata* (SWAINSON) var. *virgo* (SWAINSON), DAUTZENBERG & BOUGE, Journ. de Conchyl., 67: 257. Not figured.

Mitra, testa turbinata, cylindracea, laevi, lutcola; columella quinqueplicata; basi nigro-violaceo maculata; spira brevissima, acuta; apertura angusta, longa.

..[Cette Mitre] Elle est cylindrique, en rouleau, un peu plus large postérieurement, d'où sort une surface arrondie; une spire décroissant subitement, courte et pointue. L'ouverture est presque aussi longue que la coquille, à la manière des Auricules et des Cônes; elle est fort rétrécie, échancrée en avant. Le bord columellaire a cinq plis très-obliques; il est taché de noir-bleuâtre à sa base, tandis que le reste de la coquille est d'un jaune clair lisse. Quelques individus ont la spire plus allongée et plus pointue; . .

There were no examples of this species among Dall's USNM material, but there are four lots (8733, 8733 a, b, c) in the Thaanum Collection labelled *Imbricaria melacis* DALL — Palmyra." One of these (8733b), from Sand Flats, Palmyra, is further annotated thus in Thaanum's personal catalog: "Type lot." A careful search of the literature failed to turn up any published reference to this species-name. I have therefore included it here in order to call attention to its correct placement in the synonymy of *Imbricaria conovula* (QUOY & GAIMARD), in case other collections may contain additional specimens bearing this invalid name. The species was well described and figured by Quoy & Gaimard, even to an account of the anatomy of the animal and its habits; I know of no reason for dropping their apparently valid name.

The shell is stoutly conical, wide at the shoulders, tapering acutely adapically; the body whorl is smooth, with equidistant minutely punctured spiral lines which frequently become obsolete. The aperture is long, the lip smooth and straight, with a violet tip at the base which is similar to that of *Conus virgo* LINNAEUS — evidently Swainson's reason for choosing the name *Conoelix virgo*, which Broderip later validated.

The type locality is Vanikoro in the Solomon Islands. *Imbricaria conovula* is known generally throughout the central Pacific: Marshall Islands, Cook Islands, Palmyra and Fanning Islands. GARRETT (1882) reported it "in all parts of Polynesia except the Marquesas, living in sand at low water mark." At the present time it is not known from the Hawaiian chain.

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(* denotes *nomen nudum*)

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Literature Cited

ADAMS, ARTHUR

1853. Descriptions of fifty-two new species of the genus *Mitra* from the Cumingian Collection. Proc. Zool. Soc. London, Pt. 19: 132 - 141. (June 29, 1853)

BRODERIP, W. J.

1836. (*No title!*) Proc. Zool. Soc. London for 1835, Pt. 3: 193 - 198. (April 8, 1836)

CATE, JEAN M.

1962 a. On the identifications of five Pacific *Mitra*. The Veliger 4 (3): 132 - 134; pl. 29. (Jan. 1, 1962)

1962 b. Revision of some Hawaiian mitrid species. The Veliger 4 (3): 140 - 149; pls. 33 to 35. (Jan. 1, 1962)

DALL, WILLIAM HEALEY, PAUL BARTSCH & HARALD REHDER

1938. A manual of the recent and fossil marine pelecypod mollusks of the Hawaiian Islands. B. P. Bishop Mus. Bull. 153: i to iv, 4 to 233; pls. 1 to 58.

DAUTZENBERG, PH., & L. - J. BOUGE

1922. Mitridés de la Nouvelle Calédonie et de ces dépendances. Journ. de Conchyl. 67: 83 - 259; pl. II.

1933. Les mollusques testacés marins des établissements français de l'Océanie. Journ. de Conchyl. 77: 152 - 199.

DOHRN, H.

1860. Descriptions of new species of *Mitra* from the collection of Hugh Cuming, Esq. Proc. Zool. Soc. London, Pt. 28: 366 to 368. (Aug. 1860 to March 1861)

DUNCAN, F. MARTIN

1937. On the dates of publication of the Society's 'Proceedings,' 1859 - 1926. With an appendix containing the dates of publication of 'Proceedings,' 1830 - 1858, compiled by the late F. H. WATERHOUSE, and of the 'Transactions,' 1833 - 1869, by the late HENRY PEAVOT, originally published in P. Z. S. 1893, 1913. Proc. Zool. Soc. London 107: 71 - 81.

GARRETT, ANDREW

1873. List of species of Mitridae collected at Rarotonga, Cook's Islands, with notes, also descriptions of new species. Proc. Zool. Soc. London for 1872: 839 - 843. (April 1873)

1880. Catalogue of the Polynesian Mitridae, with remarks on their geographical range, station, and descriptions of supposed new species. Journ. Conch. 3: 1 - 73.

HABE, TADASHIGE

1961. Coloured illustrations of the shells of Japan. II: 1 to 183; 66 colored plates.

HAWAIIAN SHELL NEWS

1956. Check list of Hawaiian miters. 4 (4): 38 - 39.

1959. Check list of Hawaiian gastropods (92). Mitridae. 7 (11): suppl. 23 - 28.

HERVIER, R. P. J.

1897. Descriptions d'espèces nouvelles de mollusques, provenant de l'Archipel de la Nouvelle Calédonie. Journ. de Conch. 45: 60 - 69, 225 - 247; pls. 9, 10.

LAMARCK, J.-B. P.

1811. De la détermination des espèces de mollusques testacés Ann. Mus. d'Hist. Nat. 17: 195 - 222. Paris

MANT, CHARLES F.

1923. Mollusca from the dredging operations at Kewalo Harbor, Honolulu, 1921. *Nautilus* 36 (4): 120 - 123.

PEASE, WILLIAM HARPER

1865. Descriptions of new genera and species of marine shells from the islands of the central Pacific. *Proc. Zool. Soc. London for 1865*: 512 - 517. (October 1865)

1867. Descriptions of marine gastropodae, inhabiting Polynesia. *Am. Journ. Conch.* 3: 211 - 216; pl. 15.

PILSBRY, HENRY AUGUSTUS

1920. Marine mollusks of Hawaii. *Proc. Acad. Nat. Sci. Philadelphia* 72: 309 - 318; pl. 12.

QUOY, J. R. C., & J. P. GAIMARD

1833. Voyage de découvertes de l'Astrolabe exécuté par ordre

du Roi, pendant les années 1826 - 1829, sous le commandement de M. J. Dumont d'Urville. *Zoologie* 2: 633 - 660; pls. 45, 45 bis.

REEVE, LOVELL A.

1844 - 1845. *Conchologia Iconica. Monograph of the genus Mitra*. 10: pls. 1 - 39.

SOWERBY, GEORGE BRETtingham

1874. *Thesaurus Conchyliorum. Monograph of the genus Mitra*. 4: 1 - 46; pls. 1 - 28.

TRYON, GEORGE WASHINGTON, JR.

1882. *Manual of Conchology. Monograph of the Mitridae*. 4: 106 - 200; pls. 32 - 58. Philadelphia.

Variation and Synonymy of *Phyllaplysia* in the Northeastern Pacific (Mollusca : Opisthobranchia)

BY

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(5 Text figures)

As a sidelight to a physiological study it has become apparent that *Phyllaplysia zostericola* McCAULEY, 1960 should be considered as a synonym of *P. taylori* DALL, 1900. *Phyllaplysia zostericola* was separated from *P. taylori* mainly on the basis of the shell and color. McCAULEY, followed by MARCUS (1961), considered the striped, green, shell-less animals that they discussed to be of a different species than the patternless, yellow, shelled animal described by DALL and redescribed by BERGH (1902). It is significant that evidently DALL and BERGH saw only a few long-dead specimens of this organism. DALL gave a very brief, but identifying, description based on "some" specimens sent to him in alcohol by Rev. George W. Taylor from Nanaimo, British Columbia. He described a twenty mm long individual as "a uniform pale lemon-yellow color" and gave its general external features, but he did not mention the shell or the radula. BERGH

received one 14 mm long specimen from DALL on which he based his redescription two years later. He agreed with DALL on the color and lack of pattern, described the calcified shell as two mm long, and presented ten figures of the radula and other details. McCAULEY, working with abundant living material, felt that his animals were different from DALL's, mainly because no shell was evident and there were black stripes which persisted in alcohol even years after the green ground color had faded to yellow.

The following data are presented for the more accurate definition of this species and to provide STEINBERG's forthcoming key to the California opisthobranchs with a basis for avoiding the perpetuation of the erroneous idea that *Phyllaplysia taylori* and *P. zostericola* are different species.

Phyllaplysia taylori DALL, 1900

SYNONYMY

Phyllaplysia taylori DALL, 1900: 91-92; BERGH, 1902: 368-370, pls. 26, 27; MACGINITIE, 1930: 68; 1935: 739; SMITH & GORDON, 1948: 179; MACGINITIE, 1949: 377, 380, fig. 236; STEINBERG in LIGHT *et al.*, 1954: 264, 268; RICKETTS & CALVIN, 1962: 250, 461.

Petalifera petalifera taylori (DALL), ENGEL & HUMMELINCK, 1936: 54-55.

Phyllaplysia zostericola McCauley, 1960: 549-576, figs. 1-6; MARCUS, 1961: 10-12, figs. 27-32; LANCE, 1961: 65; HEDGPETH, 1962: 106, plt. 2; MARCUS & MARCUS, 1962: 453.

MATERIAL EXAMINED

Garrison Bay, San Juan Island, Washington, 10 July 1961, J. Gonor, col., two specimens. Coos Bay, Oregon, August 1962, Lawrence Andrews col., 12 specimens. Humboldt Bay, California, 14 January 1931, G. E. MacGinitie col., 15 specimens; August 1962, Lawrence Andrews col., four specimens. Tomales Bay, California, August 1960, Lawrence Andrews col., one specimen; 31 March 1963, R. D. Beeman, col., 36 specimens. Elkhorn Slough, California, 20 July 1926, G. E. MacGinitie col., one specimen; 27 June 1961, G. L. Reuter col., one specimen; 1961 to 1963, R. D. Beeman col., 800 + specimens. Morro Bay, California, 17 July 1962, Joan Steinberg col., three specimens. Newport Bay, California, 25 July 1955, Nettie MacGinitie col., two specimens.

DISCUSSION

During July 1961, I examined many of these green, striped anaspidicans taken from *Zostera marina* in Elkhorn Slough, Monterey Bay, California. Most of these specimens had a shell very clearly visible on the mantle shelf under the left parapodial flap. Figure 1 indicates the appearance of the shell (1.9 by 3.4 mm) on a 55 mm long living animal, and figure 2 indicates its position on the body. The shell is attached ventrally by its convex side to the dorsal surface of the mantle shelf. It is clear, except for a white thickening which is often noticeable around the apex to the left of the shell's center. The shell is almost entirely calcareous (but very delicate) and it therefore disappears in acid stains and sometimes in formalin. This structure is evidently of secondary developmental origin and is, therefore, without a nucleus. There is no trace of a shell chamber.

Further studies in 1962 and 1963 revealed that the presence of the shell is not a constant feature. The shell first appears about March in animals from Elkhorn Slough; its mean size is then much smaller than later in the year and the frequency of its occurrence is low. It is present in the large majority of mature animals by July.

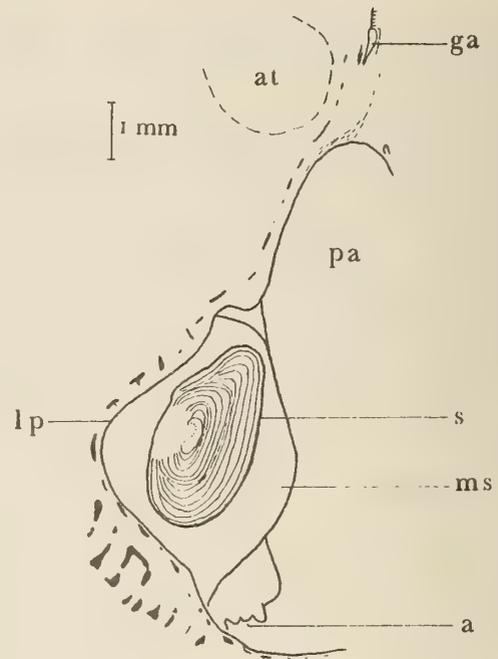


Figure 1: Area of the shell in *Phyllaplysia taylori*. The left parapodium is reflected to show the shell *in situ*. a - anus at - atrium ga - genital aperture ms - mantle shelf pa - pallial cavity s - shell

The size of the shell shows little correlation with the size of the animal bearing it. One 30 mm live animal had a 0.23 by 0.15 mm shell; another of the same length had one measuring 1.03 by 0.73 mm. A 33 mm specimen taken from the same *Zostera* blade as the latter one (in Elkhorn Slough, 15 August 1962) had none. Shells were observed in specimens from Coos Bay, Oregon and Humboldt Bay, Tomales Bay, Elkhorn Slough, Morro Bay, and Newport Bay, California. Only two specimens from Washington were available; neither revealed shells when examined.

The presence or absence of a shell does not prevent identification of the animals under consideration with the descriptions of *Phyllaplysia taylori*. ENGEL & HUMMELINCK (1936) transferred *Phyllaplysia taylori* to the genus *Petalifera* GRAY, 1847 as *Petalifera petalifera taylori* on the basis of the presence of a shell. This is especially interesting since the present article offers the first published illustration of this structure in *Phyllaplysia taylori*. ENGEL & HUMMELINCK stated that the genus *Petalifera* is characterized by an aplysiform shell. However, figure 1 shows that the shell of *Phyllaplysia taylori* is distinctly not aplysiform. MARCUS (1961: p. 11) states that "a secondary shell without nucleus may exist on the mantle roof of *Phyllaplysia*," and with this I certainly

agree. Such shells are found in at least *Phyllaplysia taylori* DALL, 1900, *P. inornata* BERGH, 1905, and *P. engeli* MARCUS, 1955. The available information indicates that the presence or absence of an unenclosed secondary shell is too labile a feature to be used even for the separation of the *Phyllaplysia* of this coast into separate species.

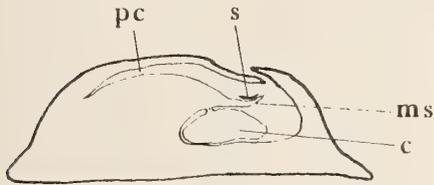


Figure 2: Diagrammatic views (not to scale) of the position of the shell in *Phyllaplysia taylori*.

Upper: transverse section. Lower: outline of parapodia in normal closed position.

c - "ctenidium" ms - mantle shelf s - shell
pc - parapodial cavity

The ground color of the living *Phyllaplysia taylori* is the same bright green as the *Zostera* on which they live. This green fades through olive to yellow in alcohol. The dark brown or black stripes are as described by McCauley (1960: 551-552). As this author observed, these stripes are quite permanent under most conditions of alcoholic preservation. I noted, during oxygen consumption experiments conducted in July, 1962, on Elkhorn Slough animals, that the stripes and green color tended to be lost after the temperature was maintained past the incipient lethal point (about 25° C in this example). Following this lead I determined that similar loss of markings frequently occurred if the animals were allowed to die in seawater before placing them in ethyl alcohol. Animals killed by being placed directly into ten percent formalin lost almost all color and markings in a few months. Since it is impossible to know the conditions of preservation for the specimens which Taylor sent to Dall,

the contrast of markings indicated by the original and recent descriptions of this animal must be disregarded. Another observation bearing on this point is that a specimen of *Phyllaplysia taylori* taken in Elkhorn Slough by G. E. MacGinitie in 1926, and at the time of capture presumably of the same green and dark brown color as other animals collected at the same location, now matches Dall's and Bergh's descriptions perfectly, as it has faded to "a uniform pale lemon-yellow color" without any sign of stripes. No living animal of the latter coloration has ever been reported. Future descriptions of color and markings must stress the condition of healthy living animals whenever possible.

Figures 3 and 4 show the appearance of a typical living adult *Phyllaplysia taylori* from Elkhorn Slough, California. The skin of all specimens examined has been smooth and free of any papillose projections. The pattern of stripes is quite variable.

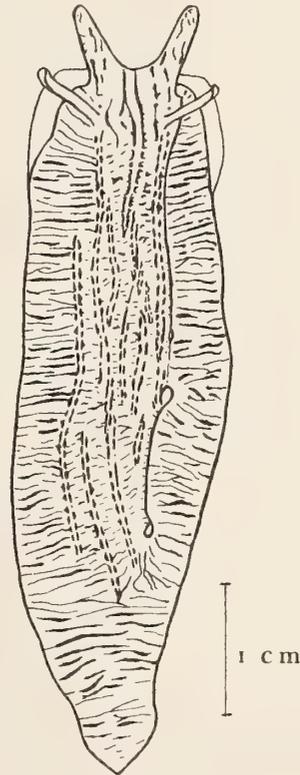


Figure 3: Dorsal aspect of *Phyllaplysia taylori* from life.

McCauley (1960: 550 to 551) felt that the characteristics of the radula served as an additional feature to separate *Phyllaplysia zostericola* and *P. taylori*. He contrasted BERGH's (1905) radula count of 33 rows of teeth

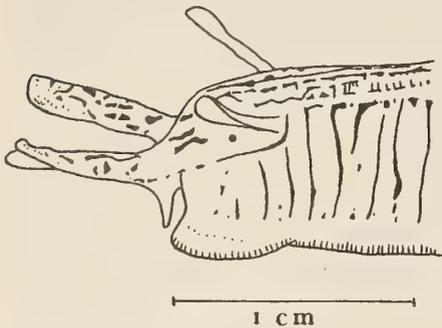


Figure 4: *Phyllaplysia taylora*, lateral anterior aspect from life.

with 32 to 34 lateral teeth on either side of the rachidian tooth for *P. taylora* with his counts of 40 to 41 rows of teeth with 42 to 52 laterals for *P. zostericola*. MARCUS (1961:11) reported 43 rows with 50 to 53 lateral teeth in the half-row for *P. zostericola*. The key point here is the size of the animal examined. Figure 5 shows the radular counts of 40 alcoholic specimens plotted against the body length. These ranged in size from an individual three mm long and weighing one mg to one 61 mm long and weighing 3.12 gms. The lateral teeth in the half-row ranged from 20 to 61. The number of rows varied from 14 in an 11 mm specimen to 50 in a 61 mm specimen. The number of rows showed only a fair correlation with body length. BERGH described a 14 mm alcoholic specimen; McCAULEY's type specimen was 50 mm alive, and MARCUS studied a 48 mm alcoholic specimen. Alcoholic preservation of relaxed specimens of this animal results in a reduction of length of about 20 percent from life. The radula counts of the above authors fall on or very near the distinct curve indicated by figure 5.

The radular teeth of all the specimens represented in figure 5 are extremely similar to those illustrated by MARCUS (1961: fig. 31). The teeth illustrated by McCAULEY (1960: fig. 1) are evidently worn. McCAULEY (1961: 550, 551, fig. 1) indicates that the rachidian tooth of *Phyllaplysia zostericola* (type locality: San Juan Island, Washington) has three cusps and he contrasts this with the five cusps on the rachidian tooth described for *P. taylora* by BERGH (1902). MARCUS (1961: 11, fig. 31) indicates five cusps for the rachidian tooth of his Tomales Bay specimen. The rachidian teeth of all radulae that I have examined, including two from San Juan Island, have three distinct cusps with an additional hump on each side of the tooth which fades into its base. These lateral rises appear somewhat less distinct than the lateral cusps shown on the rachidian tooth illustrated by MARCUS. Thus it can be seen that the specimens described as *P. zostericola*

cannot be separated from *P. taylora* by radular characteristics.

The penis of all specimens examined, including the two from San Juan Island, was armed. The number of papillae on the penis varied from three in a 19 mm alcoholic specimen to 20 in a 52 mm specimen; both of these extremes came from Elkhorn Slough. These structures are usually arranged as two rows of very large papillae on the penis base, which lead into a single row of progressively smaller papillae along the edge of the penis opposite the seminal groove. A few small papillae are scattered out of the rows. A single, hard, cuticular spine is present on each of the larger papillae. The rows on the penis are continued onto the sheath as two rows of at least three large, spined papillae. Four to six small spines are present in the soft folds of the penial sheath.

The hermaphroditic gland is lobate in Elkhorn Slough specimens.

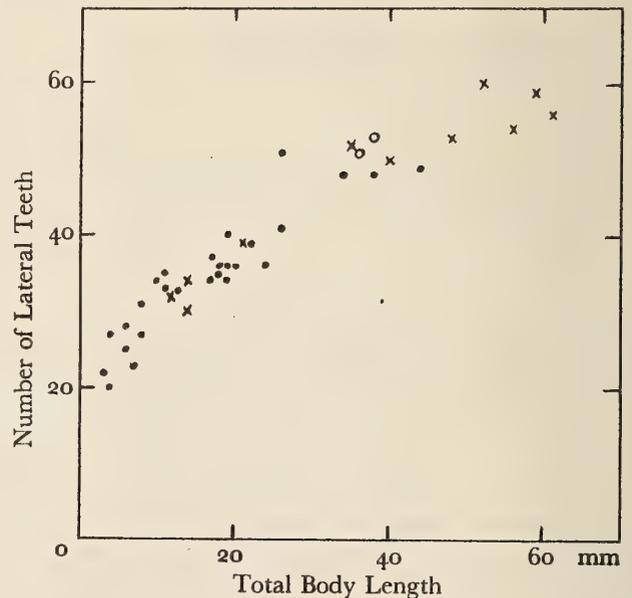


Figure 5: Number of lateral teeth on either side of the rachidian row of the radula compared with total body length of 40 alcoholic specimens of *Phyllaplysia taylora*.

● = Elkhorn Slough ○ = San Juan
x = Other areas

SUMMARY

Morphological variation in specimens of *Phyllaplysia* from the west coast of the United States between San Juan Island, Washington, and Newport Bay, California, is considered. The present evidence indicates that all the presently known *Phyllaplysia* along the coast from Nanaimo, British Columbia (49° 09' N, 123° 57' W) to San Diego, California (32° 42' N, 117° 11' W) should be

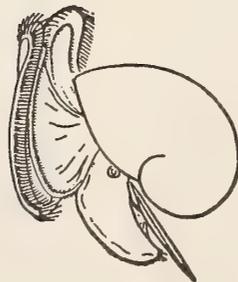
known under the name of *Phyllaplysia taylori* DALL, 1900.

ACKNOWLEDGMENTS

I wish to sincerely thank Joan E. Steinberg and Lawrence Andrews for their kindness in supplying many specimens. The critical reading of the manuscript by Dr. Rolf L. Bolin is gratefully acknowledged.

Literature Cited

- BERGH, LUDWIG S. RUDOLPH
1902. Malakologische Untersuchungen in Semper's Reisen im Archipel der Philippinen. Vol. 7, Abt. 4, Abs. 4: 313-382; pls. 25-29.
- DALL, WILLIAM HEALEY
1900. On a genus (*Phyllaplysia*) new to the Pacific coast. Nautilus 14: 91-92.
- ENGEL, HENDRICK, & P. WAGENAAR HUMMELINCK
1936. Über westindische Aplysiidae und Verwandte anderer Gebiete. Capita Zoologica 8 (1): 1-76; 43 text figs.
- HEDGPETH, JOEL W.
1962. Introduction to seashore life of the San Francisco Bay region and the coast of northern California. Univ. Calif. Press, Berkeley, Calif. 136 pp.; 8 pls.; 80 text figs.
- LANCE, JAMES R.
1961. A distributional list of southern California opisthobranchs. The Veliger 4 (2): 64-69.
- LIGHT, SOL FELTY, *et al.*
1954. Intertidal invertebrates of the central California coast. xiv + 446 pp.; 138 text figs. Univ. Calif. Press, Berkeley, California.
- MACGINITIE, GEORGE EBER
1930. Notice of extension of range and of new species of various invertebrates. Ann. Mag. Nat. Hist., ser. 10, 6: 68.
1935. Ecological aspects of a California marine estuary. Amer. Midl. Natur., 16 (5): 629-765.
1949. Natural history of marine animals. xii + 473 pp.; 282 text figs. McGraw-Hill, New York.
- MARCUS, ERNST
1961. Opisthobranch mollusks from California. The Veliger 3 (Supplement, pt. 1): 1-85; pls. 1-10. (Feb. 1, 1961)
- MARCUS, EVELINE, & ERNST MARCUS
1962. Opisthobranchs from Florida and the Virgin Islands. Bull. Mar. Sci. Gulf and Carib. 12 (3): 451-488; 28 text figs.
- MCCAULEY, JAMES E.
1960. The morphology of *Phyllaplysia zostericola*, new species. Proc. Calif. Acad. Sci. 4th ser., 29 (16): 549-576; 6 text figs.
- RICKETTS, EDWARD F., & JACK CALVIN
1962. Between Pacific tides. 3rd. ed., 2nd. rev. by JOEL W. HEDGPETH. xiii 516 pp.; 135 text figs.; 46 pls.; Stanford Univ. Press, Stanford, California.
- SMITH, ALLYN G., & MACKENZIE GORDON, JR.
1948. The marine mollusks and brachiopods of Monterey Bay, California, and vicinity. Proc. Calif. Acad. Sci., 4th. Ser., 26 (8): 147-245; pls. 3-4; textfigs. 1-4.



On the Taxonomy of the Family Tritoniidae

(Mollusca : Opisthobranchia)

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Since my systematic survey of the "Nudibranchia Dendronotacea" was published in 1936, a great many taxonomic novelties have appeared. It is necessary to undertake some revision of this part of the opisthobranch mollusks: above all, the family Tritoniidae seems to be in urgent need of revision. In 1936 I used for this family the name *Duvauceliidae*, following the opinion of IREDALE & O'DONOGHUE (1923). These authors claimed priority for the genus name *Duvaucelia* RISSO, 1826 (not RISSO 1818, as given by some authors) over *Tritonia* CUVIER, 1797, an opinion that must be changed (*cf.* PRUVOT-FOL, 1931; 1954, p. 346). Most importantly, it has seemed necessary to restore the genus names to their respective types. In some instances, too, changes of nomenclature and relations have to be adopted. Thus it may be remarked here that BERGH established in 1907 a genus *Tritonidoxa* which was omitted - while awaiting additional material or reports - from my work of 1936. In 1926, however, I did mention this genus and said about it (ODHNER, 1926 b, p. 32):

"Freilich ist die Anwesenheit von Kiemen eine für *Duvauceliidae* mit Ausnahme von *Tritoniella* charakteristische Regel, ohne Ausnahmen ist sie jedoch nicht. So beschreibt BERGH 1884 (Malac. Unters. XV, S. 726) ein Exemplar von *Tritoniopsis tetraquetra*, von dem er sagt: 'Am Rückenrand fehlten Kiemen fast ganz (abgerieben?), und DALL behauptet, aber kaum richtig, dass solche auch im Leben fehlen.' (In der Regel hat diese Art aber Kiemen, vgl. O'DONOGHUE 1922.) Dies zeigt, dass es kaum berechtigt ist, wenn BERGH 1907 die Abwesenheit von Kiemen in *T. capensis* für einen hinreichenden Grund hält, für diese Art eine besondere Gattung, *Tritonidoxa*, zu schaffen. Dieser negative Charakter ist unsomehr hinfällig, als alle positiven Charaktere der Art *Tritonia*-artig sind, so vor allem Kiefer und Radula, und ich füge daher die Art in jene Gattung ein." *Tritonidoxa*, however, may be a distinct subgenus characterized by a flagelloid penis, as BERGH himself stated in the description of the species.

In my work of 1939, however, I revived, following PRUVOT-FOL (1931) and WINCKWORTH (1932), the

genus name *Tritonia* for the large species *T. hombergi* CUVIER, 1797 (type) and *T. griegi* ODHNER, 1922 - further described and figured, as to morphology of genital organs, by me in 1926^a, when it turned out that *T. griegi* belongs to the subgenus *Tritonidoxa* because of a flagelliform male organ. I also pointed out that the large forms of *Tritonia* differ in anatomy and even in external characters from the small ones to which the genus name *Duvaucelia* should be restricted, inasmuch as *Tritonia*, just as also *Tritoniella* and *Tritoniopsis*, has the site of the anus in or behind the middle of the body, while in *Duvaucelia* the anus is situated much farther towards the front on the right side^b.

Some other differences between *Tritonia* and *Duvaucelia* are found in the number of radular teeth, which is smaller in the small species (*Duvaucelia*); but in general appearance of the teeth the two genera agree. The just mentioned two genera *Tritonia* and *Duvaucelia* are examples of the two trends of development followed by the members of the family Tritoniidae, namely the one pointed out by me in 1936 as starting from the already begun detorsion in the large species of opisthobranchs. I said in that work (ODHNER, 1936, p. 1075):

"The primitive condition in the nudibranchs is, as mentioned above, that the liver originates at the larval stage as two distinct masses, one on each side of the stomach. In their phylogeny, however, the nudibranchs are supposed to have passed a process of detorsion. This, of course, was preceded by the torsion common to all gastropods. We may assume that the liver was made the subject of these processes in such a way that its original bipartition was obliterated by the earlier torsion, which made these portions fuse intimately with each other, whereas the detorsion activated the tendency to separate them anew. Where the detorsion

^a Detailed descriptions of these organs given by THOMPSON (1961).

^b In 1932 I referred *Tritoniopsis plebeia* to *Duvaucelia*, but its position is more correct in *Tritonia* and it forms, indeed, a subgenus of its own, *Candiella*, to which it has now been restored. *Candellista*, on the other hand, is a synonym of *Tritonia* (in its restricted sense, *cf.* below).

has not been completed, as in the primitive opisthobranchs and even the Pleurobranchacea, the root of the nudibranchs, the liver still keeps this unity. According to this view we have to consider those forms of *Duvauceliidae* as the primitive ones, in which the liver remains a single mass composed by the fused right and left portions. To this section all genera belong except *Marionia* which shows a complete bipartition, inasmuch as its right liver is a distinct mass of its own. Just its position proves that the detorsion is less perfect, because in *Marionia* the right liver lies at the right side of the stomach, below the intestine, and debouches in the anterior stomach wall, whereas in *Duvaucelia* its position is to the left, on the upper side of the stomach and its mouth more medially; so in *Tritoniella*, too (cf. ODHNER 1934, figs. 58 [the designations of the liver portions in the figure have been reversed: l_1 is the right liver, l_2 the left posterior one] and 63.) *Marionia* has also another secondary character of organization, namely its stomachal plates. These thin, elevated, easily loosened laminae do not occur in the more primitive genera *Duvaucelia* and *Tritoniella* but have originated from the pyloric folds in these forms by means of their increase and strong cuticularization."

There are, besides, other characteristics to take into consideration when judging the interrelations of the genera of the family Tritoniidae, such as a continuous decrease of the body size in some of the genera combined with a displacement of the anus towards the front end. In the large species, the anus is situated as a rule in or behind the middle of the right side, while in the small species its position is decidedly more anterior, and this is especially evident in *Duvaucelia* as compared with *Tritonia*. It seems that in this combined evolution the diminishing size of the body contrasts with the tendency of the detorsion, since this latter tends to a displacement of the anus backwards. We should note, however, that a reduction of the body size has also a relation to the earlier stages of ontogeny, which in such a case can reappear in the adult stage. Therefore the conclusion seems justified that the small species constituting the genus *Duvaucelia* may have originated from larger forms and can be derived from Tritonias, in such a retrograde evolution, expressing itself in the more or less anterior displacement of the anal and genital openings. There are, together with these gradual modifications and other kinds of differentiation, good specific characters in colour or ornamentation in external appearance. We find further that there is probably a parallel evolution starting out from *Marionia*, inasmuch as in *Paratritonia* described by BABA in 1949, a reduced body size is combined with a similar anterior position of the same orifices as in *Duvaucelia* but also combined with the presence of stomachal plates, though smaller than in *Marionia*. *Paratritonia* therefore

seems to be derived in the same way as *Duvaucelia* and by means of parallel evolution, but from the distinct genus *Marionia*.

A still dubious genus, probably derived by means of a similar reduction from unknown source, is represented by a small form described by PRUVOT-FOL in 1945 as *Tritonidoxa cincta*. This species shares the reduced external habitus of the genera *Duvaucelia* and *Paratritonia* and even shows further reduction in possessing only two pairs of gills and only two simple velar papillae; it therefore could belong to a distinct genus akin to *Paratritonia*. PRUVOT-FOL (1954, p. 349, figure explanation) suggests *Tritonidoxa*. The first lateral tooth (in *Tritonidoxa ingolfiana* and *T. griegi*) is more regularly hook-shaped than it is in *Tritonia*, but it shows in *Tritonidoxa cincta* a still better agreement with that of *Paratritonia*, as does also the median tooth. PRUVOT-FOL's careful observations thus enable us to expect where the next allies of this enigmatical species may be sought.

We may take this occasion also for a revision of some species named and described by me in 1936 as belonging to the new genus *Marioniopsis*, which in external habitus is very similar to *Marionia* but differs in the anatomy in having the two liver portions fused and not distinctly separated as in the last mentioned genus.

In 1936 I described, though only preliminarily and because of lack of material, a species that had been referred by BABA in 1933 to BERGH's *Tritonia irrorata*; I renamed it *Marioniopsis babai* (ODHNER, 1936, *loc. cit.*, page 1087). In 1937 the same species was described by BABA as new under the name *Marionia obscura*. That it is identical with BABA's *T. irrorata* (and different from BERGH's species of the same name) is, however, not communicated by BABA in his description, but he has stated this fact in a letter to me dated February 9th, 1936: "Your kind letter dated Jan. 16 and 17 reached me this morning. I have (been) engaged in the monographic work of the Japanese opisthobranchs, containing more than 160 species — both known and unknown, and the manuscript has just (been) finished. In this Ms. I have made correction of the previous mistakes into which I fell: *Duvaucelia irrorata* is altered to *Marionia ornata* nov. sp. with the following description '— *Marionia ornata* nov. sp. *Duvaucelia irrorata* BABA, Annot. Zool. Japon., Vol. 14, no. 2, 1933, pp. 274-275, fig. 1. Tomioka.'" Dr. Baba also kindly sent me two specimens (under a provisional name) both of which I could identify as his *Marionia obscura* and even could state as belonging to *Marioniopsis* for they show the two liver portions fused below the stomach. In fact, therefore, BABA's *Marionia obscura* of 1937 is the same species as my *Marioniopsis babai* of 1936, though no convincing literary data have been given to this identity. Because of the priority the name of 1936 should be the valid one.

A further parallel evolution seems to have taken place in the forms which I included (1936) in the genus *Tritoniopsis* PRUVOT-FOL, 1933 (= *Tritoniopsis* ELIOT, 1905). First it should be remarked that a change of ELIOT's denomination is unjustifiable, because that name was not preoccupied by CARPENTER, since his similar genus name was *Tritonopsis* (cf. NEAVE, 1939-1940); the name *Tritoniopsis* ELIOT, 1905 therefore remained valid. The most primitive form of the three species which I included in that genus is no doubt *Tritoniopsis tetraquetra* (PALLAS, 1788), which has, in its general shape (relatively broad body and marked back margin) a greater agreement with *Tritonia* than with the smaller and more typical species of *Tritoniopsis*; even the remarkable position of the anus behind the middle of the body was striking to BERGH; further, its radula is broad as in *Tritonia*, with the sum of the lateral and marginal teeth numbering about 250 on each side of the unicuspid median tooth. In the typical species of *Tritoniopsis*, on the other hand, the anus is situated more towards the front than in the middle of the body, and the number of radular teeth is at most about 30 on each side of the radula. A still smaller number of teeth is stated to occur in *T. elegans* (radular formula: 7-9.1.7-9, cf. ODHNER, 1936) and in *T. alba* BABA, 1949 (5-6.1.5-6) in which latter species, as in *T. elegans*, the laterals bear a series of faint denticles, while they are smooth in the typical *T. brucei* ELIOT, 1905.

The differences just mentioned in the species of *Tritoniopsis* indicate clearly that the large and evidently more primitive members mentioned should be considered as nearer the original source than the smaller species and thus to form a distinct genus, separate both from the genus *Tritoniopsis* (in characters mentioned) and from *Tritonia* (in the shape of the median radular tooth). I propose for this genus the name *Tochuina* ODHNER, gen. nov. with *Limax tetraquetra* PALLAS, 1788 (= *Tritonia gigantea* BERGH, 1904, = *Tritoniopsis tetraquetra* in ODHNER, 1936) as type species. The name *Tochuina* is derived from the vernacular name Tochui, which, according to BERGH, 1879, p. 154, note, was the name of this animal in the Kurile Islands where, according to PALLAS, it was generally used as food in a raw or cooked state^o.

Lastly, some dubious species may also be mentioned. The small green coloured black-marbled *Sphaerostoma flemingi* POWELL, 1937, from Auckland, New Zealand, with a length of only 6 mm and with 5 gills on each side; its buccal veil has only two sharply conical lobes; rhinophore-sheaths entire edged. Only the left side is figured and nothing is said about the position of the openings on the right side. It may be a *Duvaucelia*.

In every case the genus *Duvaucelia* RISSO, 1826, should be held apart (as PRUVOT-FOL did in 1954) from *Tritonia*

because of its more slender body shape and the more anterior site of anus and genital pore. The anus is situated well in front of the middle of the body and the genital pore below or even in front of the first branchial tuft, quite as is the case in *Duvaucelia cincta* PRUVOT-FOL, 1945 (cf. PRUVOT-FOL, 1954, fig. on p. 349).

But it is especially in the external colouration that the differentiation of the small *Duvaucelia* forms has become specialized; and therefore these species can be recognized from external characteristics as to the descriptions given in the diagnoses by PRUVOT-FOL, 1954.

Some changes must also be made in the two closely related genera *Marionia* VAYSSIÈRE, 1877, and *Marioniopsis* ODHNER, 1936. The difference between them was stated in my latter paper; the chief character is of an anatomical nature and therefore somewhat difficult to find because observable only by means of dissection. Whereas in *Marionia* the two parts of the liver (one large left-sided and a smaller right-sided one) are separate, this is not the case in *Marioniopsis* where the two liver parts are fused, as in all Tritoniids. In comparing the two figures 14 and 16 in my paper of 1936 we find that the two liver parts are divided in *Marionia pustulosa* (fig. 16) because the left one leaves the stomach uncovered, the right, on the contrary, has its mass concentrated as a small ball to the right side. In *Marioniopsis cyano-branchiata* (fig. 14) the left liver extends in length up to gill 3, and in the intestine curves above the left liver to which the right one is fused; but in *Marionia pustulosa* (fig. 16) the intestine does not curve to the left side at all. All these differences seem, however, to be of secondary importance in comparison with the fact that a separation or a fusion of the two parts of the liver is to be clearly noted, though, of course, with some difficulty.

In "*Marionia*" *olivacea* BABA, 1937, a still stronger curve of the intestine towards the left side is observed (*loc. cit.* p. 118, textfig. 2). "The liver consists of a small anterior and a large posterior lobe," says BABA (*loc. cit.* p. 120). I found these to be not separated as in *Marionia* but fused as in *Marioniopsis*. I observed this fact in two specimens of the present species kindly sent to me by Dr. Baba in February 1936. In his "Opisthobranchia of Japan (II)" of 1937, BABA also accepts the name *babai* ODHNER, 1936 as valid for his *Duvaucelia irrorata* (which is not that of BERGH, 1905).

Considering the species of the genus *Tritonia* s. s., and especially the small ones, we have not as yet any possibility to arrange them all systematically. I refer the reader for confirmation of this difficulty to the statement by MARCUS (1961, p. 32), where he says about the Cali-

^o BERGH cites the name (incorrectly) "Tochni", but PALLAS in 1788 writes "Tochui" and I follow his orthography.

fornia *Tritonia palmeri* COOPER, 1862, that it "cannot be assigned to any of the subgenera at this time," because specimens from different localities differ too much in the stated characters of external as well as internal morphology.

SYNOPSIS OF GENERA AND SUBGENERA
OF THE FAMILY TRITONIIDAE

1. Branchial gills replaced by simple processes in lateral dorsal margins. Back surface with blunt keels. Anus in the middle of the right body side. Radula with simple or tripartite median tooth. No stomachal plates. Jaws with smooth margins. Liver in a single mass. *Tritoniella* ELIOT, 1907
(type by subsequent designation
T. belli, ELIOT, 1907)
- Branchial gills ramose in lateral dorsal margins (rarely absent), of uniform or alternating size 2
2. Liver in two masses; left liver leaving stomach uncovered, right liver distinctly marked off, debouching into frontal wall of stomach. Gills branched, of uniform - not alternating - size. Stomach plates present. Anus in the middle length of the body. Genital opening below second or third gill. Velar papillae compound. Jaws with 3 to 6 series of fine denticles. Radula as in *Tritonia* (median tooth tricuspidate; first lateral differentiated).
Marionia VAYSSIÈRE, 1877
(type by subsequent monotypy
M. berghi VAYSSIÈRE, 1877
= *Tritonia blainvillea* RISSO, 1818)
- Liver fused into a single mass, covering upper and left sides of stomach, right liver thus indistinctly marked off, with its own duct 3
3. Strong stomachal plates. Genital opening below second or third gill. Jaws with a single series of strong denticles 4
- No stomachal plates 5
4. Radula as in *Tritonia* (median tooth with 3 to 5 cusps), first lateral differentiated
Marioniopsis ODHNER, 1934
(type by original designation
Tritonia cyanobranchiata RÜPPELL & LEUCKART, 1828)
- Median tooth unicuspidate, first lateral undifferentiated. Anus in front of mid-body length. Gills and velar papillae few in number. Genital opening below first gill. *Paratritonia* BABA, 1949
(type by original designation
Paratritonia lutea BABA, 1949)
5. Median tooth of radula unicuspidate; first lateral tooth undifferentiated (similar to subsequent laterals); a narrow continuous posterior margin distinct. Jaws smooth. 6
- Median tooth of radula tricuspidate. First lateral tooth differentiated (dissimilar to subsequent laterals) 7
6. Body clumsy; anus behind mid-body length; radula broad with about 250 elongate smooth teeth on each side of the median tooth; penis flagelliform; colour of living animal reddish
Tochuina ODHNER, gen. nov.
(type *Limax tetraquetra* PALLAS, 1788)
- Body relatively slender; anus at about mid-body; radula narrow, with maximum 30 teeth on each side of the median tooth; color whitish or marbled
Tritoniopsis ELIOT, 1905
(type by original designation
Tritoniopsis brucei ELIOT, 1905 [*Tritoniopsisilla* PRUVOT-FOL 1933 is an unnecessary replacement])
7. Body clumsy. Gills numerous, of uniform or alternating size. Anus about in the middle of the body. Genital opening behind the foremost end of dense branchial series. *Tritonia* CUVIER, 1798 8
(type *Tritonia hombergi* CUVIER, 1802, (?)
[under consideration by the ICZN])
(*Candellista* IREDALE & O'DONOGHUE, 1923
according to THOMPSON, 1961)
- Body slender. Gills at most five to eight on each side. Anus decidedly in front of mid-body. Genital opening below or in front of foremost gill tuft. Velar papillae only two to six^a
Duvaucelia RISSO, 1826, ex LEACH MS
(type by monotypy
Tritonia gracilis RISSO, 1826)
8. Velum bilobed, with numerous simple papillae 9
- Velum rounded, with at most eight to ten papillae. Genital opening below the foremost one to two papillae of the more distant branchial series.
subgenus *Candiella* GRAY, 1850
(type by monotypy
Tritonia plebeia JOHNSTON, 1828)
9. Back surface smooth or pustulose. Penis short and broad, with a low crest in front and behind.
Tritonia s. s.
- Back surface smooth. Penis flagelliform.
subgenus *Tritonidoxa* BERGH, 1907
(type by monotypy
Tritonidoxa capensis BERGH, 1907)
- Back surface porous. Penis elongate conic.
subgenus *Myrella* ODHNER, nom. nov.
(pro *Microlophus* ROCHEBRUNE & MABILLE, 1889
[Mission Sci. Cap Horn, 6 (2), Moll., p. 11] non
Microlophus DUMÉRIL & BIBRON, 1837 [Reptilia])

^a A new species of *Duvaucelia* with 6 velar papillae, from the west coast of France, will be described by Mr. J. Tardy.

(type by monotypy)

Microlophus poirieri ROCHEBRUNE & MABILLE, 1889)*Literature Cited*

ALDER, J. & A. HANCOCK

1845 - 1855. A monograph of the British nudibranchiate mollusca 1845. Ray. Soc., pts. 1 - 7.

BABA, KIKUTARŌ

1933. Supplementary note on the Nudibranchia collected in the vicinity of the Amakusa Marine Biological Laboratory. Annot. Zool. Japon., 14 (2) : 273-283.

1937. A new species of the nudibranchiate genus *Marionia* from Sagami Bay, Japan. The Venus 7 (3) : 116-120, text figs.

1937. Opisthobranchia of Japan (II). Journ. Dept. Agr., Kyushu Imp. Univ., 5(7) : 289-344.

1949. Opisthobranchia of Sagami Bay, collected by his Majesty the Emperor of Japan. 4, 2, 194, 7 pp., pls. 1-50 (in color), 161 text figs. Iwanami Shoten, Tokyo.

BERGH, (LUDWIG S.) RUDOLPH

1879. On the nudibranchiate gastropod mollusca of the north Pacific ocean, with special reference to those of Alaska. Proc. Acad. Nat. Sci. Philadelphia, pt. 1: 71-132; pls. 1-8.

ELIOT, CHARLES N. E.

1905. The Nudibranchiata of the Scottish National Antarctic Expedition. Trans. Roy. Soc. Edinburgh, 41 (3) : 519-532; figures.

GRIEG, J. A.

1914(1915) Malacologiske notiser. 1. Nudibranchiater fra Bergens biologiske stations akvarier. Nyt. Magasin Naturvid. Kristiania 52: 11-17.

IREDALE, TOM, & CHARLES H. O'DONOGHUE

1923. List of British nudibranchiate mollusca. Proc. Malac. Soc. London 15 (4) : 195-233. (March 1923)

MARCUS, ERNST

1961. Opisthobranch mollusks from California. The Veliger 3 (Supplement) : 1 - 85; 10 pls.

NEAVE, S. A.

1939-1940. Nomenclator zoologicus. Four Vols. London.

ODHNER, NILS H.

1922. Norwegian opisthobranchiate mollusca in the collection of the Zoological Museum of Kristiania. Nyt. Mag. Naturvid. 60: 1-47; 15 figs.

1927. Nudibranchs and Lamelliariids from the Trondhjem Fjord. Det Kgl. Norske Vidensk. Selsk. Skrifter 1926 (2) : 1-36; 1 plt.

1926. Die Opisthobranchien. in: Further Zoological Researches of the Swedish Antarctic Expedition 1901-1903, 2 (1) : 1-100; pls. 1-3.

1934. The Nudibranchiata. in British Antarctic ("Terra Nova") Expedition, 1910. Nat. Hist. Rep. Zool. 7 (5) : 229-310; pls. 1-3. London.

1936. Nudibranchia Dendronotacea. A revision of the System. Mélanges Paul Pelseuer. Mém. Mus. Roy. d'Hist. Nat. de Belgique, Ser. II, Fasc. 3: 1057-1128; 1 plt.; text figs. 1-47.

1939. Opisthobranchiate mollusca from the western and northern coasts of Norway. Medd. fra Trondheims Biol. Stat. No. 115; pp. 1-92; 59 text figs.

PALLAS, P. S.

1788. Marina varia et rariora. Nova Acta Acad. Sci. Imp. Petropolitana 2. St. Petersburg, 1784.

POWELL, ARTHUR W. BADEN

1937. New species of nudibranchiate mollusca from Auckland waters. Rec. Auckland Inst. Mus. 2 (2) : 119-124; plate 30.

PRUVOT-FOL, ALICE

1931. Notes de systématique sur les Opisthobranches. Bull. Mus. Paris, sér. 2, 3 (3, 8) : 308-316.

1936. Note préliminaire sur les nudibranches de Risso. Rev. Suisse Zool. 43 (23) : 531-533.

1954. Mollusques opisthobranches. Faune de France 58: 1 to 460; 1 plt.; 173 text figs.

RISSE, A.

1818. Mémoire sur quelques Gastéropodes nouveaux nudibranches et tectibranches observés dans la mer de Nice. Journ. Phys., Chim. et d'Hist. Nat. 87: 368 - 377.

1826. Histoire naturelle des principales productions de l'Europe méridionale etc. 4: 439 pp.; 12 pls. Paris & Strasbourg.

ROCHEBRUNE, ALPHONSE TRÉMEAU DE, & Y. MABILLE

1889. Mollusques. Mission Scient. du Cap Horn, 1882-83. Vol. 6: Zool. Paris.

THOMPSON, T. E.

1961. The structure and mode of functioning of the reproductive organs of *Tritonia hombergi* (Gastropoda Opisthobranchia). Quart. Journ. Microscop. Soc. 102 (1) : 1 - 14; 9 figures.

WINCKWORTH, R.

1932. The British marine mollusca. Journ. Conch. 19 (7) : 211 - 252.

NOTES & NEWS

Range Extension for *Testacella haliotidea* (DRAPARNAUD)

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California Academy of Sciences
Golden Gate Park, San Francisco 18, California

The Academy of Sciences has received a fine adult living animal of *Testacella haliotidea* (DRAPARNAUD), a carnivorous slug with an external shell on the end of its tail. C. Don MacNeill of the Department of Entomology collected it in his garden at 808 Seaview Drive in El Cerrito, California, on March 26, 1963. This represents a small extension of the range of the species from my garden at 722 Santa Barbara Road in Berkeley. *Testacella haliotidea* was first found in California by T. Maslin in a garden near the corner of Vine and Oxford Streets, Berkeley, in 1941; shortly thereafter a thriving colony was discovered along the north bank of Strawberry Creek near the west edge of the University of California campus. The species seems to be spreading northward along the west side of the Berkeley Hills, although specimens from a nursery in Piedmont, south of Berkeley, were collected by the entomologist E. R. Leach, who donated them to the Academy in 1961.

N. C. M. C.

The Northern California Malacozoological Club is a non-profit educational corporation (Articles of Incorporation No. 388 588 were filed December 31, 1959 in the office of the Secretary of State). The Club publishes a scientific quarterly, the VELIGER. Donations to the Club are used to defray a part of the production costs and thus to keep the subscription rate at a minimum. Donors may designate the Fund to which their contribution is to be credited: Operating Fund (available for current production); Savings Fund (available only for specified purposes, such as publication of especially long and significant papers); Endowment Fund (the income from which is available. The principal is irrevocably dedicated

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BOOKS, PERIODICALS, PAMPHLETS

Om ett par för Sverige nya, anthropochora landmolusker, *Limax valentianus* FÉRRUSAC och *Deroceras caruanae* (Pollonera), jämte några andra, kulturbundna arter.

HENRIK W. WALDÉN

Kungl. Vetenskap- och Vittershets-Samhälles Handlingar, sjätte följden, ser. B, vol. 8, no. 8 47 pp., 10 text figures, 3 tables, (Meddelanden från Göteborgs Musei Zoologiska Avdelning, 131). Göteborg, 1960. [in Swedish, with a summary in English.]

This is an account of the spread of exotic snails and slugs into Sweden, introduced through various human agencies (anthropochora). It is of interest to American malacologists because all the species discussed have at one time or another been introduced into the United States; some of them have a permanent foothold. Much useful anatomical and ecological information is provided, including food habits, special habitats, etc. The author separates those species that thrive in man-made situations and that are largely limited to them (synanthropous), e. g. cellar snails of the genus *Oxychilus*, and those that seem to thrive under somewhat less cultivated conditions, e. g. the slug *Limax maximus*.

Species treated include: *Caecilioides acicula* (MØLLER) *Oxychilus draparnaudi* (BECK), *Zonotooides arboreus* (SAY), *Limax maximus* LINNAEUS, *Limax* (*Lehmannia*) *valentianus* FÉRRUSAC, and *Deroceras caruanae* (POLLONERA). All but *Caecilioides acicula* and *Zonotooides arboreus* are common in the San Francisco Bay region, the latter being abundant and indigenous at higher elevations in California.

WALDÉN makes *Limax* (*Lehmannia*) *poirieri* MABILLE a synonym of *L. valentianus* and comments on the confusion between this and *L. marginatus* (MULLER). This latter name has for years been applied to the species introduced into the United States but has since been

identified as *L. poirieri* on information provided by the British malacologist H. E. Quick. Another name change for a common introduced California slug pest therefore seems to be in the making.

The English summary of this study is a good one.

AGS

Fossils: a guide to prehistoric life.

FRANK H. T. RHODES, HERBERT ZIM, and PAUL R. SHAFER. Golden Press, N. Y.: Pp. 160, with 481 illustrations in color. \$ 1.- (Deluxe library edition, \$ 3.50)

One wonders whether the number of good popular works in natural history of recent years has resulted from or been the cause of increased interest. At any rate, there is now a wide variety of readily-available paperback

books. The latest comer is a new volume in the Golden Nature Guide series. Like others in this line it is well illustrated — surprisingly so considering the drab appearance of most invertebrate fossils. Several brief chapters set the stage for the amateur; then there is a well organized survey of the animals and plants that are known to us as fossils. Selection of representative groups is good, and there are few errors. On page 118 *Glycymeris* is incorrectly spelled *Glycimeris*, and one might quibble over the Jurassic-to-Recent range of *Arca*. The book contains little that the beginner might have to unlearn later, and it can be recommended not only as a reference and text book for the layman but also as a handy little review work for students in general.

Professor Rhodes is at the University College of Swansea, Wales, and Professor Shaffer at the University of Illinois.

MK

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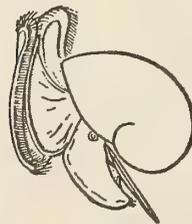
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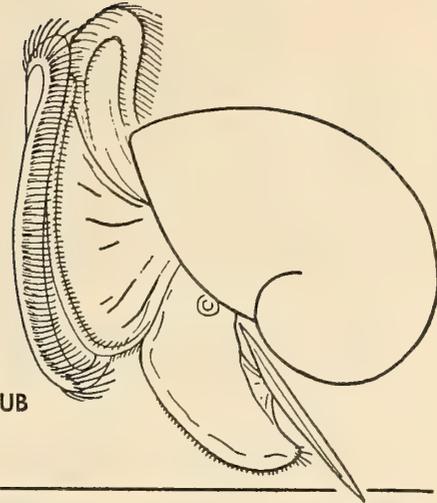
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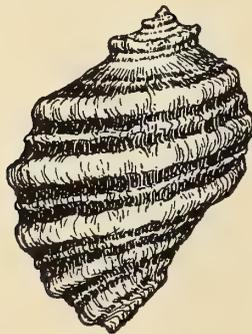
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Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION**, Subdivision, SECTION,
 SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).
New Taxa

Nest Building in the Bivalve Genera *Musculus* and *Lima*

BY

ARTHUR S. MERRILL

U. S. Bureau of Commercial Fisheries Biological Laboratory,
Woods Hole, Massachusetts

AND

RUTH D. TURNER

Museum of Comparative Zoology, Harvard University,
Cambridge 38, Massachusetts

(Plates 9 to 11)

The adaptations of bivalve mollusks are numerous. Many species burrow into soft muds and sands, fewer into harder substances only. Others can crawl, leap, and swim, and some live as commensals or parasites. There are sedentary species which attach themselves, temporarily or permanently, to objects by means of byssal threads which they secrete. Among the latter a number of species have developed the process of byssus spinning to the point where they enclose themselves in capsules, or "nests."

Bivalves have two principal methods for constructing nests. One method involves the agglutination of foreign particles with mucus produced by the animal. According to HAAS (1942, 1943) these are the main ingredients used in building the nests of *Diplodonta orbella* (GOULD, 1851) and *Cooperella subdiaphana* (CARPENTER, 1864). The second method, which utilizes byssal threads as the principal constituent, is far more common among nest builders and has been studied most extensively in the case of *Lima* and *Musculus*.

The process of nest building has been observed for *Lima hians* (GMELIN, 1791) by ROBERTSON (in JEFFREYS, 1863), GILCHRIST (1897), and others, but no one, to our knowledge, has kept *Musculus discors* (LINNAEUS, 1767) in aquaria and observed the early stages of nest building.

Recently a large number of specimens of *Musculus discors* was acquired during dredging operations of the U. S. Bureau of Commercial Fisheries research vessel *Delaware* (Cruise 62-6). These specimens were found in nests, fouling the upper valve of the sea scallop, *Placopecten magellanicus* (GMELIN, 1791), and usually well camouflaged among other fouling growth. They were

taken from the Northeast Peak of Georges Bank, off Massachusetts (Lat. 41° 57.2' N; Long. 66° 16.7' W), on June 1, 1962, at a depth of 44 fathoms, and were held aboard ship in tanks with running sea water. In the laboratory, specimens of various sizes were removed from their nests and placed in individual aquaria, supplied with running sea water (Plate 9, Figure 1), to see if they would construct new nests. After several days some did. The early phases of construction were observed closely and documented with a series of photographs.

In this paper the process of nest building of *Musculus discors* is described and illustrated; and for comparison, the process for *Lima* is reviewed. In a final section, the adaptive significance of nest building in the two genera is discussed and compared.

NEST BUILDING IN *MUSCULUS*

During the early stages of nest building *Musculus discors* tends to weave a compact structure entirely of byssal threads which it attaches to the substrate. In waters off Cape Cod, Massachusetts, however, the completed nest later becomes well camouflaged, for stolons of hydroids grow into it, small bivalves and annelids nestle among the outer threads, and colonies of bryozoans often overgrow it completely. MACGINITIE (1959) described similarly the completed nest of the Pacific variety of this species. FORBES & HANLEY (1853) remarked that those in English waters are found "enveloped in nests formed of fragments of *Flustra foliacea* [a colonial bryozoan] and masses of sand agglutinated together and combined by byssal threads." STIMPSON (1853) observed that the nests

of specimens from the vicinity of New Brunswick are formed of various marine substances. Thus, it would seem that, in a given area, the composition of the completed nest depends in part on the composition of the substrate and on the organisms closely associated with the nest builder.

Musculus discors has no permanent openings in the byssal capsule for water currents to pass through. Rather, the byssal threads radiate from their point of attachment to the animal, and surround the shell in all directions, completely concealing the resting animal. Only when the shell valves are open are the byssal threads separated and the siphons exposed for feeding and respiration.

The foot (Plate 9, Figure 2), in conjunction with special glands, is used in the formation of byssal threads. This highly specialized organ is capable of great extension. When contracted it is short and tongue-shaped, but when fully extended it becomes slender and strap-shaped. The means by which the Mytilidae form and attach threads of conchiolin have been carefully described by WHITE (1937). In essence, the foot has a groove on the posterior side which, at the base, is continuous with the byssal aperture. Secretions issue not only from glands of the byssogenous cavity but also from those lining the groove of the foot. The groove, which terminates in a depression or sucker at the distal end of the foot, is closed during the process of secretion. The sucker is rounded in *Mytilus edulis* (LINNAEUS, 1758), but somewhat triangulate in *Musculus discors*. Other glands emit a cement-like secretion into the sucker which forms the adhesive disc at the point of attachment of the thread. To fix a thread the foot extends to the object of attachment, cements the adhesive disc in place, then opens its groove, allowing sea water to enter and harden the white, transparent thread. To see a newly produced thread is not easy because of its transparency, but a bright light shined over an area where the foot has been observed at work will pick up a thread by its reflection. In time, chemical reaction causes the thread to darken; the color becomes light yellow the first day and changes later to progressively darker shades of brown. The threads of *Musculus* are thin and flexible, unlike the thick, stiff ones of *Mytilus*.

The nest is composed of a soft, flexible network of threads which may be likened to a hollow ball of twine.

The threads, however, all emanate from a single point, the byssal aperture; and it is only at this point that the animal is attached to its nest, for none of the threads is ever attached to the shell itself. Thus the animal is suspended within the nest, in a manner allowing freedom of movement when opening the valves during feeding and respiration. The animal controls the opening of the nest by the action of the byssal retractor and the two adductor muscles of the shell. When these three muscles are relaxed and the valves open, the byssal aperture becomes situated nearer the shell edges. This extension of the byssal attachment point relieves the tension on the threads and allows them to separate, forming an oval aperture in the posterior-ventral region through which the siphons protrude. When fully extended, the valves open to a considerably wider angle than those of the unprotected species of the mytilids we have observed. Closing of the nest aperture is accomplished by simultaneous contraction of the adductor muscles and of the byssal retractor muscle. As a result, the threads over the ventral margin of the shell are drawn into the mantle cavity; this causes the remaining portion of the nest to be brought into closer contact with the shell, completely hiding it.

Several specimens were observed in the process of nest building and all proceeded in the same fashion. They attached themselves to some object so that they were free of the bottom and could wrap threads completely around themselves in all directions. The specimen described here (Plate 10, Figures 1 and 2) first attached itself high on the side of the aquarium with the right valve towards the glass and the ventral margin uppermost. The first threads attached were directly above the shell and the next were placed in front and behind it. Then the very extensible foot reached out and over the left valve to attach threads on the glass below it. Once these initial "guy ropes" had been put in place, the animal proceeded to strengthen its position by producing several series of threads. Each series was composed of 5 to 12 threads arranged in straight lines. The first series was placed directly above the shell, while others occupied various points around the periphery until 40 or more separate threads had been produced. After this the animal extended its foot around the left valve of the shell and attached threads to those already produced on the opposite side. The first of these threads were placed directly around the central part of the shell,

Explanation of Plate 9

Musculus discors LINNAEUS, 1767

Figure 1: Specimen removed from the nest, lying on the right valve and partially opened, showing the incurrent (left) and excurrent siphons (about 4 x) Figure 2: Specimen with foot extended and the tip appressed against the side of the aquarium. Note the byssal groove extending the length of the posterior surface and terminating in the sucker near the tip (about 4 x)



Figure 1

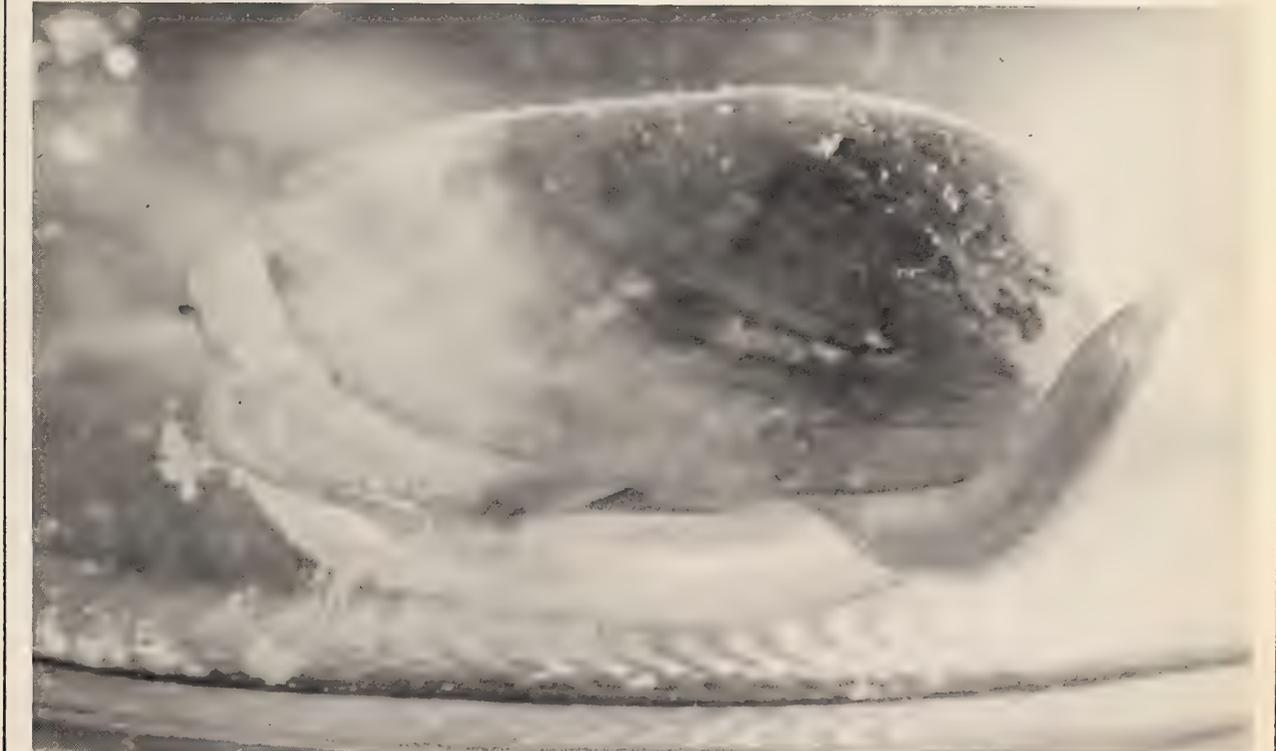


Figure 2

but thereafter they were wrapped diagonally or centrally about the shell. During this stage the remarkable agility and extensibility of the foot were most noticeable. It was also noticed that the foot always extended over the left valve and around itself, but never went in the opposite direction between the right valve and the glass except for purposes of strengthening its position of attachment.

As the nest is being produced bits of mucus and detritus collect between the threads which tend to mat the whole together. Literally thousands of threads are laid down before the nest is completely and securely matted together. After the nest is compact and well established, the animal occasionally passes its foot over and around stationary organisms which have attached to the nest, incorporating these in the outer fringes of the nest (Plate 11, Figures 1 and 2).

One animal, although disturbed intermittently for observational purposes, produced 300 to 400 threads in 8 days. Another, left undisturbed for a period of 2 weeks, had constructed a rather complete but loose nest of perhaps 1000 threads. A third specimen, observed after it had put out 5 or 6 threads, added another 24 strands in the next 2 days, 50 or 60 more during the succeeding 2 days, and over 100 the following 2 days, totaling about 200 threads in a week (Plate 10, Figures 1 and 2).

The animal works sporadically at weaving. The foot will attach several threads industriously and then retire for an indefinite period. Hours may pass before the foot is observed at work again. One animal was seen applying the tip of the foot to the glass side of an aquarium. The spot was marked on the outside of the glass, the slight jar causing the foot to retire. Twenty minutes later, six more adhesive discs, lined in a row, were noticed beside the marked one.

During the early stages of nest building mucus is produced by the mantle glands. As the threads come in contact with the mucus small globules are picked up, collecting like beads on the threads and aiding in the accumulation of adherent detritus, all of which give texture to the partially built nest (Plate 10, Figure 1).

In the field, the size of the smallest specimen of *Musculus discors* which we observed encased completely in its own nest was 8.1 mm. However, specimens up to 18.0 mm were occasionally without nests, but usually specimens over 15.0 mm had at least a rudimentary covering about themselves, and some were already housed in fairly elaborate capsules.

Adult specimens of *Musculus discors* lay egg-strings inside their nests where the embryos develop without any pelagic stage (see THORSON, 1935; MACGINITIE, 1955; and OCKELMANN, 1958 for further details). The young postlarvae remain in the nest near the edge of the adult shell, feeding from the currents produced by the parent. Even larger juveniles are found close to the

siphonal area of the parent still clinging in the outer fringes of the nest. It is not unusual to see several small specimens drawn into the mantle cavity of the parent along with the threads to which they are attached when the parent contracts its byssal muscles while closing its valves. According to SUTER (1913), a number of specimens of *Modiolaria* [= *Musculus*] *impacta* (HERMANN, 1782) are usually found in the same nest. Cohabitation of offspring in the nests of their parents is one plausible interpretation of this communal relationship.

THORSON (1935) illustrated the East Greenland form of *Musculus discors* which had drawn together blades of *Fucus* or *Laminaria* by means of byssal threads as part of its encasement. This was reported also for *Modiolaria* [= *Musculus*] *marmorata* (FORBES, 1833) by JEFFREYS (1836); incidentally, both ROBERTSON (1897) and GILCHRIST (1897) mentioned this very phenomenon for *Lima hians*: “. . . nest found with its occupant securely lodged in the folded frond of a sea weed.” We have not seen this type of nest construction in *M. discors*, perhaps only because the area in which we found the species did not include appropriate sea weed among its biota. All the specimens we have observed, however, make nests in natural crevices when possible, attaching threads loosely to various places on the substrate before fixing threads about themselves.

NEST BUILDING IN *LIMA*

The nests of several species of *Lima* have been described by a number of authors. GILCHRIST (1897) observed specimens of *Lima hians* (GMELIN, 1791) held in aquaria, and reported the process of nest building for this species. In essence, *L. hians* and presumably other nest building *Lima* construct nests by attaching byssal threads to available fragments of shell, stone, and other debris. It does this by applying the tip of the foot to some object lying nearby, to which it attaches and draws off a fine thread. This process continues, and threads are attached repeatedly to and about nearby fragments. Gradually the nest is bound together by a constant repetition of this process. The internal feltwork is smeared with a slimy secretion from the glandular tentacles which fringe the mantle edge.

Lima hians interlaces byssal threads with nullipores [coralline algae] if they are present (ROBERTSON, 1897), but if building material is lacking, it is capable of making a latticework completely of byssal threads (GILCHRIST, 1897). One specimen which ROBERTSON presented with glass beads fabricated a beautiful nest out of them.

MACGINITIE & MACGINITIE (1949) mentioned that *Lima dehiscens* [of authors, *non* CONRAD (= *hemphilli* HERTLEIN & STRONG, 1946)] builds nests in cavities by attaching byssal threads to the surrounding surface in a

scattered fashion, reminiscent of what some spiders do. FORBES & HANLEY (1853) stated, "This species [*Lima hians*] can spin for itself a compact nest of byssal threads entangling small stones, shells and fragments of nullipores; in the midst of it lies the *Lima*, resting on a smooth inner coating of fibres."

Lima pellucida C. B. ADAMS, 1846, has been found on occasion by the senior author living in nests on navigation buoys in the vicinity of Miami, Florida. In these instances, suitable foreign building materials were not present and the nests were constructed in a loose arrangement entirely of byssal threads. Although we observed no special openings for inhalant and exhalant currents, others have. JEFFREYS (1863) observed that the nest of *Lima* is funnel shaped; GILCHRIST (in JEFFREYS, 1863) described it as oblong; and MACGINITIE & MACGINITIE (1949) stated that the nest of *Lima dehiscens* [= *hemphilli*] is open at both ends, a feeding current entering one end and discharging through the other.

DENNIS (in JEFFREYS, 1863), searching for *Lima hians* under rocks, noted as many as seven specimens living in the same nest. Unfortunately no explanation was given as to how this community nest was built. JOHNSON (1931), while overturning a rock at St. Augustine, Florida, tore a nest apart and revealed a specimen of *Lima inflata* LAMARCK, 1819 [= *pellucida*]. SMITH (1951) also observed several nests of this species under stones in Biscayne Bay, Florida. Recently, at Lake Worth, Florida, the senior author was fortunate in uncovering several specimens of *L. pellucida* while turning over a rock. Close examination of the rock and the immediate substrate showed no evidence of a torn nest. In this instance the animals were simply hiding in crevices, attached by a byssus. This corroborates remarks by FORBES & HANLEY (1853) that *Lima hians* is much more frequently taken free than in nests. When our specimens from Lake Worth were later placed in aquaria containing rocks, they

quickly found their way to the deepest and most protected crevices where they soon attached. GILMOUR (1963) notes also that *Lima hians* is quick to find protective crevices.

Our specimens of *Lima pellucida* were held in rounded glass containers and their movements observed. The foot of this species is even more agile than that of *Musculus discors*, and just as extensible. However, unlike *Musculus*, the movements of the foot are amazingly coordinated with the swimming movements of the valves and tentacles. When *Lima* is observed to ascend the side of a glass, it appears to flap its valves and swim straight up. Closer examination, however, indicates that the foot first extends upward, the tip attaching to the glass surface. Then the animal actually propels itself forward with a flap of the valve to where the foot is attached. When the forward motion of the shell is about spent, the foot quickly extends and attaches again, repeating the movements as described until it reaches a desired height. The tentacles play an active part in these movements, aiding both in propulsion and in balancing. The coordination of the tentacles, valve muscles, and foot is developed to such a degree that the animal can "walk" up the side of glass almost as fast as it can swim freely. After watching it perform in this manner for a few minutes, one is better able to perceive its ability to find protective crevices so quickly and easily.

COMPARISON OF NEST BUILDING ADAPTATIONS IN *MUSCULUS* AND *LIMA*

The methods of nest building of the species mentioned here are essentially the same in *Musculus* and *Lima* except that the process is more refined in the former. The major difference is that *Lima* incorporates foreign materials in the early phases of construction, if such material is accessible. This allows *Lima* to produce a shelter more

Explanation of Plate 10

Musculus discors LINNAEUS, 1767

Figure 1: Specimen in the early stages of nest building showing byssal threads emanating from between the nearly closed valves near the center of the ventral margins. Note the ball of mucus near the anterior end of the valves (right) and the beads of mucus on the threads. About 200 threads were produced at this time (about 7 x)

Figure 2: Another view of the same specimen showing the byssal threads extending to the side of the aquarium and the adhesive disc at the points of attachment (about 7 x)

Explanation of Plate 11

Musculus discors LINNAEUS, 1767

Figure 1: Specimen concealed within a complete and well camouflaged nest (about 3 x)

Figure 2: Same specimen with the valves opened during feeding (about 3 x)

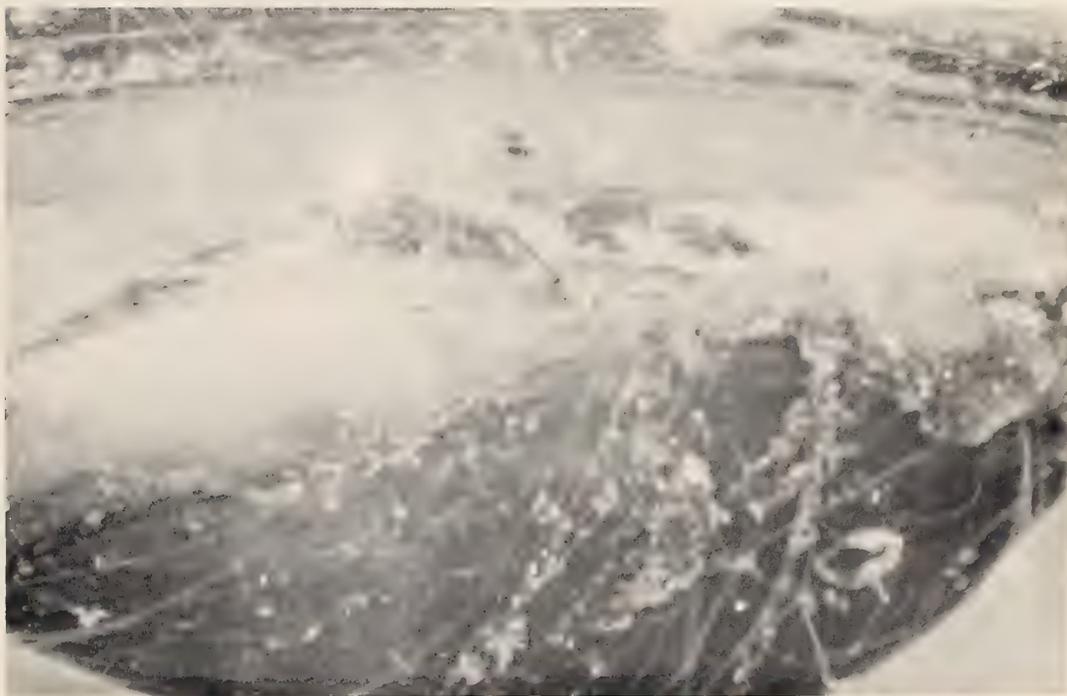


Figure 1



Figure 2



Figure 1



Figure 2

rapidly than *Musculus*, but one that is not as well constructed nor as permanent as that of *Musculus*.

While the byssal capsules are essentially protective coverings, the need for protection is not the same in the two groups. The ability of *Lima* to swim is a means of protection in itself. When feeding, however, *Lima* puts out extremely long and delicate tentacles along the mantle edge which extend well beyond the shell edges. Such a habit would probably make *Lima* extremely vulnerable to predation, as suggested by JOHNSON (1931), if the species were not well protected in crevices or covered with a structure so resembling the surroundings as to escape detection. GILMOUR (1963) postulated that mucus secreted by the tentacles may contain an irritant substance. He found that specimens of *L. hians* were always rejected when attempts were made to feed them to a number of carnivores. However, we saw a carnivore devour a specimen of *Lima*. When specimens of *L. pellucida* were released into an aquarium containing large sea anemones one of them was immediately seized and engulfed by a sea anemone. Later the shell valves only were expelled.

In contrast to *Lima*, which is not able to withdraw completely into its shell at any time, *Musculus* is well protected from predation by a strong shell as is its close relative *Mytilus edulis*, which is not a nest builder. *Musculus* does open its valves wider than *Mytilus*, and in this behavior there may be a reflection of the protection afforded by the nest.

It may be that the nest of *Musculus* has its greatest significance in regard to reproduction and protection of the young. Whereas *Lima* and *Mytilus* extrude their sexual products into the open waters where fertilization and early development take place, *Musculus* deposits its eggs in capsules along the inner lining of the nest where they remain throughout larval and early postlarval development. Protected *Musculus* lay fewer eggs and much larger ones than *Lima* or *Mytilus*. As THORSON (1950) has shown, this fact and the fact that the eggs and young are given protection is typical of marine invertebrates with non-planktonic or only brief planktonic stages in their early development.

LITERATURE CITED

- FORBES, EDWARD, & SYLVANUS HANLEY
1853. A history of British Mollusca, and their shells. Van Voorst, London. 2: 1-557
- GILCHRIST, J. D. F.
1897. *Lima hians* and its mode of life. Proc. Trans. Nat. Hist. Soc. Glasgow. 4 (n. s.): 218-225.
- GILMOUR, T. H. J.
1963. A note on the tentacles of *Lima hians* (GMELIN) (Bivalvia). Proc. Malacol. Soc. London 35: 81-85.
- HAAS, FRITZ
1942. The habits of some west coast bivalves. Nautilus 55 (4): 109-113.
1943. Malacological notes - III. Zool. Ser. Field Mus. Nat. Hist. 29 (1): 1-23; figs. 1-8.
- JEFFREYS, JOHN GWYN
1863. British Conchology. Van Voorst, London. 3: 1 to 393; pls. 1-8.
- JOHNSON, C. W.
1931. *Lima inflata* and its nest. Nautilus 44 (4): 126.
- MACGINITIE, GEORGE EBER
1955. Distribution and ecology of marine invertebrates of Point Barrow, Alaska. Smithson. Misc. Coll. Publ. 4221. 128 (9): 1-201; pls. 1-8.
- MACGINITIE, G. E., & NETTIE MACGINITIE
1949. Natural history of marine animals. McGraw-Hill Book Co., Inc. New York. pp. 1-473; 282 text figs.
- MACGINITIE, NETTIE
1959. Marine Mollusca of Point Barrow, Alaska. Proc. U. S. Nat. Mus. 109 (3412): 59-208; pls. 1-27.
- OCKELMAN, W. K.
1958. The zoology of East Greenland. Marine Lamellibranchiata. Medd. Grønland, København. 122 (4): 1-256; pls. 1-3; 29 text figs.
- ROERTSON, DAVID
1897. Jottings from my note-book. On *Lima hians*, Gmel. Proc. Trans. Nat. Hist. Soc. Glasgow. 4 (n. s.): 331-332.
- SMITH, MAXWELL
1951. East coast marine shells (4th ed.). Edwards Bros. Ann Arbor, Michigan. pp. 1-314; pls. 1-77; 54 figs.; 1 map.
- STIMPSON, WILLIAM
1853. Synopsis of the marine Invertebrata of Grand Manan. Smithson. Contrib. to Knowledge, 1-66; pls. 1-3.
- SUTER, HENRY
1913. Manual of New Zealand Mollusca. MacKay, Wellington, New Zealand. 1-1120.
- THORSON, GUNNAR
1935. Biologische Studien über die Lamellibranchier *Modiolaria discors* L. und *Modiolaria nigra* GRAY in Ostgrønland. Zool. Anz. 111 (11-12): 297-304.
1950. Reproductive and larval ecology of marine bottom invertebrates. Biol. Rev. 25 (1): 1-45.
- WHITE, KATHLEEN M.
1937. *Mytilus*. L. M. B. C. Memoirs XXXI. The Univ. Press of Liverpool. 1-117; pls. 1-10.

Remarks on *Conus telatus* REEVE (Mollusca: Gastropoda)

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(Plate 12)

A number of specimens of *Conus* recently collected in the Philippines, notably by the Norton - Dayrit - de Mesa Palawan Expedition, were submitted to us for examination. They were found to be difficult to assign to any easily recognizable species. Although the color pattern suggests a general affinity to *Conus textile* LINNAEUS, 1758, the specimens obviously differ in several characteristics from any known form of *C. textile*. The two most marked characters of the present specimens are the strong spiral ridges on the body whorl and the nodulose spire with excavated whorls.

It was suggested by the collectors that the specimens might be referable to *Conus telatus* REEVE, 1848, in spite of no mention having been made by REEVE (1848) of spiral ridges and nodes on the spire. Two specimens were submitted to the British Museum (Natural History) for comparison with the holotype. In a personal communication, Mr. S. P. Dance kindly answered our inquiry as follows:

"The type of *C. telatus* REEVE is rather more inflated than either of your specimens. The spire is more like that of the larger of your two shells [figs. 2 and 2a], and is very weakly nodulate. In colouring and surface sculpture it is closer to your smaller shell [figs.

1 and 1a]. If you want a subjective opinion, I am inclined to think both your shells represent the same species, which would seem to be very variable."

The brief description and the figure of *Conus telatus* in the "Conchologia Iconica" suggest that this taxon is one of the numerous named varieties of the *C. textile* group, and has led most students to reject or dubiously accept the validity of *C. telatus*. REEVE's brief description is repeated here, and is followed by our supplementary description.

"Shell oblong-conical, somewhat pyramidal, smooth, striated towards the base, spire concavely acuminate; white, marked throughout with a fine orange-brown net-work, encircled with two bands of large golden-yellow blotches, marked with longitudinally waved black lines.

Habitat ——" {Suppl. Pl.1, fig. 270. - Ed.}

Supplemental Description: Entire body whorl spirally ridged, whorls on spire concave, striated and nodulose; the nodes strongest from penultimate whorl to apex on a strong ridge over the suture.

SOWERBY (1858) considered *Conus telatus* as "approaching *Conus gloriamaris* rather than *textile* in form, and in the light sandy character of its reticulations."

Explanation of Plate 12

Figures 1 and 1a: *Conus telatus* REEVE. Palawan Island, Philippines (American Museum of Natural History no. 102773). Figure 1 - Apertural view; Figure 1a - Dorsal view. x one and one third.

Figures 2, 2a, and 3: *Conus telatus* REEVE, from between Coron and Busuanga Islands, Palawan, Philippines. Figure 2 - Apertural view. Specimen in J. Norton collection. x one and one third. Figure 2a - Close-up of spire. x three. Figure 3 - Dorsal view of specimen in A. D'Attilio collection. x one and one third.

American Museum of Natural History, photographs.

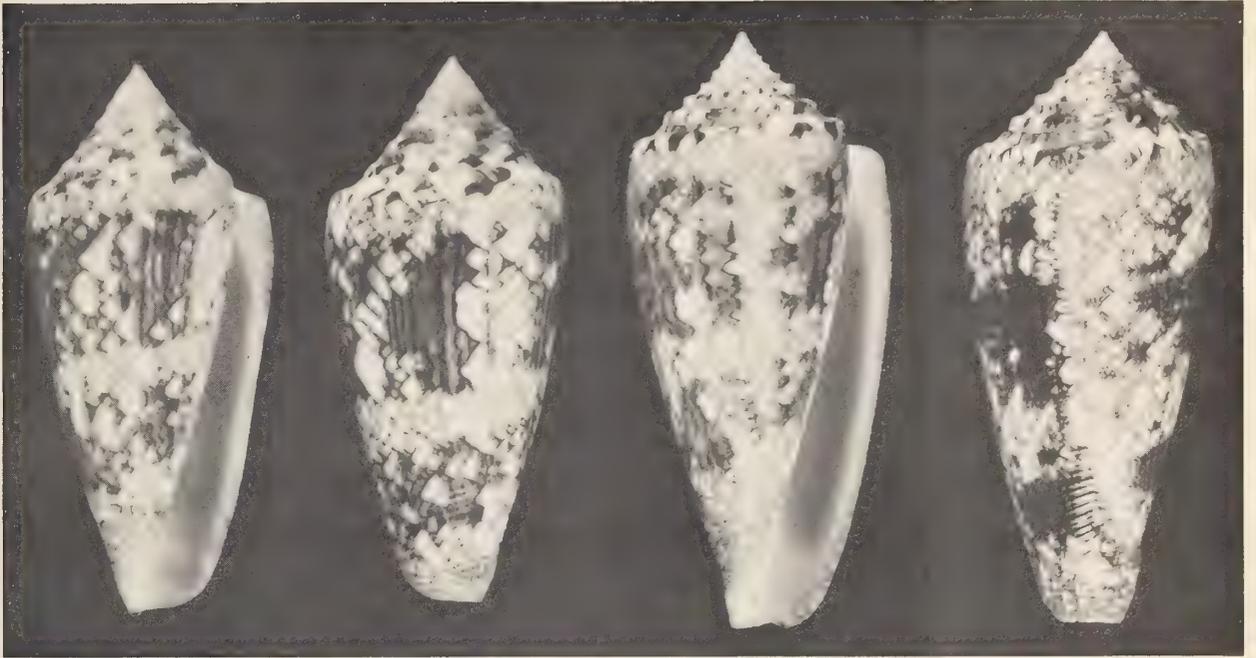


Figure 1

Figure 1 a

Figure 2

Figure 3



Figure 2 a

MELVILL (1900) likened it in shape to *Conus ammiralis* LINNAEUS, 1758 and in markings to *C. archithallassus* DILLWYN, 1817, which is an interesting conclusion, in that *C. archithallassus* was long considered a form of *C. ammiralis* with a nodulose spire and that commonly displays a pustulose body whorl. MELVILL made no reference to any particular character in this comparison. TOMLIN (1937) simply states in his catalogue of the cones, "[E. A.] Smith calls it a var. of ammiralis."

The color and pattern in combination with the spiral ridges are suggestive of *Conus aureus* HWASS in BRUGUIÈRE, 1792. However, that species has a smaller, narrower, more ovate shell with a spire that is not nodulose, except for some microscopic beads on the apical whorls. *Conus telatus* differs from *C. textile* and its varieties by its different spire. The spire of *C. textile* has straight sides and lacks nodules. It should be pointed out that the first few apical whorls of *C. textile* and all its known forms are minutely nodulose.

In some specimens of *Conus telatus* examined, the spiral ridges on the body whorl and the nodulose spire are not present. The absence of these characters, in the specimens studied, appears to be due to wear, rather than natural variability. This condition occurs even with live-collected material (The time lapse between collecting and actual cleaning should not be overlooked. Specimens left in a container of water - especially in the Tropics - often become delicately "self-etched.") The amount of attrition to these shells does not greatly affect their appearance, but the worn condition is unmistakable when examined under magnification.

Material examined: Between Coron and Busuanga Islands, Palawan, Philippines, in 5 to 10 fathoms, "on sand between corals and rocks," A. D'Attilio collection, 1 specimen; J. Norton collection, 1 specimen; Philippine

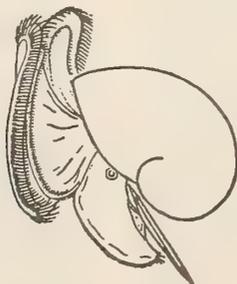
National Museum, 1 specimen (all of these were collected by the Norton - Dayrit - de Mesa Palawan Expedition, May 1962). Cuyo, Palawan, Philippines, S. Levine collection, 1 specimen (*Ex* Donald Dan). Palawan Island, Philippines, American Museum of Natural History collection, 1 specimen; G. Jacobs collection, 4 specimens; R. Dunn collection, 1 specimen; Mrs. W. Barker collection, 1 specimen (all *ex* Donald Dan). Philippine Islands, American Museum of Natural History collection (no. 11789), 1 specimen (*Ex* Haines collection).

ACKNOWLEDGMENTS

We wish to thank Mr. S. P. Dance, Mr. J. Norton, Mr. G. Jacobs, Mr. S. Levine, Mr. R. Dunn, and Mrs. W. Barker for assistance, or for the loan of material. We are especially indebted to Dr. William K. Emerson, Chairman, Department of Living Invertebrates, American Museum of Natural History, for critically reading the manuscript.

LITERATURE CITED

- MELVILL, JAMES COSMO M.
1900. A revision of the textile cones, with description of *C. cholmondeleyi*, n. sp. Journ. Conchol.; London, 9: 303 - 311.
- REEVE, LOVELL AUGUSTUS
1848 - [1849]. Conchologia iconica; or illustrations of the shells of molluscous animals. London, Monograph of the genus *Conus*, suppl.: 1 - 7; pls. 1 - 9.
- SOWERBY, GEORGE BRETtingham (second of name)
[1857 -] 1858. Thesaurus conchyliorum, or monographs of genera of shells. London, vol. 3, *Conus*, pts. 17 - 19: 1 - 56; pls. 1 - 24 [187 - 210].
- TOMLIN, JOHN READ LE BROCKTON
1937. Catalogue of Recent and fossil cones. Proc. Malacol. Soc. London, 22: 205 - 330; addenda, p. 333.



Notes on the Opisthobranchia of Baja California, Mexico, with Range Extensions

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Very little work has been done on the Opisthobranchia of Baja California, Mexico, either on the Pacific or the Gulf side (MARCUS, 1961, p. 57). Many species are listed with a southern range limit of San Diego or the Coronado Islands. These species may be presumed to extend into Mexico but due to a lack of proper collecting no authentic record of this exists. The purpose of this paper is to report extensions of the range of some of these animals along the Pacific coast of Baja California as well as to add a few notes on some that have been collected on the Gulf coast of the peninsula.

The senior author has made collections on both coasts and in addition the following persons have donated specimens or contributed collecting time: Dr. Kenneth Norris, Dr. Richard Banks, John and Priscilla Sloan, and Fay Wolfson.

The new range of each species is followed by the formerly known range in parentheses.

Collecting was done at the following points:

Ensenada	31° 51' N	116° 38' W
Isla de Cedros	28° 07' N	115° 11' W
Isla Natividad	27° 53' N	115° 10' W
Puerto Rompiente	27° 44' N	114° 59' W
Isla Angel de la Guarda	29° 33' N	113° 35' W
Puertecitos	30° 25' N	114° 40' W

Glossodoris californiensis (BERGH, 1879)

Monterey to Puerto Rompiente, Isla Angel de la Guarda (Monterey to the Coronado Islands).

Glossodoris macfarlandi (COCKERELL, 1902)

Monterey to Ensenada (Monterey to the Coronado Islands).

Rostanga pulchra MACFARLAND, 1905

Vancouver Island to Chile; Japan. Several specimens were taken at Isla Angel de la Guarda, extending

the range of this animal into the Gulf, as would be expected.

Anisodoris nobilis (MACFARLAND, 1905)

One specimen on a boat landing in Ensenada Bay. Vancouver Island to Ensenada (Vancouver Island to the Coronado Islands).

Discodoris heathi MACFARLAND, 1905

Twenty-eight specimens were collected on two trips in March and April of 1963, just north of Ensenada in a rocky habitat. Vancouver Island to Ensenada (Vancouver Island to Laguna Beach).

Aldisa sanguinea (COOPER, 1862)

Bodega Bay to Natividad Island; Japan (Bodega Bay to San Diego; Japan).

Aegires albopunctatus MACFARLAND, 1905

One animal on a float in Ensenada Bay. Vancouver Island to Ensenada (Vancouver Island to the Coronado Islands).

Triopha maculata MACFARLAND, 1905

Bodega Bay to Ensenada (Bodega Bay to San Diego).

Acanthodoris rhodoceras COCKERELL & ELIOT, 1905

Dillon Beach to Punta Mesquite, 32 miles south of the border (Dillon Beach to the Coronado Islands).

Hopkinsia rosacea MACFARLAND, 1905

Several specimens in the lower tidal region of Ensenada Bay. Eureka to Ensenada (Eureka to Point Loma).

Dendrodoris albopunctata (COOPER, 1863)

Monterey to Puertecitos (Monterey to Pt. Eugenia).

Dirona picta COCKERELL & ELIOT, 1905

Two specimens were collected at Rosarito Beach in a rocky tide pool. Three animals were collected at Puertecitos, the latter in association with coralline algae, bryozoans, and ostrich-plume hydroids. Dillon Beach to Puerto Rompiente; Puertecitos (Dillon Beach to Point Loma).

Coryphella piunca MARCUS, 1961

Dillon Beach to Ensenada; Isla Angel de la Guarda
(Dillon Beach to the Coronado Islands).

Flabellina iodinea (COOPER, 1862)

One specimen collected in a low tide pool in close association with surf grass. Vancouver Island to Ensenada (Vancouver Island to the Coronado Islands).

Hermisenda crassicornis (ESCHSCHOLTZ, 1831)

Sitka, Alaska to Isla Angel de la Guarda (Sitka, Alaska to Pt. Eugenia).

Spurilla chromosoma COCKERELL & ELIOT, 1905

San Pedro to Ensenada (San Pedro to Point Loma).

Phidiana pugnax LANCE, 1962

One animal was collected in a low tide pool on the southeast end of Cedros Island. Monterey to Puerto

Rompicente (Monterey to the Coronado Islands).

Doto ganda MARCUS, 1961

Dillon Beach to Ensenada (Dillon Beach to Monterey Bay).

LITERATURE CITED

LANCE, JAMES R.

1961. A distributional list of southern California opisthobranchs. *The Veliger* 4 (2): 64-69.

1962. Two new opisthobranch mollusks from Southern California. *The Veliger* 4 (3): 155-159; pl. 38; 8 text figs.

MARCUS, ERNST

1961. Opisthobranch mollusks from California. *The Veliger* 3 (Supplement): 1-85; 10 pls.

Notes on the Opisthobranchs of the West Coast of North America - III. Further Nomenclatorial Changes in the Order Nudibranchia

BY

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In 1961, I proposed some nomenclatorial changes for nudibranchs from Southern California. In preparing a distributional list of nudibranchs for the area from Point Conception, California to Vancouver Island, British Columbia, I have found that further changes must be made in order to bring the nomenclature up to date.

It has been necessary to collect and examine animals from several areas before most of the conclusions stated in this paper could be reached. I would like to thank Dr. Robert Fernald, Director of the Friday Harbor Laboratories (University of Washington) for allowing me to borrow the opisthobranch collection from the Laboratory Museum. Mr. Lawrence Andrews of San Anselmo, California has provided me with living animals from Northern California, from Coos Bay, Oregon and from Friday Harbor. His comments on my work have been most helpful. Mr. James Lance has also given much advice and assistance.

In 1922 (b), O'DONOGHUE described *Doris echinata* from the Vancouver Island region. In 1926, as a result of

his work with IREDALE on the nudibranchs of Great Britain (IREDALE & O'DONOGHUE, 1923), he reassigned this species to the genus *Doridigitata* D'ORBIGNY, 1839. However, he also gave this species a new name, *Doridigitata maculata*. No reason was given for this change.

The genus *Doridigitata* is now considered to be synonymous with *Doris* CUVIER, 1804 (e. g. see PRUVOT-FOL, 1954). As both names, *Doris echinata* LOVÉN, 1846 and *Doris maculata* GARSTANG, 1896, preoccupy the same names proposed by O'DONOGHUE, a new name must be chosen for the latter. In honor of Dr. O'Donoghue, I propose *Doris odonoghuei* nom. nov. pro *Doris echinata* O'DONOGHUE, 1922.

There are two small specimens of this species in the collection of the Friday Harbor Laboratory. They were both collected in the vicinity of Friday Harbor, Washington. There is some question in my mind as to whether they are correctly assigned to the genus *Doris* as it is now defined. I have dissected the smaller of the two specimens but cannot come to a satisfactory conclusion. More mate-

rial must be collected and examined critically before the correct generic placement of this species is established.

Acanthodoris nanaimoensis O'DONOGHUE was described from the Vancouver Island region in 1921. In 1926, *Acanthodoris columbina* was described by MACFARLAND from Moss Beach in California. MACFARLAND had received a single specimen of the former species from O'DONOGHUE and, although he noted their similarity, he stated that he found the two species to be distinct.

MACFARLAND first compared the coloration of the two species. He stated that *Acanthodoris nanaimoensis* had notal papillae which were white or yellowish, while the notal papillae of *A. columbina* were brownish tipped with lemon yellow. He also pointed out that his specimens from Moss Beach had a line of lemon yellow around the notal margin and flecks of the same color on the rhinophores.

I have examined living animals from Friday Harbor, Washington and from Moss Beach, California, as well as from several localities on the Marin County and Sonoma County coasts (California). I also have had a report on the coloration, in life, of specimens from Coos Bay, Oregon, which were collected for me by Mr. Andrews. Specimens from all areas show considerable variation in the "brownish-mauve" coloration of the notum and notal papillae, and in the amount and intensity of yellow pigmentation. The yellow color may be intense in specimens from all localities or it may be pale or totally absent. Mr. Andrews also noted some variation in the red coloration of the rhinophores and gills in specimens from Coos Bay. This is consistent with what I have observed in specimens from California. I suggest that variation in coloration has no value as a criterion in separating these two species.

MACFARLAND also gave a summary of other differences which he found between the two species. I do not believe that characters such as the average measurements and proportions of the first lateral teeth of the radula are significant when a single specimen from one locality is being compared with only six specimens from another distant locality. Nor do I think that MACFARLAND's comparison of the absolute measurements of the median plate of the labial armature, or of the number of rhinophore leaves is useful under these circumstances.

MACFARLAND gave the number of rows in the radula of *Acanthodoris nanaimoensis* as 35. He described 40 to 43 rows for *A. columbina*. It is my opinion that the number of rows in the radula of any given species cannot definitively be established until a large number of animals, of varying sizes and from different localities, has been examined.

MACFARLAND and O'DONOGHUE both stated that *Acanthodoris nanaimoensis* has no denticles on the first lateral teeth of the radula. MACFARLAND described six to eight denticles on the first lateral teeth of *A. columbina*. I have

not been able to examine the radulae of any specimens from the Vancouver Island - Friday Harbor region. However, the specimens from Coos Bay have five to eight denticles on the first lateral teeth. As in specimens from Moss Beach, these denticles are small and can be seen well only under high magnification.

O'DONOGHUE described six to seven teeth laterad to the differentiated first lateral tooth in *Acanthodoris nanaimoensis*. However, he carefully described and figured five teeth laterad to the first lateral tooth and then stated that the outermost lateral tooth (which would be the sixth) is apparently not always present. He made no further mention of, nor did he figure, anything which may be construed as a seventh lateral tooth.

In the specimens from Coos Bay, a sixth lateral tooth may sometimes be seen at the end of some rows. But, in general, the radular formula is 5.1.0.1.5. This is the radular formula reported by MACFARLAND for *Acanthodoris columbina*.

A final character which must be considered is the number of rows of labial elements present in the labial armature. O'DONOGHUE did not record the number of rows in his specimens. MACFARLAND stated that he found 70 to 80 rows in *Acanthodoris nanaimoensis* as compared to 30 to 35 rows in *A. columbina*. Again, I do not consider such a difference to have much meaning until a larger number of specimens from several areas has been examined.

I propose, therefore, that *Acanthodoris columbina* MACFARLAND, 1926 be considered a synonym of *Acanthodoris nanaimoensis* O'DONOGHUE, 1921.

MARCUS (1961) suggested that the name *Armina vancouverensis* (BERGH, 1876) is probably the valid name for *Armina columbiana* O'DONOGHUE, 1924. It is my opinion that both species should be considered synonymous with *Armina californica* (COOPER, 1862), (see LANCE, 1962). All three species have been recorded from the Vancouver Island region.

I have observed several living specimens from Friday Harbor, Washington in order to determine how much variation in external body form may occur in any given individual. The nuchal papillae, which MARCUS described for one of the two preserved specimens from California he examined, may or may not be apparent in a living animal depending on whether or not the nuchal area is expanded or contracted.

O'DONOGHUE (1924) made a point of comparing the arrangement of the white lines (which are actually distinct ridges) on the notum of *Armina columbiana* with those on the notum of *A. californica*. If the head region in both living and preserved animals is contracted, the pattern of the ridges is similar to the pattern O'DONOGHUE described for *A. californica*. If the living or preserved animal has the head region expanded, the pattern

is that which O'DONOGHUE described for *A. columbiana*. If a living animal which shows the *A. columbiana* pattern is subjected to irritation or adverse conditions, it can contract the head region to resemble the *A. californica* pattern.

I have examined the radulae of two specimens from Friday Harbor and have compared my findings with descriptions of radulae of all three species as found in the literature. I have come to the conclusion that we are confronted by a single species in which the radular teeth are quite variable in structure.

It is my opinion, therefore, that *Armina vancouverensis* (BERGH, 1876) and *A. columbiana* O'DONOGHUE, 1924 should be considered synonyms of *A. californica* (COOPER, 1862. MARCUS (1961) points out that *A. digueti* PRUVOT-FOL, 1955 differs only slightly from *A. californica*. This difference is only in the denticulation of the radular teeth. I consider that *A. digueti* is also a synonym of *A. californica*.

In 1960, I recorded the presence of a species of *Okenia* in San Francisco Bay which was markedly different from *Okenia vancouverensis* (O'DONOGHUE, 1921), the only other member of this genus described from the west coast of North America. Mr. Andrews has since located an area at China Camp in Marin County where the San Francisco Bay species is often abundant. The animals are usually found on small stones which are partially embedded in the mud.

The specimens from China Camp, as well as other specimens from San Francisco Bay which I had examined earlier, agree with the description of *Okenia (Okenia) plana* BABA, 1960. The range of this species must be considered, at present, to be disjunct with populations occurring both in California and Japan.

In 1960, I also noted the presence on the west coast of a small cuthonid eolid belonging to the genus *Tenellia* A. COSTA, 1851. This species was occasionally quite abundant in San Francisco Bay and in the boat harbor at Monterey. I have been unable to find any further specimens of this species in either area since 1958. The localities from which I had previously collected this species have undergone considerable change in recent years, thus, perhaps accounting for the absence of this species.

A high wall of pilings heavily impregnated with creosote has been erected in the boat harbor at Monterey to protect new pleasure boat docks. A small sport fishing boat company located on the seaward side of the wall has since removed its floating dock. This was the only dock in Monterey harbor on which I ever collected *Tenellia* sp. It was also the only dock in the harbor from which I had ever taken *Doto amyra* MARCUS, 1961. As the type locality for the latter species is the boat harbor at Monterey,

it may be that the type locality for *D. amyra* has been destroyed.

It has been suggested to me by several workers in California that changes in the treatment of sewage in the San Francisco Bay region possibly has caused the disappearance of *Tenellia* sp. from that region. In any event, I have had to rely on preserved material and serial sections made several years ago in order to evaluate, again, the systematic position of my specimens.

Using only the material at hand, I can find no reason to separate *Tenellia* sp. in California from *Tenellia pallida* (ALDER & HANCOCK, 1855) which occurs in Europe and which is most likely the same species reported from the east coast of the United States.

PRUVOT-FOL (1954) has suggested that the correct name of this species should be *Tenellia ventilabrum* (DALYELL, 1855). However, I prefer to use the name for this species which is most commonly accepted for the European form. The range of *T. pallida* is, therefore, extended to California. Mr. Lawrence Andrews has informed me that he has recently collected and observed numerous specimens of *T. pallida* in the yacht harbors at Berkeley and Richmond in San Francisco Bay (February and March, 1963).

O'DONOGHUE (1922a) placed *Aeolis barbarendis* COOPER, 1863 in the genus *Janolus* BERGH, 1884. In 1924, O'DONOGHUE described another species, *Janolus fuscus*, from the Vancouver Island region. However, he noted that more work needed to be done before it could be determined if *Antiopella* HOYLE, 1902 should be separated from *Janolus*. He suggested that, if the split is made, his species should be placed in *Antiopella*. It is the opinion of later workers (see PRUVOT-FOL, 1954; MARCUS, 1955) that the two should be considered as separate genera.

Earlier this year, Mr. Lance discussed with me the status of *Janolus barbarendis*. He suggested that this species should be included in the genus *Antiopella*, and sent me the jaws and radula of a specimen from Southern California for examination.

The strong denticulations on these jaws are characteristic of *Antiopella*. The jaws of *Janolus fuscus* are also characteristic of a species of *Antiopella*. *Janolus fuscus* has already been assigned to *Antiopella* by PRUVOT-FOL (1954).

There are, therefore, two species of *Antiopella* on the west coast of North America: *A. barbarendis* (COOPER, 1863) which occurs in Southern California and *A. fusca* (O'DONOGHUE, 1924) which occurs from Monterey to the Vancouver Island region. The two are very similar both in external appearance and in the structure of the jaw plates. It may be that they should be considered to be but a single species. However, I do not have enough material from Southern California for comparison with

the northern forms. Further work is needed before this question can be resolved.

Janolus coeruleopictus COCKERELL & ELIOT, 1905 differs from the two species discussed above in having jaws which are undenticulated. This is characteristic of the genus *Janolus*. O'DONOGHUE (1922a, 1924, 1926) suggested that this species should possibly be considered as a synonym of *Janolus barbarentis* (now *Antiopella barbarentis*). *Janolus coeruleopictus* is known only from a single, small and rather poorly preserved specimen which was sent by Cockerell to Eliot in England. The characters of this single specimen are very poorly described. It is my opinion that this name should be considered to be a *nomen dubium*.

The name *Antiopella aureocincta* MACFARLAND *ms.*, which appeared in a textbook by JOHNSON & SNOOK (1927) must be considered a *nomen nudum*. It was derived from one of the late Dr. MacFarland's unpublished manuscripts. The characters described by JOHNSON & SNOOK are not sufficient to identify it generically, although it is obviously assignable to *Antiopella barbarentis*.

The name *Antiopella aureotincta* appeared in a textbook by MACGINITIE & MACGINITIE (1949) under a photograph of what appears to be *A. barbarentis*. This name was apparently also derived from Dr. MacFarland's manuscript. *Antiopella aureotincta* MACGINITIE & MACGINITIE 1949 must also be considered a *nomen nudum*.

MARCUS (1961) has listed three characters by which he distinguishes *Coryphella piunca* MARCUS, 1961 from *C. trilineata* O'DONOGHUE, 1921. He describes about ten rows of tubercles on the masticatory border of the jaws of *C. piunca* and states that the masticatory border of the jaws of *C. trilineata* bears only one row of tubercles. O'DONOGHUE (1921), however, stated that the masticatory border of the jaws of *C. trilineata* bears "... a series of tiny pointed denticles." He compared the general form of the jaws of this species to *C. fusca* O'DONOGHUE, 1921, not to those of *C. longicaudata* O'DONOGHUE, 1922.

I have examined a number of specimens from California which are attributable to MARCUS' species. I have also examined three specimens of *Coryphella* from Friday Harbor which matched O'DONOGHUE's description of *C. trilineata*. However, they also matched the description of *C. piunca*. The masticatory border of the jaw, of the one specimen whose jaws and radula I examined, bore a series of denticles arranged in approximately ten rows.

MARCUS apparently was unaware of O'DONOGHUE's comment on the illustration he provided of the lateral teeth of the radula of *Coryphella trilineata*. O'DONOGHUE stated that the teeth figured were turned sideways. However, in the text, he described them as though they were in that position in life. If the teeth figured by O'DONOGHUE

are righted, the denticulations appear on one leg of the right triangle formed by the tooth. The hypotenuse of this triangle, therefore, is undenticulated.

My examination of the radula taken from the specimen from Friday Harbor mentioned above showed that the lateral teeth could be oriented to fit either O'DONOGHUE's or MARCUS' description. This is also true of the lateral teeth of radulae of specimens from California.

The position of the genital aperture is the third character which MARCUS uses to distinguish the two species. O'DONOGHUE noted that the position of this structure was "... high up on the right side of the body about one third of the way back." MARCUS states that it "... generally lies one sixth of the body length from the anterior end ..." These two descriptions are not incompatible with the position of the genital aperture as I have observed it in many specimens from California. In some animals it may even be considered to be in the first eighth to tenth of the body length. The significant fact is that the genital aperture lies much closer to the head in these animals than it does in any of the other species of *Coryphella* described from the west coast of North America.

I consider, therefore, that *Coryphella piunca* MARCUS, 1961 is a synonym of *C. trilineata* O'DONOGHUE, 1921.

In 1961, I suggested that *Hervia lagunae* O'DONOGHUE, 1926 should be considered to be a *nomen dubium*. This species was based on the description of an eolid from Laguna Beach, California, by GUERNSEY (1912) which she called *Hervia* sp.?

On August 25, 1961, Mr. Lance and I collected five specimens of an eolid at Moss Beach (near San Francisco, California) which were identical in external form and coloration with GUERNSEY's species. This species is distinctive because of the orange head and rhinophores which contrast markedly with the white head tentacles and body. The head and rhinophores may be red orange or yellow orange. The digestive diverticula are black and the cerata are tipped with orange.

I have since collected several more of these animals just north of Cayucos (San Luis Obispo County) in July, 1962 and again at Moss Beach in August, 1962.

The body form, the stylet on the penis, the jaws and the radula of each of these specimens match exactly the description of *Catriona rongae* MARCUS, 1961. MARCUS' color description is not adequate. He states that "... in the living and preserved state the animal is white with dark brown digestive diverticula in the cerata." This is true of the preserved animal only.

As *Hervia* sp.? GUERNSEY, 1912 is recognizable and can definitely be referred to a valid genus, it is, therefore, proposed that *Catriona rongae* MARCUS, 1961 be considered a synonym of *C. lagunae* (O'DONOGHUE, 1926).

LITERATURE CITED

BABA, KIKUTARÔ

1960. The genera *Okenia*, *Goniodoridella* and *Goniodoris* from Japan (Nudibranchia - Goniodorididae). Publ. Seto Mar. Biol. Lab. **8** (1): 79-83; pls. 7, 8.

COCKERELL, THEODORE DREW ALISON, & CHARLES ELIOT

1905. Notes on a collection of Californian nudibranchs. Journ. Malacol. **12** (3): 31-53; pls. 7, 8.

GUERNSEY, MABEL

1912. Some of the mollusca of Laguna Beach. Pomona Coll. Rep. Marine Lab. **1**: 68-72; figs. 32-43.

IREDALE, TOM, & CHARLES H. O'DONOGHUE

1923. List of the British nudibranchiate mollusca. Proc. Malac. Soc. London **15**: 195-233.

JOHNSON, MYRTLE E., & H. J. SNOOK

1927. Seashore animals of the Pacific coast. 659 pp.; illus. MacMillan, New York.

LANCE, JAMES R.

1962. A new species of *Armina* (Gastropoda: Nudibranchia) from the Gulf of California. The Veliger **5** (1): 51-55; 6 text figs.

MACFARLAND, FRANK MACE

- 1925-1926. The Acanthodorididae of the California coast. Nautilus **39** (2): 49-65; (3): 94-103; pls. 2, 3.

MACGINITIE, GEORGE, & NETTIE MACGINITIE

1949. Natural history of marine animals. 473 pp.; illus. McGraw-Hill, New York.

MARCUS, ERNST

1955. Opisthobranchia from Brazil. Bol. Mac. Fil. Univ. São Paulo, Zoologia **20**: 89-262; pls. 1-30.

1961. Opisthobranch mollusks from California. The Veliger **3** (Supplement, pt. 1): 1-85; pls. 1-10.

O'DONOGHUE, CHARLES H.

1921. Nudibranchiate mollusca from the Vancouver Island region. Trans. Roy. Canad. Inst. **13**: 147-210; pls. 7-11.

- 1922 a. Notes on the taxonomy of nudibranchiate mollusca from the Pacific coast of North America. Proc. Malacol. Soc. London **15**: 133-150.

- 1922 b. Notes on the nudibranchiate mollusca from the Vancouver Island region, III. Trans. Roy. Canad. Inst. **14**: 145-167; pls. 5, 6.

1924. Notes on the nudibranchiate mollusca from the Vancouver Island region, IV. Trans. Roy. Canad. Inst. **15** (1): 1 to 33; pls. 1, 2.

1926. A list of the nudibranchiate mollusca recorded from the Pacific coast of North America, with notes on their distribution. Trans. Roy. Canad. Inst. **15** (2): 199-247.

1927. Notes on a collection of nudibranchs from Laguna Beach, California. Journ. Ent. Zool. Pomona Coll. **19**: 77 to 119; pls. 1-3.

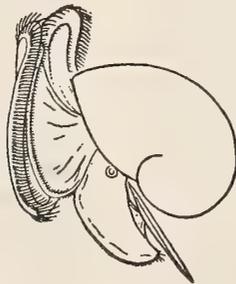
PRUVOT-FOL, ALICE

1954. Mollusques opisthobranches. in Faune de France, **58**: 460 pp.; 1 plt.; 173 text figs.; Paris, Paul Lechevalier.

STEINBERG, JOAN E.

1960. Rare and little known opisthobranch mollusks from the west coast of North America. The Veliger **3** (2): 49.

1961. Notes on the opisthobranchs of the west coast of North America. — I. Nomenclatural changes in the order Nudibranchia (Southern California). The Veliger **4** (2): 57-63.



Notes on the Opisthobranchs of the West Coast of North America - IV. A Distributional List of Opisthobranchs from Point Conception to Vancouver Island

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In recent years there has been an intensified interest in opisthobranch mollusks on the west coast of North America as evidenced by the contributions of MARCUS (1961), LANCE (1961, 1962a, 1962b), GONOR (1961), BEEMAN (1963a, 1963b), STEINBERG (1960, 1961, 1963a, 1963b) and others. In addition to these studies, further work on the systematics, geographical distribution, morphology and ecology of these mollusks is currently being conducted. Accordingly, it seems desirable at this time to clarify our present knowledge of the systematic identity and distribution of opisthobranchs on our Pacific Coast.

LANCE (1961) has summarized the distribution of opisthobranchs on the west coast of North America south of Point Conception. This list was preceded by a commentary on several species whose systematic status was in question (STEINBERG, 1961). The present work is an extension of LANCE's list for species which are found north of Point Conception.

The marine province treated in this paper is defined as that region from Point Conception, California to Vancouver Island, British Columbia, although the ranges of a number of species may continue north to Alaska and the Western Pacific or south to Southern and Lower California. The cephalaspideans have been discussed in another paper (STEINBERG, 1963a). Also excluded are the pteropods, the onchidiaceans and the pyramidellids. The systematic status of several species, whose names needed reviewing, has been discussed in another paper (STEINBERG, 1963b - see article preceding this paper) A dagger (†) precedes the species name of each species so treated.

The systematic arrangement used follows that of ODHNER (1939). The habitats listed are similar to those used by LANCE. They are divided into (1) intertidal; (2) subtidal; (3) offshore kelp, referring specifically to *Macrocystis pyrifera* in sheltered areas such as Monterey Bay; (4) boat landings, pilings, wharves and buoys in bays

and estuaries; and (5) mudflats, including rocky areas associated with them, in bays. The information concerning relative abundance is based on approximately 160 field trips along the California coast over the past 15 years, principally to Moss Beach, San Mateo County; the Monterey Peninsula; San Francisco Bay and the Marin and Sonoma County outer coasts and bays. In addition, numerous collections, both alive and preserved, have been examined from these areas. Material, both alive and preserved, from the Mendocino and Humboldt County coasts, has also been examined on several occasions. Although I have collected in the San Juan Island, Washington area only once, I have obtained further information on the distribution of animals in the northern limit of the range by examining collections from the Friday Harbor Laboratory and in conversations with Mr. Jefferson Gonor (University of Washington).

The degrees of abundance are arbitrarily indicated as (1) - common: at least several specimens will be encountered in incidental collecting and many more may be found if collecting is intensive; (2) - uncommon: one or two specimens may be found in incidental collecting and only a few more may be found if collecting is intensive; (3) - rare: only a few individuals have ever been collected; (4) - known only from the type locality, and indicating that the species has never been collected except by the original collector.

New ranges are followed by the old in parentheses. A single asterisk (*) preceding a species name indicates that I have never collected that form north of Point Conception. Two asterisks (**) signify that I have never seen any specimens which could be referred to this species. Latitudes and longitudes for the geographical localities mentioned in the list are given in the following table. Most of the references will be found in the bibliography of MARCUS (1961). Those which are not listed there will be found in the list of references at the end of this paper.

Alaska

Sitka 57° 03' N 135° 20' W

British Columbia

Vancouver Island (Nanaimo)
49° 10' N 123° 56' W

Washington

San Juan Island 48° 30' N 123° 00' W

Oregon

Coos Bay 43° 20' N 124° 10' W

California

Crescent City 41° 45' N 124° 10' W

Humboldt Bay (Eureka) 40° 45' N 124° 14' W

Shell Beach (Sonoma County)

38° 25' N 123° 08' W

Bodega Bay 38° 18' N 123° 03' W

Dillon Beach 38° 14' N 122° 58' W

Tomales Bay 38° 14' N 122° 59' W

Bolinas Bay 37° 55' N 122° 40' W

San Francisco Bay 37° 47' N 122° 27' W

Moss Beach 37° 32' N 122° 31' W

Santa Cruz 36° 58' N 122° 01' W

Point Pinos (Pacific Grove)

36° 38' N 121° 55' W

Monterey 36° 37' N 121° 53' W

Pismo Beach 35° 09' N 120° 38' W

Point Conception 34° 27' N 120° 28' W

Laguna Beach 33° 32' N 117° 44' W

Ja Jolla 32° 52' N 117° 15' W

San Diego 32° 42' N 117° 11' W

Point Loma 32° 40' N 117° 14' W

México

Los Coronados Islands 32° 24' N 117° 14' W

Bahía de Los Angeles 28° 55' N 113° 32' W

Cedros Island 28° 22' N 115° 12' W

Point Eugenia 27° 51' N 115° 05' W

La Paz 24° 10' N 110° 19' W

Cape San Lucas 22° 52' N 109° 53' W

ANASPIDEA

APLYSIIDAE

Aplysiinae

Aplysia californica COOPER, 1863

Rare intertidally at northern end of range. Humboldt Bay to the Gulf of California (Bodega Bay to the Gulf of California).

Dolabriferinae

Phyllaplysia taylori (DALL, 1900)

Common intertidally and subtidally in muddy bays on the eelgrass, *Zostera marina*. San Juan Island to San Diego Bay.

NOTASPIDEA

Pleurobranchacea

PLEUROBRANCHIDAE

Pleurobranchus californicus DALL, 1900

Rare intertidally; uncommon subtidally. Crescent City to San Diego.

SACOGLOSSA

Elysiacea

ELYSIIDAE

Elysia hedgpethi MARCUS, 1961

Seasonally common intertidally on *Codium* sp. and on mudflats on *Ulva* sp. San Juan Island to La Jolla (Tomales Bay to La Jolla).

OLEIDAE

Olea hansineensis KJERSCHOW AGERSBORG, 1923

Common in bays. San Juan Island (*vide* GONOR, 1961).

STILIGERIDAE (=HERMAEIDAE)

Alderia modesta (LOVÉN, 1844)

Common on *Salicornia* marshes associated with *Vaucheria* sp. San Juan Island to Elkhorn Slough; Europe.

Hermaea vancouverensis O'DONOGHUE, 1924

Known only from type locality. Vancouver Island.

Hermaeina smithi MARCUS, 1961

Seasonally common in high intertidal pools and on mudflats. San Juan Island to San Diego.

Stiliger fuscovittata LANCE, 1962

Seasonally common, April through June, in bays on *Polysiphonia* sp. San Juan Island to San Diego (San Diego).

NUDIBRANCHIA

Doridacea

EUDORIDACEA

Cryptobranchia

DORIDIDAE

Glossodoridinae

Cadlina flavomaculata MACFARLAND, 1905

Uncommon intertidally. Vancouver Island to Point Eugenia.

Cadlina marginata MACFARLAND, 1905

Common intertidally and subtidally. Vancouver Island to Point Eugenia.

Glossodoris californiensis (BERGH, 1879)

Rare at northern end of range. Monterey to the Coronado Islands.

Glossodoris dalli (BERGH, 1879)

Known only from the type locality. Puget Sound.

Glossodoris macfarlandi (COCKERELL, 1902)

Rare subtidally at northern end of range. Monterey to the Coronado Islands.

* *Glossodoris porterae* (COCKERELL, 1902)

Rare at northern end of range. Monterey to Cedros Island.

Thorunninae

Aldisa sanguinea (COOPER, 1862)

Common intertidally at Point Pinos; otherwise rare intertidally. Bodega Bay to San Diego; Japan.

Rostanga pulchra MACFARLAND, 1905

Common intertidally. Vancouver Island to Chile; Japan.

Doridinae

† *Doris odonoghuei* STEINBERG, 1963

Vancouver Island to San Juan Island (Vancouver Island).

Archidoridinae

Archidoris montereyensis (COOPER, 1862)

Common intertidally and on bay boat landings and pilings. Alaska to San Diego.

Discodoridinae

Anisodoris nobilis (MACFARLAND, 1905)

Common intertidally, subtidally and on bay boat landings and pilings. Vancouver Island to the Coronado Islands.

Diaulula sandiegensis (COOPER, 1862)

Common intertidally; uncommon subtidally. Japan to Cape San Lucas.

Discodoris heathi MACFARLAND, 1905

Seasonally common intertidally during summer months; otherwise uncommon. Vancouver Island to Laguna Beach.

Platydoridinae

* *Platydoris macfarlandi* HANNA, 1951

Subtidally to about 516 feet. Pismo Beach.

Phanerobranchia

NONSUCTORIA

NOTODORIDIDAE

Aegires albopunctatus MACFARLAND, 1905

Seasonally common intertidally, January through August; common subtidally. Vancouver Island to the Coronado Islands.

POLYCERIDAE

Polycera atra MACFARLAND, 1905

Seasonally common in bays on boat landings and pilings on *Bugula* sp., April through September; rare intertidally and subtidally. San Francisco Bay to the Coronado Islands.

Polycera zosterae O'DONOGHUE, 1924

Rare intertidally and on bay boat landings. Vancouver Island to San Juan Island (Vancouver Island).

Polycera sp.

Uncommon on undersurfaces of bay boat landings on *Bugula* sp., August and September. Tomales Bay to San Francisco Bay.

Laila cockerelli MACFARLAND, 1905

Seasonally common intertidally in winter and spring; otherwise uncommon. Vancouver Island to Cape San Lucas.

TRIOPHIDAE

Triopha carpenteri (STEARNS, 1873)

Common intertidally and subtidally. Vancouver Island to San Diego (Dillon Beach to San Diego); Japan.

Triopha elioti O'DONOGHUE, 1921

Rare intertidally and subtidally. Vancouver Island to San Juan Island (Vancouver Island).

Triopha grandis MACFARLAND, 1905

Seasonally common during summer months on offshore kelp. Santa Cruz to Catalina Island.

Triopha maculata MACFARLAND, 1905

Immature forms common intertidally; mature forms uncommon intertidally and on boat landings in San Francisco Yacht Harbor. Bodega Bay to San Diego.

SUCTORIA

ONCHIDORIDIDAE

** *Acanthodoris atrogriseata* O'DONOGHUE, 1927

Known only from the type locality. Vancouver Island.

** *Acanthodoris armata* O'DONOGHUE, 1927

Known only from the type locality. Vancouver Island.

Acanthodoris hudsoni MACFARLAND, 1905

Rare intertidally. Vancouver Island to Monterey Bay.

Acanthodoris lutea MACFARLAND, 1925

Seasonally common intertidally during summer months, population peak in August. Dillon Beach to Point Loma (Moss Beach to Point Loma).

† *Acanthodoris nanaimoensis* O'DONOGHUE, 1921

Seasonally common intertidally during summer months. Vancouver Island to Moss Beach (Vancouver Island).

** *Acanthodoris pilosa* (ABILDGAARD, 1789)

Intertidal and subtidal to 180 feet. Alaska to Vancouver Island; circumboreal.

Acanthodoris rhodoceras COCKERELL & ELIOT, 1905

Seasonally common intertidally, on bay boat landings and on mudflats in summer months. Dillon Beach to the Coronado Islands.

Onchidoris bilamellata (LINNAEUS, 1767)

Seasonally common intertidally, subtidally and on bay boat landings during summer months. Alaska to Monterey Bay (Alaska to Bodega Bay); circumboreal.

Onchidoris hystricina (BERGH, 1878)

Common intertidally and on mudflats during summer months; subtidal to 54 feet. Alaska to Point Loma (Alaska to Dillon Beach).

GONIODORIDIDAE

Ancula pacifica MACFARLAND, 1905

Rare intertidally during summer months. Moss Beach to Point Loma.

Hopkinsia rosacea MACFARLAND, 1905

Seasonally common intertidally and subtidally. Coos Bay to Point Loma (Eureka to Point Loma).

****** *Okenia vancouverensis* (O'DONOGHUE, 1921)

Known only from type locality. Vancouver Island.

† *Okenia plana* BABA, 1960

Common on rocks on mudflats at China Camp, Marin County, San Francisco Bay; rare on bay boat landings and subtidally in San Francisco Bay; Japan (Japan).

Trapania velox (COCKERELL, 1901)

San Francisco Bay to San Diego. [San Francisco Bay is a doubtful locality, quoted by LANCE (1961) from my records.]

CORAMBIDAE

Corambe pacifica MACFARLAND & O'DONOGHUE, 1929

Seasonally common during summer months on colonies of *Membranipora* sp., on offshore kelp. Vancouver Island to Point Eugenia.

Corambella steinbergae LANCE, 1962

Seasonally common during summer months on colonies of *Membranipora* sp., on offshore kelp. San Juan Island to the Coronado Islands.

POROSTOMATA

DENDRODORIDIDAE

Dendrodoris albopunctata (COOPER, 1863)

Common intertidally and subtidally. Salt Point to Point Eugenia (Bollinas Bay to Point Eugenia).

DENDRONOTACEA

TRITONIIDAE

****** *Tritonia diomedea* BERGH, 1894

Subtidal. Alaska to Vancouver Island.

Tritonia exsulans BERGH, 1894

Intertidal and subtidal to 1020 feet. Vancouver Island to Lower California; Japan; Manatee Bay, Florida.

Tritonia festiva (STEARNS, 1873)

Common intertidally and subtidally under ledges. Vancouver Island to the Coronado Islands.

****** *Tritoniopsis tetraquetra* (PALLAS, 1788)

Intertidal and subtidal. Alaska to Monterey Bay; circumboreal.

HANCOCKIIDAE

Hancockia californica MACFARLAND, 1923

Rare intertidally at northern end of range. Dillon Beach to Lower California.

DENDRONOTIDAE

Dendronotus frondosus (ASCANIUS, 1774)

Common intertidally and subtidally; common during summer months on campanularid hydroids on bay boat landings; uncommon on algae and hydroids on mudflats; uncommon on offshore kelp. Cosmopolitan in northern hemisphere.

Dendronotus iris COOPER, 1862

Uncommon subtidally and on mudflats. Vancouver Island to the Coronado Islands.

DOTONIDAE

Doto columbiana O'DONOGHUE, 1921

Uncommon intertidally and subtidally to 140 feet. Vancouver Island to Dillon Beach.

Doto amyra MARCUS, 1961

Intertidally and on bay boat landings. Monterey.

Doto ganda MARCUS, 1961

Intertidally and on bay boat landings. Dillon Beach to Monterey.

Doto kya MARCUS, 1961

Intertidally and on bay boat landings. Moss Beach to Monterey wharf and Point Pinos (Point Pinos).

Doto wara MARCUS, 1961

Intertidally and on bay boat landings. Dillon Beach to Point Pinos.

TETHYIDAE

Melibe leonina (GOULD, 1853)

Seasonally common on offshore kelp and on kelp in boat harbors. Alaska to La Paz Bay.

Arminacea

EUARMINACEA

ARMINIDAE

Armina californica (COOPER, 1862)

Common subtidally at northern end of range; uncommon subtidally in Central California. Vancouver Island to Panama.

PACHYGNATHA

DIRONIDAE

Dirona albolineata COCKERELL & ELIOT, 1905

Sporadically common intertidally, on mudflats and on bay boat landings. Vancouver Island to Laguna Beach.

Dirona picta COCKERELL & ELIOT, 1905

Seasonally common intertidally during summer months; at other times rare. Dillon Beach to Point Loma.

ANTIOPELLIDAE

† *Antiopella fusca* (O'DONOGHUE, 1924)

Rare intertidally and subtidally. Vancouver Island to Monterey Bay (Vancouver Island).

Eolidacea

PLEUROPROCTA

CORYPHELLIDAE

Coryphella fusca O'DONOGHUE, 1921

Uncommon on boat landings; subtidal to 210 feet. Vancouver Island to San Juan Island (Vancouver Island)

Coryphella longicaudata O'DONOGHUE, 1922

Uncommon intertidally. Vancouver Island to San Juan Island (Vancouver Island).

† *Coryphella trilineata* O'DONOGHUE, 1921

Common intertidally, on bay boat landings and on mudflats; also subtidally at northern end of range. Vancouver Island to the Coronado Islands (Vancouver Island).

FLABELLINIDAE

Flabellina iodinea (COOPER, 1862)

Rare intertidally at northern end of range. Vancouver Island to the Coronado Islands.

ACLEIOPROCTA

EUBRANCHIDAE

Capellinia rustya MARCUS, 1961

Seasonally common on bay boat landings. San Francisco Bay to Bahía de Los Angeles.

Eubranchnus olivacea (O'DONOGHUE, 1922)

Seasonally common during summer months intertidally and on boat landings. Vancouver Island to San Juan Island (Vancouver Island).

† *Tenellia pallida* (ALDER & HANCOCK, 1855)

Seasonally common from March to June on bay boat landings and pilings. San Francisco Bay to Monterey Bay; Europe.

FIONIDAE

Fiona pinnata ESCHSCHOLTZ, 1831

Sporadically common on floating wood with small lepadid barnacles. Cosmopolitan.

CUTHONIDAE

** *Catriona columbiana* (O'DONOGHUE, 1922)

Subtidal to 72 feet. Vancouver Island.

† *Catriona lagunae* (O'DONOGHUE, 1926)

Common intertidally during summer months. Moss Beach to Laguna Beach (Laguna Beach).

** *Cuthona concinna* (ALDER & HANCOCK, 1843)

Intertidal. Vancouver Island; British Isles.

Præcuthona divac MARCUS, 1961

Uncommon intertidally. Dillon Beach to Monterey (Dillon Beach).

CLEIOPROCTA

FACELINIDAE

Hermisenda crassicornis (ESCHSCHOLTZ, 1831)

Common intertidally, subtidally, on bay boat landings and on mudflats. Sitka, Alaska to Point Eugenia.

PHIDIANIDAE

Phidiana pugnax LANCE, 1962

Seasonally common intertidally and subtidally in January and July on Monterey Peninsula; otherwise rare. Monterey to the Coronado Islands.

AEOLIDIIDAE

Aeolidia papillosa (LINNAEUS, 1761)

Uncommon intertidally, subtidally and on mudflats. Cosmopolitan.

LITERATURE CITED

BABA, KIKUTARÔ

1960. The genera *Okenia*, *Goniodoridella*, and *Goniodoris* from Japan (Nudibranchia - Goniodorididae). Publ. Seto Mar. Biol. Lab. 8 (1): 79-83; pls. 7, 8.

BEEMAN, ROBERT D.

1963 a. Notes on the California species of *Aplysia* (Gastropoda: Opisthobranchia). The Veliger 5 (4): 145-147. (Apr. 1, 1963)

1963 b. Variation and synonymy of *Phyllaplysia* in the north-eastern Pacific (Mollusca: Opisthobranchia). The Veliger 6 (1): 43-47; 5 text figs. (1 July, 1963)

COCKERELL, THEODORE DREW ALISON

1902. Three new species of *Chromodoris*. Nautilus 16: 19 to 21.

EALES, NETTIE B.

1960. Revision of the world species of *Aplysia* (Gastropoda, Opisthobranchia). Bull. Brit. Mus. (Nat. Hist.) Zool. 5 (10): 267-404; 51 text figs.

GONOR, JEFFERSON J.

1961. Observations on the biology of *Hermisenda smithi*, a sacoglossan opisthobranch from the west coast of North America. The Veliger 4 (2): 85-98; 13 text figs.

HANNA, G DALLAS

1951. A new West American nudibranch mollusk. Nautilus 65 (1): 1-3, figs. 1-5.

KJERSCHOW-AGERSBERG, H. P.

Notes on a new cladohepatic nudibranch from Friday Harbor, Washington. Nautilus 36: 133-138.

LANCE, JAMES R.

1961. A distributional list of Southern California opisthobranchs. The Veliger 4 (2): 64-69.

A New Member of the Genus *Atagema*
(Gastropoda:Nudibranchia)
a Genus New to the Pacific Northeast

BY

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(5 Text figures)

Despite the fact that the Pacific Northeast has been extensively worked with regard to the nudibranchiate fauna there still remains a great deal to be done. In addition to much review work that is needed, there seem to remain many species that have been missed, due either to faulty collecting, or, more likely, due to their rarity.

The latter is the case with the following animal. It is one of the "novelties" MARCUS (1961, page 56) speaks of, that can be expected to turn up on this coast with the recent increase of collecting activity.

I wish to thank all those who were kind enough to send me literature and give assistance in other ways. I am especially grateful to Mr. Wesley Farmer of the San Diego Museum of Natural History and Dr. William Hazen of San Diego State College for their help and encouragement in preparing this paper and Jessie Zimmerman for the preparation of the figures. The work was conducted at San Diego State College.

Cryptobranchia

DORIDIDAE

Archidoridinae

Atagema quadrimaculata COLLIER, spec. nov.

The one animal collected measured 30 mm in length and 11 mm in width when actively crawling. Preserved it measures 16 mm and 8 mm respectively. The body form is similar to the shape of the other members of the genus with the front rounded and the posterior end slightly pointed. The foot measures 25 mm in length and 8 mm in width; it extends about 2 mm beyond the notum at the posterior end.

The notum has a coarse texture due to the many small papillae covering it as well as the spicules in it. The notum is a very light beige, almost white, with the papillae a darker beige. The presence of these papillae gives the animal a beige sponge-like appearance. The color of the

animal is kept to some degree in the preserved form although it tends to bleach out around the edge of the notum. The side of the foot has brownish-beige spots on it which are quite dense at the base but become sparser until they end at the point where the foot joins the notum. These spots show through the foot, to some degree giving the appearance that the sole of the foot has a color



Figure 1: Outer Laterals

pattern. On close observation, the underside of the notum is reticulated by fine white lines. There is a very prominent dorsal ridge which begins slightly posteriorly to the rhinophores and extends along the mediodorsal line to end in a prebranchial hump.

There are two pairs of laterally located dark brown to black spots on the notum. These spots are in a depression caused by the absence of papillae and measure one to two millimeters in diameter. One pair is located immediately posterior to the rhinophore sheaths at the base of the dorsal ridge. The other pair is posterior to the prebranchial hump, lateral to the branchial valves.

There are three horizontal branchial valves which project posteriorly and correspond to three of the five bipinnate gills which they protect. Two of the gills have no corresponding valve. The gills were never observed to project farther than $\frac{1}{2}$ mm beyond these valves in the extended position. Because the branchial valves are hori-

zontal, the branchial cavity opens posteriorly instead of dorsally.

The retractile rhinophores are contained in sheaths

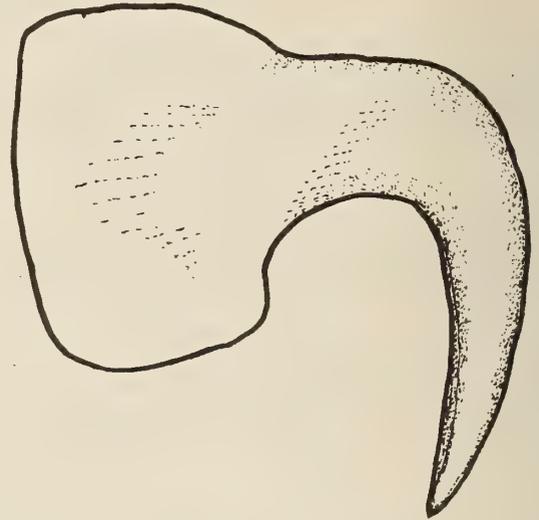


Figure 2: Single Tooth

two millimeters high which have the same texture and color pattern as the notum. The rhinophores are two millimeters high when extended and have 16 leaves. They are white at the base with the distal $\frac{3}{4}$ mm brown.

At the anterior end of the foot is a strongly indented

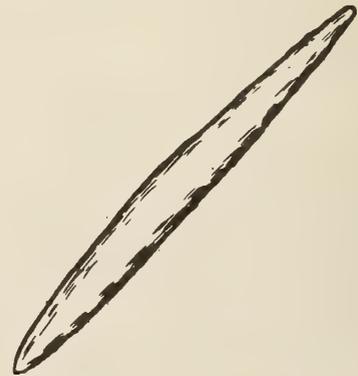


Figure 3: Spicule

upper lip with two oral tentacles visible above the lip (text figure 4). The upper lip normally hides the mouth.

There is a weak, rodless labial cuticle. The radular formula is 18 x 18 - 19·0·19 - 18. The teeth are strongly hooked and without denticles. The outer and inner laterals are small (40μ) and the teeth get progressively larger from one to seven, with the seventh through eleventh

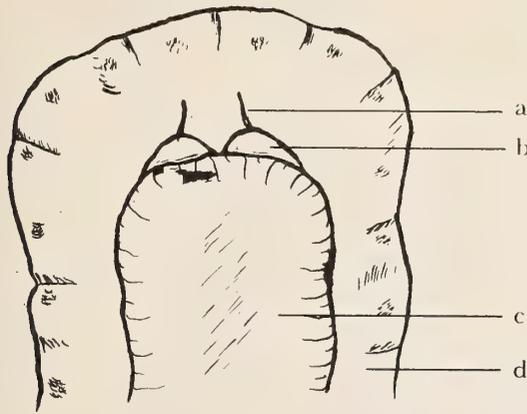


Figure 4: Ventral View of the Anterior End of *Atagema quadrimaculata* COLLIER, spec. nov.
a. oral tentacles b. lip c. foot d. notum

being approximately the same size (160μ). They then get progressively smaller.

The spicules of the notum are about 100μ long but vary greatly, with some as large as 270μ .

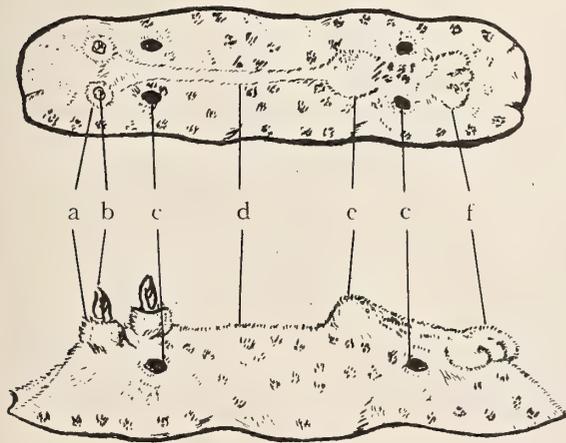


Figure 5: Lateral and Dorsal View of the Living Animal of *Atagema quadrimaculata* COLLIER, spec. nov.

- a. rhinophore sheath
- b. rhinophore
- c. dark brown spots
- d. dorsal ridge
- e. prebranchial hump
- f. branchial valves

The genital aperture is located approximately one quarter of the total length from the anterior end on the right side.

Type Locality: One specimen in the intertidal region of Sunset Cliffs, San Diego, California (Lat. $32^{\circ} 42' N$, Long. $117^{\circ} 16' W$).

REMARKS

This genus is exotic with only a few species known from the South Seas area and the Mediterranean. Most species are based on only one or two specimens. The genus is characterized by the strongly hooked teeth, an unarmed penis, and in most members, the presence of the prebranchial hump and dorsal ridge.

The name *quadrimaculata* was chosen to call attention to the four black spots on the notum, which together with the radular formula can be used to distinguish *Atagema quadrimaculata* from the other members of the genus. The radular formula is considerably smaller than in the other members of the genus, which have formulae of at least $30 \times 29.0.29$.

The holotype is deposited in the California Academy of Sciences Type Collection, No. 00 000. It will be incorporated in the Frank Mace MacFarland Memorial Collection of Nudibranchs.

LITERATURE CITED

ALDER, JOSHUA, & ALBANY HANCOCK

1864. Notice on a collection of nudibranchiate mollusca made in India, etc. *Trans. Zool. Soc.* 5: 133-184; figs. 28-33. (28 April 1864)

GRAY, MARIA EMMA

1850. Figures of molluscous animals selected from various authors; etched for the use of students. London, Brown, Green, & Longmans. 4: iv + 219 pp.

LANCE, JAMES R.

1961. A distributional list of Southern California Opisthobranchs. *The Veliger* 4 (2): 64-69

MARCUS, ERNST

1961. Opisthobranch mollusks from California. *The Veliger* 3 (Supplement, pt. I): 1-85; pls. 1-10. (Feb. 1, 1961)

O'DONOGHUE, CHARLES H.

1926. A list of the nudibranchiate mollusca recorded from the Pacific coast of North America, with notes on their distribution. *Trans. Roy. Canad. Inst.* 15 (2): 199-247.

PRUVOT-FOL, ALICE

1951. Études des nudibranches de la Méditerranée (2 partie). *Arch. Zool. Expér. Génér.* 88: 1-80; 42 figs.; pls. 1-4
1954. Mollusques opisthobranches. *Faune de France*. Paris, Lechevalier. 58: 460 pp.; 173 figs.; 1 plt.

Abnormal Dextral Hyperstrophy of Post-Larval *Heliacus* (Gastropoda: Architeconicidae)

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(Plates 13 and 14)

In 1868, LAGODA described and figured (see Plate 13, fig. 2) a "sinistral," scalariform gastropod shell, naming it (on the plate only) "*Torinia variegata*, LAMARCK, var. *sinistrorsa*." In this paper we present proof that a similar abnormally coiled "*Torinia*" [= *Heliacus*] (Plate 13, fig. 4) is dextral, and that LAGODA's shell was also dextral.

As the terms are used in this paper, dextrality and sinistrality are not defined with reference to the coiling of the mantle-shell and contained viscera — albeit the apertures of most dextral gastropod shells are "right-handed" and of most sinistral gastropod shells "left-handed." Fundamentally, one is anatomically the mirror image of the other. In dextral forms the primitively paired organs associated with the mantle cavity (ctenidia, osphradia, hypobranchial glands, auricles and kidneys) are reduced or absent (except in some primitive archaeogastropods) on the post-torsional right side, and the anus is displaced to the right. In sinistral forms these paired organs are reduced or absent on the left side, and the anus is displaced to the left. The spires of most dextral gastropod shells project to the post-torsional right side, and the spires of

most sinistral shells project to the left (the condition termed orthostrophy) — although an elongate spire may be twisted upwards and posteriad during locomotion. However, some larval and a few post-larval gastropods are dextral but have "left-handed" apertures; their "spires" project to the left (hyperstrophy). In effect, the true spire has become a false umbilicus and the true umbilical area a false spire. Thus, a dextral gastropod shell can superficially appear sinistral (and vice versa) if it is hyperstrophic. For diagrams and further discussion of dextrality, sinistrality, orthostrophy, and hyperstrophy, see KNIGHT (1952, pp. 7 to 9, figure 2).

The protoconchs (\approx larval shells) of some gastropods with orthostrophic teleoconchs (\approx post-larval shells) are hyperstrophic. Such protoconchs are possessed by many opisthobranchs, a few primitive pulmonates, and two families (with living representatives) still classified in the Subclass Prosobranchiata (Streptoneura): Mathildidae and Architectonicidae. [For a study of the hyperstrophic larval shells of the Architectonicidae, see ROBERTSON (in preparation, A)]. All gastropods with hyperstrophic proto-

Explanation of Plate 13

Figure 1: *Heliacus bicanaliculatus* (VALENCIENNES). Normal shell, with orthostrophic teleoconch. South side Bahía San Luis Gonzaga, Baja California Norte, México (W est). Intertidal; associated with *Zoanthus danae* (LE CONTE) on sides of rocks. Collected by Dr. Donald R. Shasky, May 28, 1961. A. N. S. P. no. 276232. x 5.

Figure 2: *H. bicanaliculatus*. Abnormal shell, with hyperstrophic teleoconch. "Californic." "*Torinia variegata*, LAMARCK, var. *sinistrorsa*" LAGODA (from LAGODA, 1868). x 5.

Figure 3: *Heliacus cylindricus* (GMELIN). Normal shell, with orthostrophic teleoconch (surface corroded). Tea Table Key, Florida Keys. Collected by Mr. Thomas L. McGinty. A. N. S. P. no. 195956. x 6. See also Plate 14, figs. 1 and 3.

Figure 4: *H. cylindricus*. Abnormal shell, with hyperstrophic teleoconch. Tea Table Key, Florida Keys. Collected by Mr. Frank Lyman, 1938. U. S. N. M. no. 597759. x 6. See also Plate 14, figs. 2 and 4.

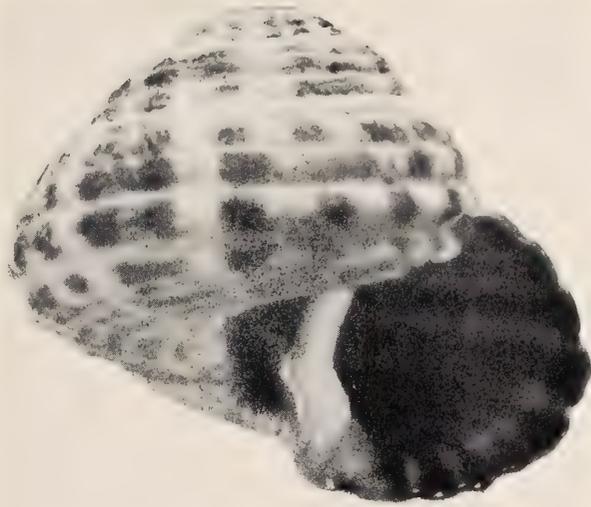


Figure 1



Figure 2

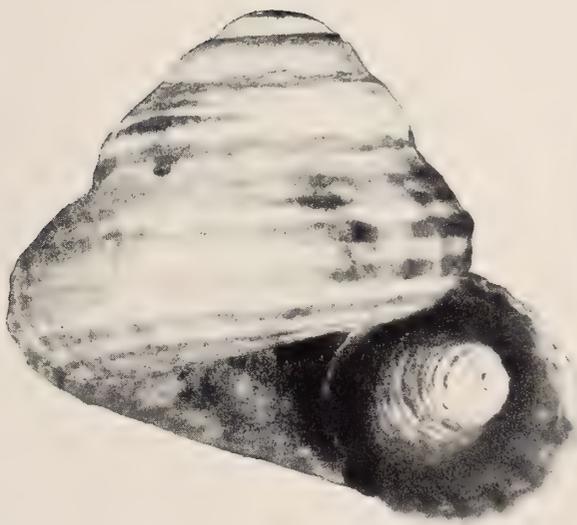


Figure 3



Figure 4

conchs normally are dextral, and the change from hyperstrophic to orthostrophic coiling involves only minor repositioning of the mantle.

Dextrality or sinistrality is determined very early in the embryologic development of every living gastropod, and, once determined, is never reversed; either dextrality or sinistrality is retained thereafter through life. A change from sinistral to dextral (or dextral to sinistral) coiling late in larval life is altogether impossible.

There is no *a priori* reason to exclude the possibility that, abnormally, architectonic shells may occasionally be sinistral. However, both the protoconch and the telcoconch would have to be sinistral. This profound aberration might or might not affect the normal larval hyperstrophy and post-larval orthostrophy.

A far less profound aberration, not involving sinistrality, would be the abnormal retention of the normal hyperstrophic larval coiling by a post-larval, benthic architectonic. Such an abnormal shell superficially would appear sinistral if the "spire" were oriented upwards. An architectonic showing precisely this kind of aberration is illustrated here (Plate 13, fig. 4), together with a normally coiled shell of the same species (Plate 13, fig. 3) from the same locality (Tea Table Key, Florida Keys). This abnormally coiled specimen of *Heliacus cylindricus* (GMELIN, 1791), United States National Museum (U. S. N. M.) no. 597759, can be proved to be dextral and hyperstrophic by using two kinds of evidence: (1) the coiling of the operculum, and (2) the external sculpture of the shell and the form and coloration of the aperture.

PELSENEER (1893) has shown how spiral opercula can be used to distinguish orthostrophic sinistrality from dextral hyperstrophy: viewed externally, spiral opercula of dextral gastropods are coiled counterclockwise, and of sinistral gastropods clockwise. The *Heliacus* operculum is a conical, spiral, and lamellar structure (Plate 13, figs. 3, 4). As can be seen from Plate 14, figures 1 and 2, the coiling of the apices of the opercula in the normal and in the abnormal specimens is counterclockwise.

There are thirteen normal specimens of *Heliacus cylindricus* from Tea Table Key (Florida Keys) in the collection at the Academy of Natural Sciences of Philadelphia (A. N. S. P. nos. 195956, 221378, and 264095). The external sculpture of these shells consists of broad spiral cords separated by sulci. The spiral cords are irregularly wrinkled by axial growth lines. In the umbilicus, the cords and sulci are absent or obscure. Not counting these, there are ten sulci on the last whorl of each of the thirteen shells. There are eleven cords of various widths separated by sulci (including the cord at the periphery of the umbilicus and the irregular cord below the suture). Along the

center of some of the sulci there are raised lirae. With the sulci counted clockwise from the suture (Plate 14, fig. 3), lirae most frequently are present in sulci 3 and 5 (on some specimens the lirae are wide enough to resemble narrow cords). Lirae may also be present in sulci 4, 6, and 7, and rarely in sulci 1 and 2. On normal shells, lirae invariably are absent from sulci 8, 9, and 10 (i. e., those on the umbilical half of the base).

Using conchological evidence, it can be shown in three ways that the apertures of the normally and abnormally coiled shells (Plate 14, figs. 3, 4) are both oriented in the same way (i. e., that fig. 4 shows a dextral hyperstrophic shell). On the exterior of the abnormal shell, lirae are present in sulci 2, 3, 4, 5, and 6. If the sulci are counted counterclockwise from the (false) suture (FS), these are sulci v, vi, vii, viii, and ix. Unless the shell is hyperstrophic, the presence of lirae in sulci "8" and "9" is discordant with the normal external sculpture.

The form of the aperture is the second conchological indication that the abnormal shell is properly oriented. The anterior siphonal channel (ASC) is in almost the same position in both apertures. Curiously, in the abnormal shell this channel is opposite the cord between sulci 9 and 10, while on all normal shells it is opposite the cord between sulcus 10 and the umbilicus.

The coloration of the aperture is the third indication of correct orientation. Within the aperture of the abnormal shell is yellowish brown except the upper left quadrant, the parietal area (PA), where it is white tinged with very pale amber. This area corresponds to the parietal callus of normal shells, which is thinner (affixed to the parietal wall), semitransparent, and white or very pale amber. The parietal area is in the same position in both apertures.

In 1867, more than two decades before the reality of hyperstrophy was conclusively proved, LAGODA not unnaturally assumed that his abnormal "*Torinia variegata*" was sinistral. In a paper in which the concept of hyperstrophy was questioned, FISCHER & BOUVIER (1892, p. 125) included "*Torinia variegata*" in a list of the then known teratologically "sinistral" gastropods. PELSENEER (1893) wrote an elegant paper in rebuttal, one of his series of papers proving the reality of hyperstrophy.

Without discussion, CHARLES BAYER (1948, p. 28) has stated that "*Torinia variegata*, LAMARCK, var. *sinistrorsa* LAGODA" is a "laeotropic [i. e., sinistral] scalarid" [i. e., epitoniid], not a "*Torinia*." In our opinion this statement is incorrect and there is no reason whatever to question LAGODA's generic identification. LAGODA's shell was white variegated with brown, had the granulated spiral cords of *Heliacus*, and lacked the axial costae possessed by most epitoniids.

LAGODA stated that his shell was brought to him from "Californie" by a friend. The genus *Helicacis* does not occur on the California coast proper. However, the name *Torinia variegata* (LAMARCK, 1816) used to be misapplied to *Helicacis bicanaliculatus* (VALENCIENNES, 1832), which does occur in the Gulf of California. Four lots of this species in the Academy's old collection are labeled "variegata," and one is labeled merely "California." True *Helicacis variegata* (LAMARCK, 1816) is an Indo-West Pacific species, whereas *H. bicanaliculatus* ranges from Bahía San Luis Gonzaga (Baja California Norte) south to Acapulco (Guerrero), México (KEEN, 1958, p. 293), and (near the northern end of its range) is a symbiont with the colonial (zoanthiniarian) sea anemone *Zoanthus danae* (LE CONTE) (ROBERTSON, in preparation, B).

A normal shell of *Helicacis bicanaliculatus* is illustrated here (Plate 13, fig. 1) at the same magnification (x 5) as that of LAGODA's shell (Plate 13, fig. 2). Despite the different size and greatly different shape and appearance, we believe that LAGODA's shell was probably a young, dextral, hyperstrophic *H. bicanaliculatus*. The difference in size is noteworthy. LAGODA's shell had five whorls. Full-grown *H. bicanaliculatus* has no more than five and three quarters whorls. We suggest that the abnormal coiling may have increased the relative number of whorls of the young shell.

Normal shells of *Helicacis bicanaliculatus* have ten granulated, spiral cords of various widths on the last whorl (excluding those in the umbilicus). Above the periphery there are four of these cords; below and on the base there are six. The shells are variously patterned with brown. Twenty-two of the forty normal shells in the Academy's collection have the brown paler below the periphery than above; two lack brown coloration below the periphery altogether; sixteen have as much brown below as above, and in none is the brown pale or lacking above the periphery. LAGODA's shell had four spiral cords above the periphery and six (?) below, and nearly all the brown markings are above the periphery (orientation of Plate 13, fig. 2). LAGODA's shell contained neither the dried animal nor the operculum. Nevertheless, this conchological evidence is enough to show that LAGODA's

abnormal shell was closely comparable to the dextral hyperstrophic specimen of *H. cylindricus* (Plate 13, figure 4).

Both abnormal shells are scalariform and have partially disjunct whorls. Their apertures are slightly more elongate than those of normal shells. Normal, full-grown shells of *Helicacis bicanaliculatus* and *H. cylindricus* have spire angles of 70° to 98° (average 83°) and 66° to 83° (average 73°) respectively. The angle of the false spire of the abnormal specimen of the former species is approximately 40°; that of the latter is 30°.

LAGODA wrote his article in "Saint-Petersbourg" (now Leningrad) in 1867. It was published in Paris the following year. LAGODA's dextral hyperstrophic *Helicacis* was in his private collection. Searches in the major shell collections in Leningrad and Paris have failed to locate his specimen (see Acknowledgments).

Whether post-larval hyperstrophy was caused twice by an injury to the mantle of a larva cannot, unfortunately, now be determined. LAGODA did not adequately describe and illustrate the apex of his shell, and the spire of the dextral hyperstrophic *Helicacis cylindricus* is decollated (three and one half whorls remain).

The normal coiling of the thecosomatous pteropod *Spiratella* [incorrectly "*Limacina*"] is directly comparable to the abnormal coiling of the two *Helicacis* specimens in that all are dextral and hyperstrophic. *Spiratella* can be considered a neotenous opisthobranch larva, remaining in the plankton throughout life. The shell remains hyperstrophic throughout life. The larvae of *Helicacis* likewise have dextral hyperstrophic shells and are pelagic. However, they soon settle to the bottom and are thereafter benthic. Although having the larval coiling, the two abnormal *Helicacis* specimens undoubtedly were benthic; both have fairly thick, heavy shells, one 13 mm long, the other 15 mm long. The largest *Spiratella*, *S. helicoides* (JEFFREYS, 1877), does attain a shell diameter of 12.5 mm (TESCH, 1946, p. 9), but has a much thinner shell and long parapodial "wings" used for swimming.

A few other gastropods normally are dextral and hyperstrophic throughout life. A good example is *Lanistes*, a benthic, fresh-water prosobranch. To our knowledge, ours

Explanation of Plate 14

Figures 1 and 2: *Helicacis cylindricus* (GMELIN). Views showing the counterclockwise (dextral) coiling of the multispiral operculum (*in situ* in the aperture) of the normal (fig. 1) and abnormal (fig. 2) shells. Both x 14.
 Figures 3 and 4: *H. cylindricus*. Diagrams showing the sculpture on the exterior of the outer lip, and the form and coloration of the aperture of the normal (fig. 3) and abnormal (fig. 4) shells. The parietal area (PA), anterior siphonal channel (ASC), suture (S), false suture (FS) and sulci (numbered 1 to 10 and i to x) are shown. In fig. 3 there are lirae in sulci 3 to 7; in fig. 4, in sulci 2 to 6 (the lirae in sulci 5 and 6 are wide). Both x 10.
Note: All the shells illustrated on both plates are dextral and all are conventionally oriented (with the aperture to the right of the axis of coiling).

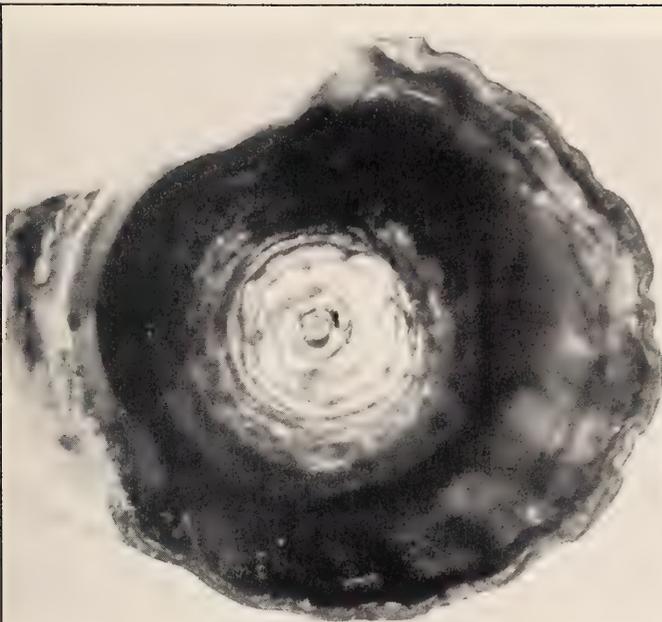


Figure 1

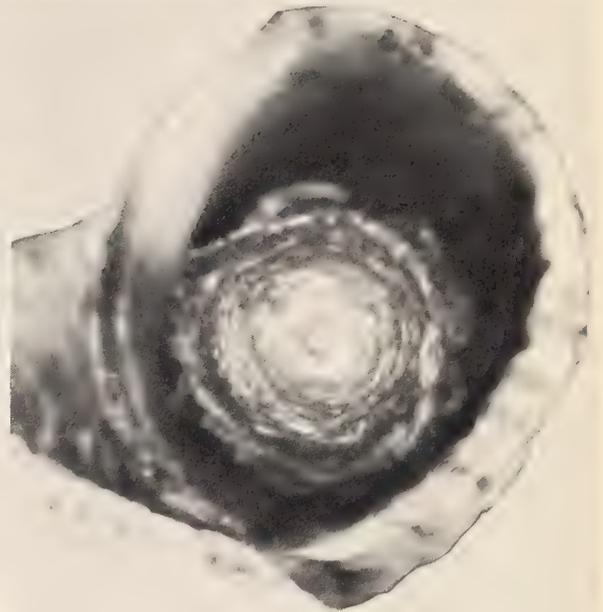


Figure 2

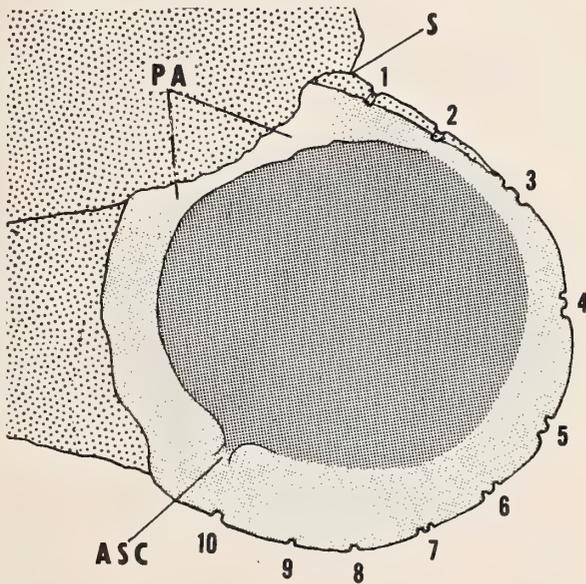


Figure 3

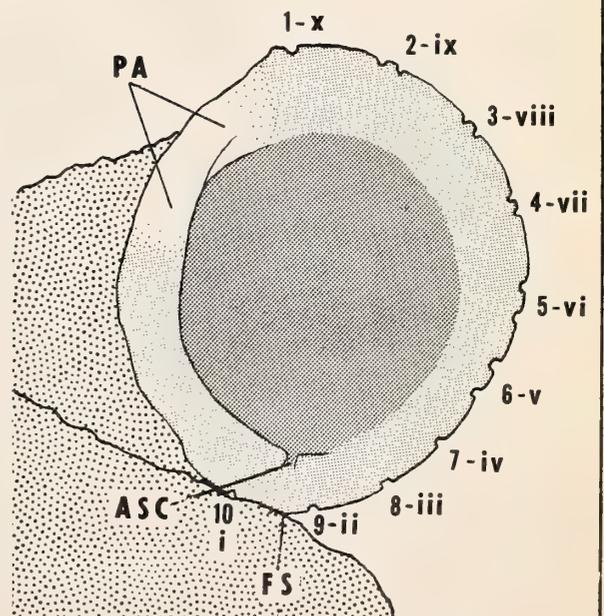


Figure 4

is the first report of abnormal, post-larval dextral hyperstrophy in gastropods normally having hyperstrophic protoconchs. [The "sinistral," semi-terrestrial ellobiid *Blauneria* may be a benthic example of a dextral gastropod with the hyperstrophic coiling of the protoconch retained normally by the teleoconch. This possibility appears never to have been investigated.] Our discovery has bearing on the relative adaptive values of orthostrophy and hyperstrophy.

Abnormal hyperstrophy must have had minor or no adverse effects on the two post-larval, benthic *Heliacus* specimens. Despite their retained larval coiling, these animals survived their abnormal (incomplete) metamorphosis and grew shells 13 mm and 15 mm long. Theoretically, hyperstrophy should impede benthic locomotion and possibly also the removal of wastes from the anus and mantle cavity. The usual orientation of the foot is reversed relative to the "spire" of the shell, as is also the position of the anus. During locomotion, the shell-mantle and contained viscera would have to be twisted more than 90° relative to the head-foot mass because otherwise the false spire of the shell would be pushed ahead of the foot. A hyperstrophic *Heliacus*, living in sedentary association with zoanthinarian sea anemones, would find such locomotory and associated problems minimized. More active benthic gastropods might not survive abnormal hyperstrophy.

SUMMARY

All normal architectonicids are dextral and have hyperstrophic protoconchs and orthostrophic teleoconchs. "*Torinia variegata*, LAMARCK, var. *sinistrorsa*," described by LAGODA (1868), is probably a young, abnormally coiled *Heliacus bicanaliculatus* (VALENCIENNES). This species lives on the West coast of México in association with *Zoanthus danae* (LE CONTE), a colonial sea anemone (Zoanthinaria). LAGODA's shell is directly comparable with a full-grown, dextral hyperstrophic specimen of *Heliacus cylindricus* (GMELIN) from the Florida Keys. The counterclockwise coiling of the multispiral operculum, the shape and external sculpture of the shell, and the form and coloration of the aperture prove that the latter is dextral. Both shells were dextral throughout life, and the normal hyperstrophic coiling of the protoconch

was retained abnormally by the teleoconch. Hitherto, such an abnormality appears not to have been reported.

ACKNOWLEDGMENTS

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LITERATURE CITED

- BAYER, CHARLES
1948. Catalogue of the Solariidae in the Rijksmuseum van Natuurlijke Historie. III. *Torinia*. Zool. Verhandel. (Rijksmus. Nat. Hist. Leiden), no. 4: 44 pp.
- FISCHER, PAUL, & E. - L. BOUVIER
1892. Recherches et considérations sur l'asymétrie des mollusques univalves. *Journ. Conchyl.* 40: 117 - 207; pls. 1 - 3.
- KEEN, A. MYRA
1958. Sea shells of tropical west America; marine mollusks from Lower California to Colombia. Stanford Univ. Press, xi + 624 pp.; illus. Stanford, Calif.
- KNIGHT, J. BROOKES
1952. Primitive fossil gastropods and their bearing on gastropod classification. *Smithson. Miscell. Collects.* 117 (13): i - iii; 1 - 56; 10 figs.; 2 pls.
- LAGODA, A. DE
1868. Note sur une variété anormale du *Torinia variegata*, LAMARCK. *Journ. Conchyliologie* 16: 264 - 265; plt. 9, fig. 7.
- PELSENEER, PAUL
1893 ["1892"]. À propos de l' "Asymétrie des Mollusques univalves." *Journ. Conchyliologie* 40: 229 - 233; 1 fig.
- ROBERTSON, ROBERT
In preparation, A. A study of the hyperstrophic larval shells of the Architectonicidae (Gastropoda). *Malacologia*.
In preparation, B. Symbiosis between *Heliacus* (Gastropoda: Architectonicidae) and Zoanthinaria (Coelenterata).
- TESCH, J. J.
1946. The thecosomatous pteropods. I. The Atlantic. *Dana - Report*, no. 28; 82 pp.; 37 figs.; 8 pls.



The *Cypraea martini* of SCHEPMAN, 1907

(Mollusca: Gastropoda)

BY

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(Plate 15; 4 Text figures; 1 Map)

Our knowledge of some of the rarer cowries is limited, and identification is made difficult by the lack of photographs to complement the original descriptions of many of these species. The recent discovery of a freshly dead *ex pisce* specimen of *Cypraea (Notadusta) martini* SCHEPMAN, 1907 (see Plate 15, figs. 2a and 2b) has caused me to search for other records of this rare species; it is the purpose of this paper to collate all the available information, to publish what may be the first field report of a recently collected specimen, and to provide photographs of it and other comparable shells.

Relatively little has been known about *Cypraea martini*. It has been represented by only ten recorded specimens, eight of which, from the Pleistocene of northwest Celebes, were preserved in the museums at Leiden and Amsterdam. Only two Recent specimens have been recorded, one from the New Hebrides in the Schilder Collection (see Plate 15, figs. 4a and 4b) and one in the Shuttleworth Collection in the museum at Bern, Switzerland, with the locality label "Philippines." This latter specimen was misidentified as *Cypraea beckii* GASKOIN, 1836, but has been definitely substantiated as *C. martini* by Dr. F. A. Schilder, who has examined it several times.

This, then, was the status of *Cypraea martini* when I received a specimen for identification: no examples were known outside of Europe; most were fossil shells; the type figure was in a foreign journal (SCHEPMAN, 1907) not readily available to most collectors of *Cypraea*, and the only other illustration known to me was that of ALLAN, 1956, which is a rather exaggerated drawing that does not provide an adequate guide for identification.

The specimen on which my study is based (see Plate 15, figs. 2a and 2b) was collected during a phase of the Palawan Expedition in April 1962 that centered in the area of the Monpog sea passage off southern Luzon—more precisely, in the vicinity of Pulo Island, northeast of the large island of Marinduque and west of Luzon's

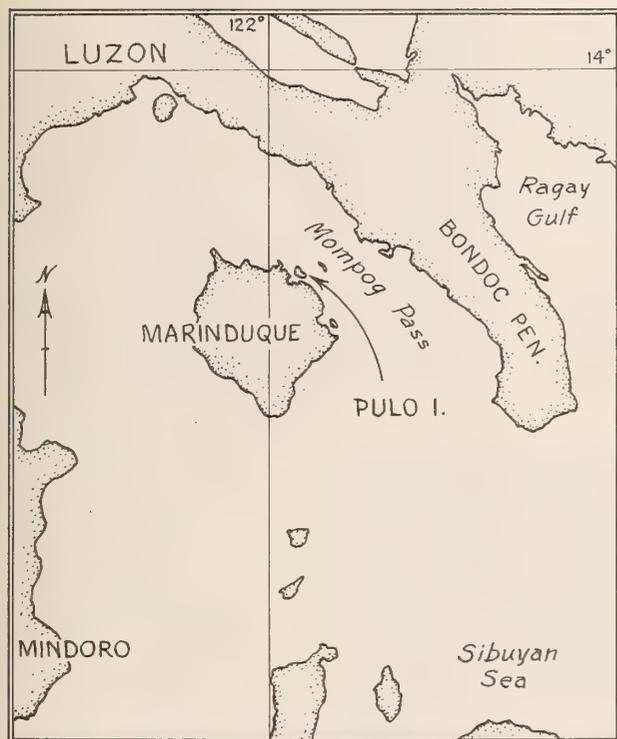
Bondoc Peninsula (see map). In from one to five fathoms of water in this area, where the substrate varied from rock to coral, spearfishermen collected a specimen of fish known only as a member of the Grouper genus *Plectropomus* (family Serranidae). Subsequent examination of the stomach contents revealed a small brown cowrie of unknown identity. No other similar specimens were collected during the trip, nor is it known in any of the Philippine collections. Mr. Fernando G. Dayrit sent it to me for identification, and has furnished the information relating to its discovery.

There is another exceedingly rare cowrie, *Cypraea fultoni* SOWERBY, 1903, an *ex pisce* form whose predator fish, known to me simply as a Musselcracker, is a migratory species seen only for a short time each year off the coast of South Africa. Since it is not known where the Musselcracker travels during the remainder of the year, it is impossible to ascertain an exact locality where *C. fultoni* lives. With this analogy in mind, I inquired into the living habits of the Grouper family. Mr. John E. Fitch, Research Director of the California Department of Fish and Game, informed me that his department has studied the behavior of certain species of Grouper, applying marking tags and checking the movements of those particular species; the results of the study showed that these fish normally live within a general area of no more than a square mile, not moving about as do the Musselcrackers of South Africa. The non-migratory characteristic seems to be typical of all the species of Grouper studied; therefore it can probably be assumed to be true in this instance also. The supposed habits of the fish from whose stomach the *C. martini* was taken would seem to establish the Pulo Island vicinity as a reasonably reliable locality record for this mollusk; further, the small size of this shell (approximately 15 mm in length) suggests the possibility that if the mollusk had been ingested more than a few hours (and, consequently, some miles away) before the fish was caught, normal digestive

processes would have caused it to be eliminated. The relatively larger size of *C. fultoni* (approximately 65 mm in length) could conceivably prevent its passage out of the fish's stomach and into the intestine. These possibilities all lend credence to the heretofore questioned Philippine locality for the Bern specimen of *C. martini*.

Additional *Cypraea* species collected in the Pulo Island area, living in shallow water, were *C. contaminata* SOWERBY, 1832; *C. punctata* LINNAEUS, 1771; *C. gracilis* GASCOIN, 1848; *C. cribraria* LINNAEUS, 1758; *C. caurica* LINNAEUS, 1758; *C. asellus* LINNAEUS, 1758; there were other common species taken at the same time, also. This community of species might suggest to future collectors other localities where *C. martini* could conceivably be found.

Of the eight recorded fossil specimens from the Celebes Pleistocene, five (including the holotype) were deposited in the Rijksmuseum van Geologie en Mineralogie at Leiden, and three in the Zoological Museum at Amsterdam.



All were originally collected by R. Fennema, but the latter three specimens had been in Schepman's private collection.

Over a period of many years, Dr. Schilder has several times visited the three museums possessing specimens of *Cypraea martini*, and has made notes in his personal records concerning the appearance of those specimens,

measurements of most of them, and in some instances, sketches of part or all of a particular shell (see text figures 1, 2, and 4). He has generously sent to me not only photographs of his specimen of *C. m. superstes* (see Plate 15, figs. 4a and 4b), but also all the data in his possession

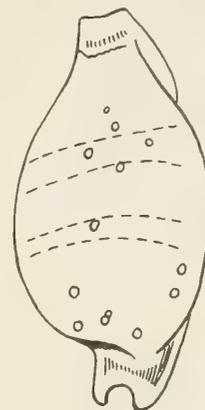


Figure 1: Copy of a drawing of *Cypraea martini martini* (Paratype 4) by F. A. Schilder

pertaining to any of the known examples, and drawings of the identifying characters of certain of the specimens at Amsterdam and Leiden; these are reproduced here in text figure 2. Dr. Schilder particularly points out that one of the Amsterdam paratypes has a greater than normally thickened right side, with a conspicuously bent-up margin in the middle (see text fig. 4). The statistics he has furnished are summarized at the end of this paper (see Table 1). He has expressly given me his permission

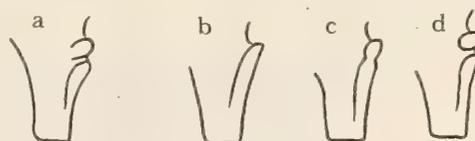


Figure 2: Rough sketches of the terminal ridge of
a - Holotype b - Paratype 5
c - Paratype 6 d - Paratype 7
Sketches by F. A. Schilder

to use any of these data or to quote from his letters to me; some of his remarks have been incorporated in my text.

The genus *Notadusta* SCHILDER, 1935 was established for *Cypraea victoriana* SCHILDER, 1935, a Tertiary form from southern Australia. *Notadusta* at present includes two living species, *N. martini* (SCHEPMAN, 1907) and *N. katsuae* (KURODA, 1960).

Cypraea martini comprises two races in the Indo-Pacific: *C. martini martini* SCHEPMAN, 1907 from the Celebes

Pleistocene (Pl. 15, figs. 1a, 1b) and with one Recent specimen reportedly from the Philippines (Bern specimen; Pl. 15, figs. 3a, 3b), and *C. martini superstes* SCHILDER, 1930 from the New Hebrides islands (Pl. 15, figs. 4a, 4b). *Cypraea martini superstes* differs from *C. m. martini* by having a more inflated shell with more numerous labial teeth. Upon first viewing the specimen at Bern in 1932, SCHILDER considered it a second example of *C. m. superstes*, but after further deliberation (1938, 1941, 1952) referred it back to *C. m. martini* "because of the slighter density of the teeth on the outer lip."

Because SCHEPMAN's description of the species is based on a fossil example and many important descriptive characters of a live-collected shell have necessarily been omitted by him, it seems advisable to include them here.



Figure 3: Terminal ridge approximation of *Cypraea martini martini* (Hypotype 2)

The purpose of this emendation is to clarify the record and to facilitate identification of other specimens that may later be discovered.

The shell is elliptically ovate; the narrow aperture, long for the shell, widens constrictedly to the front from the medial area, curving gently left adapically; the terminal ridge is sharp, perpendicular, angling only perceptibly (see text fig. 3); shell is umbilicate, apex hardly visible, adapical columellar extension obscures one-third of umbilicus; both front and rear terminal collars well defined, extended into beaks, the posterior curving upward to the left. The labial teeth are short, well developed, comparatively far apart; the columellar teeth are much finer, longer, closer together, though becoming noticeably shorter centrally as well as posteriorly. The adaxial surface of the columella is smooth, the last third posteriorly becoming ribbed just before merging into the fossula. The ribbed fossula is fairly deeply concave, flattening adapi-

cally into a long, depressed columella; the last eight axial teeth reappear as strong, well defined knobs on the adaxial margin of the fossula. The dorsal inductura is smooth, glossy, somewhat opaquely thin (possibly because of the

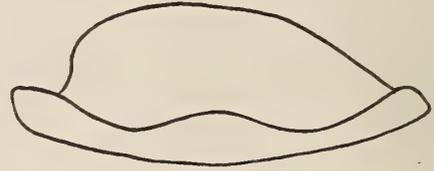


Figure 4: Rough sketch showing the high callused flare of the right margin of Paratype 6. Sketch by F. A. Schilder

stomach fluids of the fish), light brown, with an occasional vague brown spot; there is a dark brown blotch on either side of both terminal extensions; the lateral margins, beaks, base, and interstices are a lighter café-au-lait color; there are five widely separated large brown spots irregularly spaced the length of the right margin, with smaller and more numerous spots on the left side; four broad brown bands, the first one exceedingly faint, originate in the toothed area of the base, fading into the upper left side of the shell. The teeth (27 columellar, 22 labial) and terminal ridge are dark brown, the labial teeth extending well into the aperture; the median axial teeth terminating abruptly at the outer margin of the fossula; eight tooth-like knobs on the inner edge are white.

Because of its unusual flanged appearance, the right margin needs special mention. Being comparatively thick and strong, it flattens out almost at a right angle, forming an extension of the outer lip which serves to strengthen the front beak; the dorsal curving slope thus forming a quasi-sutural effect at the juncture with the flange that is a very distinctive feature of this species. The right margin is very broad at both ends, with a flattened upward curve in the center.

I have enjoyed the opportunity of working with this unusual species. Since only one shell was collected and because of the equivocal manner in which it was taken, it is impossible at this time to determine its exact ecological

Explanation of Plate 15

Dorsal and ventral aspects of *Cypraea (Notadusta) martini martini* SCHEPMAN, 1907, and *Cypraea (Notadusta) martini superstes* SCHILDER, 1930.

Figure 1a, 1b: Holotype of *Cypraea martini martini* (photograph © Rijksmuseum van Geologie en Mineralogie, Leiden)

Figure 2a, 2b: Hypotype No. 2 of *Cypraea martini martini* (photo by Takeo Susuki)

Figure 3a, 3b: Hypotype No. 1 of *Cypraea martini martini* (photo © Naturhistorisches Museum, Bern)

Figure 4a, 4b: Holotype of *Cypraea martini superstes* (photo © Dr. F. A. Schilder, Halle (Saale), German Democratic Republic)



Figure 1 a



Figure 2 a



Figure 3 a



Figure 1 b



Figure 2 b



Figure 3 b



Figure 4 a



Figure 4 b

niche. Its presence in the area of Pulo Island, however, and the non-migratory living habits probably typical of its predator would seem to establish the central Philippine Sea as an additional locality record for the living *Cypraea martini martini*.

During the course of my research for this paper, one additional specimen of *Cypraea martini* was located in the collection of Mrs. Rose Burch of Los Angeles. This

be more closely allied to *Cypraea martini superstes* than to *C. m. martini*; however, it appears to lack the more numerous columellar teeth noted by SCHILDER in his description of the subspecies. The measurements and known data for Mrs. Burch's specimen are included in Table 1, and I wish to express my appreciation for her cooperation in allowing me to include her shell in my study.

Table 1

	Measurements (in mm)			Dentition		Locality	Collection	Details
	Length	Width	Height	Lip	Columella			
<i>Cypraea martini martini</i> SCHEPMAN, 1907								
Holotype	17.0	9.0	7.25	21	29	Kajoe Ragi, N. W. Celebes	Leiden No. 107543	Type figure hand drawn by Schepman These shells are typical of the species Extremely rostrate: see text figure 1 Collected by R. Fennema Right margin exten- sively callused Collected by R. Fennema See Plate 15, figures 3a and 3b From Palawan Expedition, 1962 Recent, though faded in color
Paratype 1	16.8*	8.9*		21	27	Kajoe Ragi, N. W. Celebes	Leiden No. 107544	
Paratype 2	13.6*	7.5*		23	27	Kajoe Ragi, N. W. Celebes	Leiden No. 107544	
Paratype 3	15.4*	7.9*		21	28	Kajoe Ragi, N. W. Celebes	Leiden No. 107544	
Paratype 4	15.6*	broken		23	29	Kajoe Ragi, N. W. Celebes	Leiden No. 107544	
Paratype 5	15.8*	8.0*				Kajoe Ragi, N. W. Celebes	Amsterdam	
Paratype 6	13.0*			22	29	Kajoe Ragi, N. W. Celebes	Amsterdam	
Paratype 7	14.7*	7.8	7.4			Kajoe Ragi, N. W. Celebes	Amsterdam	
Hypotype 1	15.7*					Kajoe Ragi, N. W. Celebes	Bern	
Hypotype 2	13.8	7.0	6.0	20	25+2	Philippines ?		
Hypotype 3	14.7	7.4	6.5	22	27	Pulo Island, Philippines	C. N. Cate No. 1635	
Hypotype 4	19.0	10.0	9.0	23	32	Hayman Island, Queensland	Mrs. John Q. Burch	
<i>Cypraea martini superstes</i> SCHILDER, 1930								
Holotype	16.7*	9.0*		28	29	New Hebrides	F. A. Schilder No. 2586	Type figure hand drawn by Schilder

Note: paratype numbers refer only to Dr. Schilder's personal registry and have not been officially assigned to the museum specimens.

* denotes measurements taken by Dr. Schilder

shell was collected in 1959 at Hayman Island in the Great Barrier Reef, eastern Australia; the collector is unknown.

Mrs. Burch's specimen is in excellent condition, though faded in color and chipped on the right edge of the terminal collar; it was evidently not collected alive. It is the largest specimen known; because of its large size and comparatively more inflated appearance than most of the others, and due to its geographical origin, it may

ACKNOWLEDGMENTS

It has been the object of this paper to bring our knowledge of *Cypraea martini* up to date. I have many to thank for their assistance towards this end, and beyond those I have already mentioned I wish particularly to thank Ray H. Summers for providing reference material, Mrs. Emily Reid for her excellent drawing of the map and the text

figures, Dr. Lothar Forcart of Basel and Miss Vreni Gerber of Bern, Switzerland, for assisting with the Bern research, Mrs. W. S. S. van der Feen-van Benthem Jutting and Miss G. E. de Groot of the respective Dutch museums for photographs and information regarding type material, Dr. Rudolf Stohler for his translation of the Schepman reference, and Jean Cate in particular for her valuable assistance with research work.

LITERATURE CITED

ALLAN, JOYCE

1956. Cowry shells of world seas. Georgian House, Melbourne. i - x; pp. 1 - 170; pls. 1 - 15.

SCHEPMAN, M. M.

1907. Mollusken aus posttertiären Schichten von Celebes. Sammlungen des Geologischen Reichs-Museums in Leiden. Ser. 1; 8: 153 - 203; pls. 10 - 13.

SCHILDER, FRANZ ALFRED

1930. Beiträge zur Kenntnis der Cypraeacea (Moll. Gastr.) — II. Zool. Anz. **87** (3-6): 109 - 118; 2 text figs.
1930. Revision of the Tertiary Cypraeacea of Australia and Tasmania. Proc. Malacol. Soc. London **21** (6): 325 - 355.
1941. Verwandtschaft und Verbreitung der Cypraeacea. Arch. Mollusk. **73** (2-3): 57-120; 2 pls.

SCHILDER, FRANZ ALFRED, & MARIA SCHILDER

- 1938 - 1939. Prodrôme of a monograph on living Cypraeidae. Proc. Malacol. Soc. London, **23**(3-4): 119 - 231.
1952. Ph. Dautzenberg's collection of Cypraeidae. Mém. Inst. Roy. Sci. Nat. Belgique (2) **45**: 1 - 243; 4 pls.

Preliminary Report on the Molluscan Fauna of the Martin River Glacier and Associated Area (South-Central Alaska)

BY

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Geology Department, University of North Dakota

(1 Map)

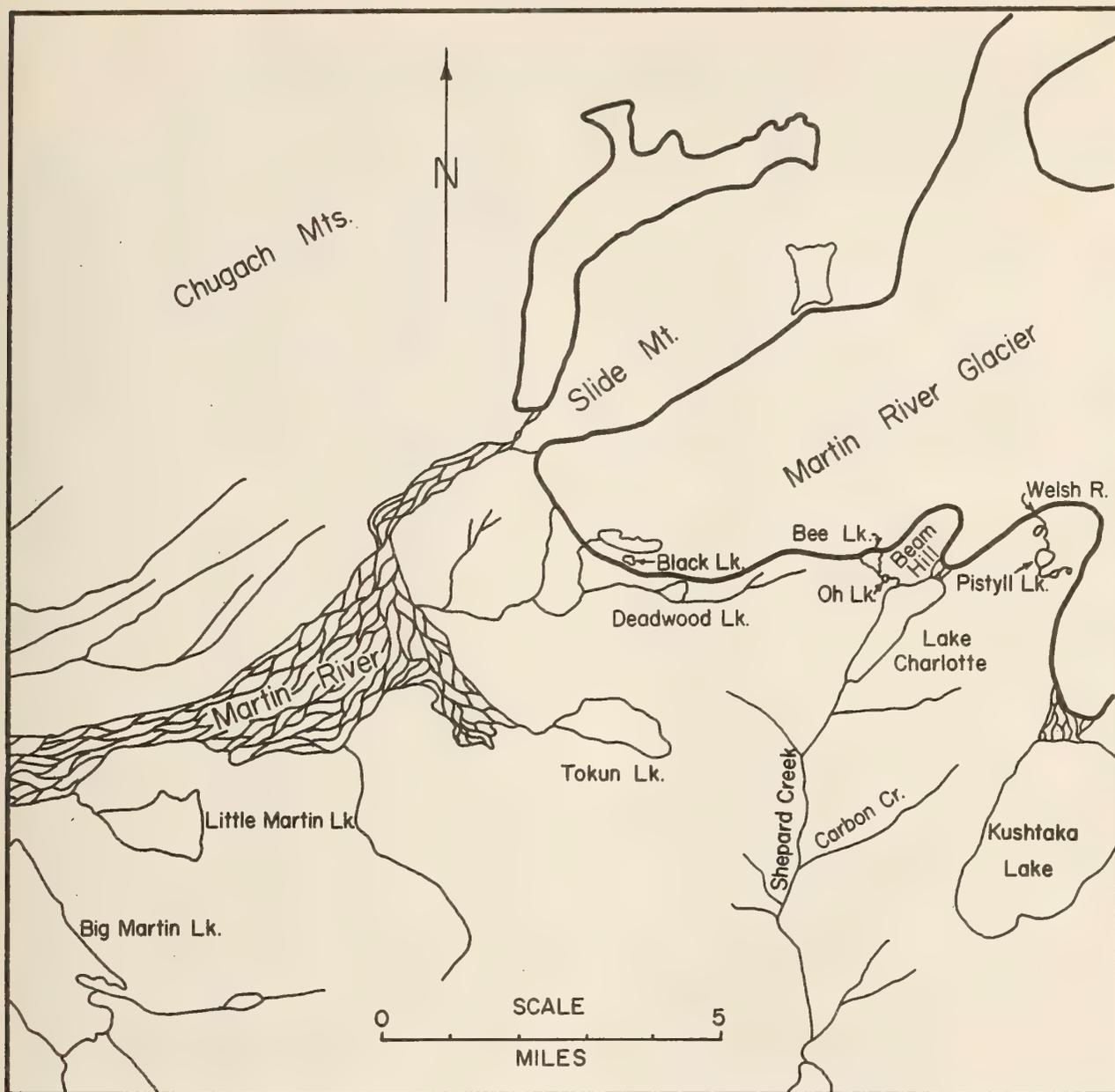
During June, July, and August of 1962 a research team from the University of North Dakota, under the leadership of Dr. Wilson M. Laird, Professor of Geology and North Dakota State Geologist, studied several aspects of the Martin River Glacier which is located about 60 miles east-southeast of Cordova, Alaska ($144^{\circ} 22' 30''$ to $144^{\circ} 00' 00''$ W. Longitude by $60^{\circ} 34' 30''$ to $60^{\circ} 25' 00''$ N. Latitude). Six species of terrestrial gastropods, 3 species of aquatic gastropods and one species of pelecypod were found on the glacier and in associated lakes. One additional species of gastropod and one additional species of pelecypod were found in lakes not directly associated with the glacier, but in rock basin lakes in the nearby area. The expedition was financed by grant number NSF-G22016 from the National Science Foundation. The study of the molluscan fauna was only a part of the overall research program.

This investigation is the first of its kind in the area of the Martin River Glacier and will be continued during

the 1963 field season. The thermal and water chemistry data which were obtained in conjunction with the collection of mollusks are presented here. The results of the first season's research are summarized on Tables 1 and 2. The thermal data reported are taken from the locations at which mollusks were found and at the time of their collection and are not intended as an analysis of the thermal character of the lakes. The botanical associates of the terrestrial gastropods are also being studied.

The existence of aquatic mollusks in turbid meltwater lakes and terrestrial gastropods on the thin drift cover of the glacier itself is significant in that it clearly indicates the ability of some species of mollusks to adjust to unusual conditions and the danger of generalizing about ecologic controls near glaciers. The existence of an order of invasion of glaciated areas by mollusks is suggested by the early results of this investigation.

The use of fossil mollusks in reconstructing the climates which existed in the midcontinent during Pleistocene



SKETCH MAP OF THE
MARTIN RIVER GLACIER & THE ADJACENT AREA

LEGEND

- Lakes
- Rivers
- Glacial boundary

Northeast corner of map at
 144°W. Long. & 60°34'30" N. Lat.



LOCATION MAP

time prompted this study. Our results are not yet complete enough to warrant conclusions as to the validity of inferring climate from fossil mollusks, but they do suggest that the great adaptive capabilities and the environmental factors which may control geographic distribution of mollusks are not yet fully understood.

THE MARTIN RIVER GLACIER

The Martin River Glacier arises in the eastern Chugach Mountains, part of the St. Elias Range, emerges from these mountains and fills an east-northeast trending valley which is 4 to 6 miles wide (Fig. 1). It has a tripartite terminus with lobes extending into the valleys of Lake Charlotte, Kushtaka Lake and the Martin River. The main mass of the glacier occupies the Martin River Valley. Reconnaissance of the region indicates that the maximum Pleistocene expansion of the glacier did not extend beyond the southern shore of Kushtaka Lake, $\frac{1}{4}$ mile below Lake Charlotte, and the point where the Martin River is deflected by a moraine from its southwestern direction to a southerly direction (See fig. 1). A band approximately 1 to $1\frac{1}{2}$ miles wide along the margin of the Martin River Glacier is covered by a dense growth of alder (*Alnus*).

Along the southern margin between Beam Hill and the Deadwood Lake area the glacier is covered by a mature Sitka Spruce (*Picea sitchensis* (BONG.) CARR.) forest which extends about $\frac{1}{2}$ mile onto the glacier. The presence of dense growths of alder makes field operations very difficult in the entire area. A vegetative succession appears to exist. Lupin (*Lupinus Nootkatensis* DONN.) and fireweed (*Epilobium latifolium* LINNÉ) first invade the drift covered portions of the glacier and are followed by alder, then willow (*Salix*) and finally Sitka Spruce. These observations are in agreement with those expressed by HEUSSER (1960, p. 51 to 52). The establishment of stable slopes by the accumulation of debris on the surface of the glacier seems to be a major controlling factor of the vegetational invasion. The amount of debris required to provide the necessary insulating effect to establish stable slopes is surprisingly small, being as little as 18 inches beneath the mature spruce forest near Deadwood Lake.

Unvegetated debris almost entirely covers the balance of the surface of the Martin River Glacier as far as 6 miles from the margin.

LAKES OF THE MARTIN RIVER GLACIER

The lakes of the Martin River Glacier can be divided into several different groups on the basis of the condition of their waters: polar-atrophic, temperate-oligotrophic, and temperate-mesotrophic. Or they may be divided on basin characters; ice-contact, ice-dammed, moraine dam-

med, and non-glacial. An informal classification is used here, which combines aspects of both of the above.

ICE-CONTACT LAKES

Sinkhole Lakes: The marginal $1\frac{1}{2}$ miles of the Martin River Glacier contains many tens of lakes which are polar, atrophic, ice-contact water bodies. The temperature of the water rarely reached 3° C. The profiles of their basins are usually nearly conic and the basin itself is mostly an ice surface. Debris falls into these lakes and collects at the bottom, but has no insulating effect because the high turbidity of the water melting from the sides and flowing into the basins prevents light penetration below a few inches. A few insects and their larvae were the only organisms found in these lakes.

Ice-walled Clear Lakes: When the downward melting of the glacial terminus reaches a stage where the bottoms of the "sinkhole" lakes are not on ice, but on the subglacial surface or are otherwise stabilized, the accumulation of debris is sufficiently great to insulate the water from the ice walls of the basins. The development of stable slopes and forest cover near these lakes so impedes melting in the local area that turbid water rarely, if ever, enters the lakes. Over a period of years the suspended material completely settles out and the increased transparency of the water permits the warming of the lakes. Any inflow of water from melting ice is sufficiently filtered by the drift to remove most detrital material. Ice, deeply buried (at least 10 feet of drift being present in the area of Black Lake, fig. 1), still accounts for the basin and probably also the seal, but the water of the lake is effectively insulated from it. Black Lake is the only lake of this type from which water and sediment samples and mollusks have been taken so far, but upward of 20 such lakes are known to exist in the area north of Deadwood Lake. Beaver (*Castor canadensis* LINNAEUS, 1758) and water fowl were observed, but no fish or other vertebrates were seen during the several hours spent on Black Lake. Three species of mollusks were found there (See Table 2).

ROCKBASIN MELT-WATER LAKES

Bee, Charlotte, and Oh Lakes are all temperate, turbid, oligotrophic water bodies. Three species of mollusks, Red Salmon (*Oncorhynchus nerka* (WALBAUM, 1792)), Dolly Varden trout (*Salvelinus alpinus malma* (WALBAUM, 1792)), Sculpin (*Cottus* sp.), beaver and water fowl were all observed in these lakes. Table 1 summarizes the water conditions. Bee Lake is dammed at its north end by the Martin River Glacier so that while having a rock basin in part, it represents a different situation than the other lakes mentioned. The epilimnion is thin but persists for more than a month in Bee and Charlotte Lakes. Oh Lake

receives its water from only the top 12 inches of Bee Lake and is of the same temperature as that stratum of the higher lake. It is not stratified, being approximately the same temperature from top to bottom.

NON - GLACIALLY ASSOCIATED LAKES

Tokun and Little Martin Lakes lie in basins which may have been occupied by a glacier during the Pleistocene. The portion of the basin along the valley of the Martin River may be fortified by glacial outwash deposits in the case of Martin Lake, and outwash or marginal moraine in the case of Tokun. I visited Tokun Lake for only an hour and did not visit Martin Lake at all. Mr. Rae Baxter, Biologist of the Alaska Department of Fish and Game collected 16 articulated valves of the naiad *Anodonta beringiana* MIDDENDORFF, 1851 from Big Martin

Lake and was kind enough to give them to me. Three species of gastropods were found in Tokun Lake, one of which is a branchiate form. The lakes of the Welsh River area (Pistyll Lake, fig. 1; Table 1) do not receive melt water from the Martin River Glacier, but their basins are in depressions between moraines deposited by the glacier during times when the glacier occupied a greater area. The water of the lakes is temperate and clear. An abundant population of Dolly Varden trout exists in all of these lakes. The Welsh River flows subglacially for over 2 miles. Thus it seems that the trout made their entry into the drainage system at some time when the river flowed along the glacial margin or over the glacier. Two species of mollusks were found in the lakes of the Welsh River area.

Shores of Lake Charlotte:

Scientific Name	Common Name
<i>Picea sitchensis</i> (BONG.) CARR.	Sitka Spruce
<i>Tsuga heterophylla</i> (RAF.) SARG.	Hemlock
<i>Coeloglossum viride</i> (L.) HARTM.	Long-bracted Orchid
<i>Limnorchis convallariaefolia</i> (FISCH.) RYDB.	Orchid
<i>Salix</i> sp.	Willow
<i>Alnus fruticosa</i> RUPR.	Alaska Alder
<i>A. fruticosa</i> var. <i>sinuata</i> (REGEL) HUFF.	
<i>Claytonia siberica</i> L.	Siberian Spring Beauty
<i>Caltha palustris</i> L. var. <i>asarifolia</i> (DC) HULT.	
<i>Aconitum delphinifolium</i> DC	Delphinium-leaved Aconite
<i>Cardamine umbellata</i> GREENE	Umbel-flowered Bitter Cress
<i>Tiarella trifoliata</i> L.	Trifoliate Foamflower
<i>Saxifraga spicata</i> D. DON.	Spiked Saxifrage
<i>Rubus pedatus</i> SMITH	Five-leaved Bramble
<i>R. spectabilis</i> PURSH	Salmonberry
<i>Geum macrophyllum</i> WILLD.	Large-leaved Avens
<i>G. calthifolium</i> MENZ.	Caltha-leaved Avens
<i>Sanguisorba sitchensis</i> C. A. MEY.	
<i>Lupinus nootkatensis</i> DONN.	Nootka Lupine
<i>Viola biflora</i> L.	Two-flowered Violet
<i>V. epipsila</i> LEDEB. var. <i>repens</i> (TURZ.) W. BCKR.	Northern Marsh Violet
<i>V. langsдорffi</i> FISCH.	Alaska Violet
<i>Epilobium latifolium</i> L.	Dwarf Fireweed
<i>Cornus canadensis</i> L.	Bunchberry
<i>C. unalaskensis</i> LEDEB.	Bunchberry
<i>C. suecica</i> L.	Bunchberry
<i>Pyrola asarifolia</i> MICHX.	Liver-leaf Wintergreen
<i>P. asarifolia</i> var. <i>incarnata</i> DC	
<i>Mimulus guttatus</i> DC	
<i>Erigeron yukonensis</i> RYDB.	Daisy Fleabane
<i>Anapholis margaritacea</i> (L.) BENTH & HOOK	Pearly Everlasting
<i>Arnica latifolium</i> BONG.	

TABLE 1 WATER ANALYSES FROM SIX LAKES IN THE AREA OF THE MARTIN RIVER GLACIER, ALASKA

(The upper figure in each box is the mean, the middle is the number of samples analyzed, and the lowest is the range)

Water body	Dis. CO ₂ *	Dis. O ₂	Cu	NO ₃	SO ₃	SO ₄	Total CO ₃ **	Dis. SiO ₂	Cl	Total Fe**	CO ₄	Turbidity	pH	Temperature at locality and time of collection of Mollusks (°C)
Lake Charlotte	2.6	3.9	0	0	1.5	5.83	47.85	1.85	0	0.1	0	53.6	7.14	6/16-12.9 7/14-9.4
	4	4	1	2	2	3	3	2	2	2	2	11	11	6/20-6.8 7/19-10.2
	4.7	4.4	0	0	3	10.6	27	0.6	0	0.1	0	87	0.6	7/4-8.5 7/25-11.1
Bee Lake	2.1													7/9-8.0 8/3-9.4
	7													8/8-8.3
	2.1													7/30-6.5
Oh Lake	3.5													
	1													
	0													7/30-9.6
Pistyll Lake	4													
	1													
	0													7/28-12.8
Black Lake	7.45													
	2			3.8	1.5	6.0	7.0	0	0	0.3	0	0	7.25	8/10-18.2
	0.4			1	1	1	1	1	2	2	2	2	2	
Tokun Lake	2.8													
	1													
	0													8/10-14.2

* The determination of water content was made with a Helige model 950-A colorimeter. Because of the difficulty of operations only partial analyses were made. All of the CO₂ determinations except those from Lake Charlotte and Black Lake were made on samples which were several hours old and may not be reliable.

** Includes suspended material

Vegetated portions of Martin River Glacier (at Charlotte lobe and near Black Lake):

Scientific Name	Common Name
<i>Picea sitchensis</i> (BONG.) CARR.	Sitka Spruce
<i>Salix</i> sp.	Willow
<i>Alnus fruticosa</i> RUPR.	Alaska Alder
<i>A. fruticosa</i> var. <i>sinuata</i> (REGEL) HULT.	
<i>Streptopus amplexifolius</i> (L.) DC	Clasping Twisted Stalk
<i>Cardamine umbellata</i> GREENE	Umbel-flowered Bitter Cress
<i>Tiarella trifoliata</i> L.	Trifoliolate Foamflower
<i>Rubus spectabilis</i> PURSH	Salmonberry
<i>Lupinus nootkatensis</i> DONN.	Nootka Lupine
<i>Epilobium latifolium</i> L.	Dwarf Fireweed
<i>Pyrola chlorantha</i> SWARTZ	Greenish-flowered Wintergreen
<i>Polemonium pulcherrimum</i> HOOK.	Jacob's Ladder

TERRESTRIAL ENVIRONMENT

Land snails were found along the shores of Lake Charlotte in grasses and other low vegetation, most frequently on peeled alder debris. They were also found under alders as far as 1/2 mile from the present terminus of the Lake Charlotte lobe of the glacier and on the shores of Black Lake. Table 2 shows the distribution of the species with regard to the glacier. The order suggested by this arrangement of data may be due to the small number of individuals collected. It is hoped that further study during the

FAUNAL LIST OF MOLLUSKS

Gastropods:

- Menetus callioglyptus* (VANATTA, 1895)
- Gyraulus parvus* (SAY, 1817)
- Lymnaea humilis* (SAY, 1822)
- Valvata siberica* MIDDENDORFF, 1851
- Vertigo columbiana* STERKI, 1892
- Euconulus fulvus alaskensis* PILSBRY, 1899
- Vitrina alaskana* DALL, 1905
- Discus cronkhitei* (NEWCOMB, 1865)
- Punctum* sp.
- Deroceras laeve* (MÜLLER, 1774)
- ? *Prophysadon* sp.

Pelecypods:

- Anodonta beringiana* MIDDENDORFF, 1851
- Pisidium* sp.

1963 field season will clarify the question of whether an order of invasion of the glaciated area by mollusks actually exists. Temperature in the grass-covered outwash near the head of Lake Charlotte varied between 7° C and

35° C during the week of August 7 to 14. Temperatures reached as high as 38° C in the superglacial alder growths during July. Thus, despite the near proximity of ice, a temperate environment exists in which species of mollusks are maintaining successful populations.

The flora was unsystematically sampled at several locations during the course of the summer. Specimens were collected by the various members of the party, pressed in the field, and submitted to Dr. Vera Facey, Professor of Biology of the University of North Dakota for identification. The plants collected from locations from which land snails were collected are listed below. They represent only a small part of the flora known to exist in the area, but are given here as they are at least a part of the floral associates of the molluscan fauna. The taxonomic reference is ANDERSON, 1959.

ACKNOWLEDGMENTS

I am indebted to several people for assistance during the course of this investigation. Dr. Wilson M. Laird, Professor of Geology, University of North Dakota and North Dakota State Geologist and Mr. Lee Clayton, geologist, expended much time and effort in behalf of the limnological research, despite their primary responsibility to other aspects of the team's program of study. Mr. Rae Baxter, Biologist, Alaska Department of Fish and Game, offered valuable advice as well as actually collecting specimens in areas I was unable to visit. Dr. John Reid, Assistant Professor of Geology, University of North Dakota and Mr. Gerald McDonald, student assistant, helped pack equipment to two remote localities. Dr. Vera M. Facey, Professor of Biology, University of North Dakota, very kindly identified the plant specimens collected.

The people of Cordova, especially Mr. Karl Barth, Mr. James Osborne, Mr. Harley King and Mr. Ed King, were

Table 2
Geographic Distribution of Molluscan Fauna of the
Martin River Glacier Area (S. C.) Alaska 1962

MOLLUSKS	LOCALITIES								
	Lake Charlotte & area	Bee Lake	Tokun Lake	Big Martin Lake	Black Lake & area	Lk. Charlotte lobe Martin R. Gl.	Oh Lake	Welsh Riv. area (Pistyll Lk.)	Totals
Aquatic Forms:									
<i>Menetus callioglyptus</i>	78	17	74	—	58	—	—	—	227
<i>Lymnaea humilis</i>	15	8	42	—	—	—	—	24	89
<i>Gyraulus parvus</i>	—	—	—	—	20	—	—	—	20
<i>Valvata siberica</i>	—	—	4	—	—	—	—	—	4
<i>Anodonta beringiana</i>	—	—	—	8	—	—	—	—	8
<i>Pisidium</i> sp.	—	—	—	—	2	—	X	17	19
Terrestrial Forms:									
<i>Vertigo columbiana</i>	42	22	—	—	4	28	—	—	96
<i>Euconulus fulvus alaskensis</i>	13	13	—	—	19	9	—	—	54
<i>Vitrina alaskana</i>	1	—	—	—	—	3	—	—	4
<i>Discus cronkhitei</i>	10	—	—	—	—	—	—	—	10
<i>Punctum</i> sp.	1	—	—	—	—	—	—	—	1
<i>Deroceras laeve</i>	—	—	2	—	—	—	—	—	2
? <i>Prophysadon</i> sp.	1	—	—	—	—	—	—	—	1
Total:	161	60	122	8	103	40	X	41	535
Times collected:	10	2	1	1	1	4	1	1	

most helpful to the party and I am grateful for their advice and assistance.

Dr. R. Tucker Abbott, Director of Mollusks, The Academy of Natural Sciences of Philadelphia, graciously permitted me to use the Academy's collections. This assisted me in identifying the mollusks collected and I am appreciative of his efforts.

Dr. G Dallas Hanna, Curator of Geology, and Mr. Allyn G. Smith, Associate Curator, Department of Invertebrate Zoology, California Academy of Science, criticized the manuscript and checked the identifications of

the mollusks. I am very appreciative of their efforts in behalf of the study reported here, as well as the many courtesies extended to me personally by them.

LITERATURE CITED

ANDERSON, JACOB P.

1959. Flora of Alaska and adjacent parts of Canada. Ames, Iowa, The Iowa State Univ. Press; 543 pp.; 45 pls.

HEUSSER, CALVIN J.

1960. Late-Pleistocene environments of North Pacific North America. New York, Am. Geograph. Soc. Special Publ. No. 35; 308 pp.; illus.

Synopsis and Discussion of the Association of Ctenidia and Labial Palps in the Bivalved Mollusca

BY

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(5 Text figures)

As well described by YONGE (1939), classical understanding of evolution within the bivalved Mollusca has the Nuculidae as ancestral types of all other members of the class. In his functional interpretation of protobranchiate structure, YONGE was apparently led to conclude that the anatomy of Recent Nuculidae is thus a true reflection of primitive conditions. Among these conditions was the presence of extensible palp appendages or proboscides with which the organisms fed directly upon deposits in the substratum. Correspondingly there was believed to be a lack of association of ctenidia and labial palps, an association typifying lamellibranchiate groups, all of which rely upon the ctenidia as food collecting and primary food sorting organs. As in the Nuculidae, the palp lamellae of other bivalves sort the gathered particles prior to ingestion.

The classical view of evolution within the Bivalvia may be summarized in several ways; namely, taxonomically (Nuculidae → higher Bivalvia), anatomically (lack of gill-palp association → gill-palp association), and functionally (proboscidial deposit feeding → suspension feeding).

With the classical view well in mind it is significant that recent work (STASEK, 1961) demonstrated an anatomical feeding association of ctenidia and labial palps in the Nuculidae. While it is true that the ciliated palp proboscides convey large quantities of potential food into the mantle cavity, the relative functional importance of the various methods of feeding in the family remains speculative; particles trapped by the ctenidia may be almost wholly ingested, whereas masses gathered by the proboscides seem to be more rigorously subject to sorting and rejection. Although lacunae exist in our knowledge, the Nuculidae can no longer be thought to exemplify the now hypothetical primitive condition in which the ctenidia lack close relationship with the labial palps.

The discovery that a well defined association of gill and palp is present in the Nuculidae led me to study the

relationship of these organs throughout the Bivalvia. The present paper describes only the broadest anatomical features of the relationship as determined from 55 families of the class. Of these, conditions in six were not personally observed but were deduced from illustrations in carefully chosen papers in the literature, which is generally unreliable in this respect.

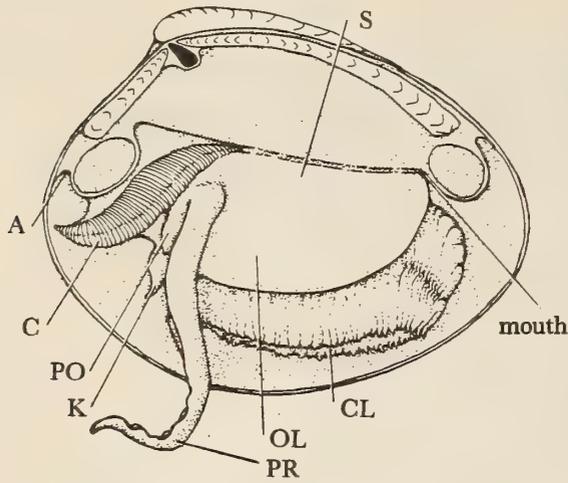
Synopsis of Observations

To date, specimens of 193 species in 127 genera have been studied. Observed associations of ctenidium and palp may be segregated into three major anatomical categories:

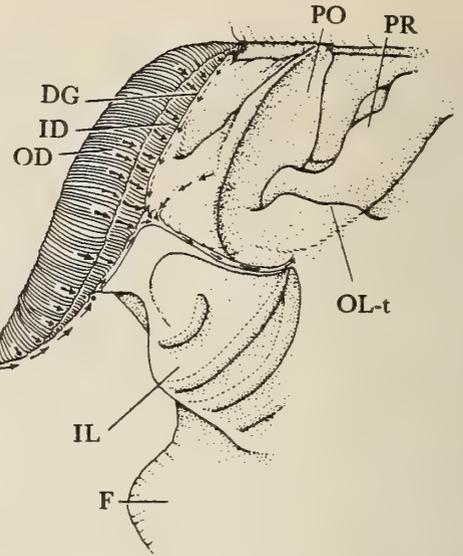
Category I is one in which the ventral tips of at least the first few or, usually, of many anterior filaments of the inner demibranch are inserted *unfused* into a distal oral groove (a designation originated by KELLOGG, 1915). Exemplary types are *Acila castrensis* (HINDS, 1843) (Nuculidae, Fig. 1) and *Anodonta californiensis* LEA, 1852 (Unionidae, Fig. 1). Category I characterizes the following groups: Nuculacea, Mytilacea, Unionacea, Astartidae, and possibly the Trigoniacea (PELSENEER, 1891).

Category II is one in which the ventral tips of the anterior-most filaments of the inner demibranch are inserted *and fused to* a distal oral groove. An exemplary type is *Clinocardium nuttalli* (CONRAD, 1837) (Cardiidae, Fig. 1). Category II characterizes the following groups: Carditacea, Isocardiacea, Cyprinacea, Chamacea, Cardiacea, Veneracea (with certain exceptions being placed in Category III), Mactracea (in part), Semelidae, Gastrochaenacea, *Xylophaga* (?) and Lyonsiidae.

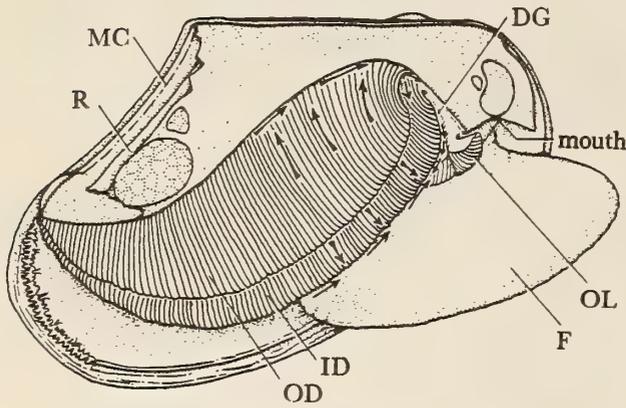
Category III is one in which the ventral tips of the anterior filaments of the inner demibranch are not inserted into a distal oral groove, although the antero-ventral margin of the inner demibranch may be fused to the inner palp lamella as in *Mactra dolabrata* REEVE, 1854 (*ex* DESHAYES MS) and *Macoma nasuta* (CONRAD, 1837). Exemplary types are *Kellia laperosii* (DESHAYES, 1839)



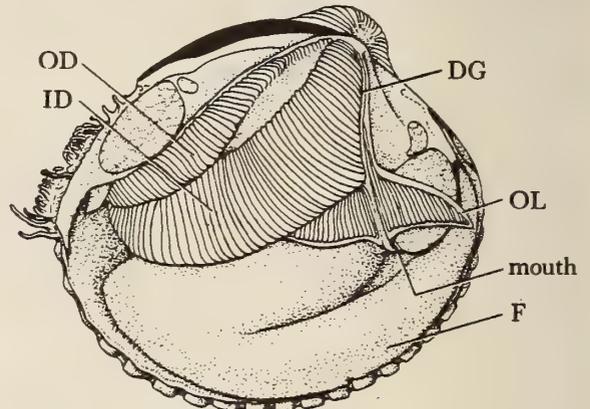
a - *Acila castrensis* (HINDS, 1843)



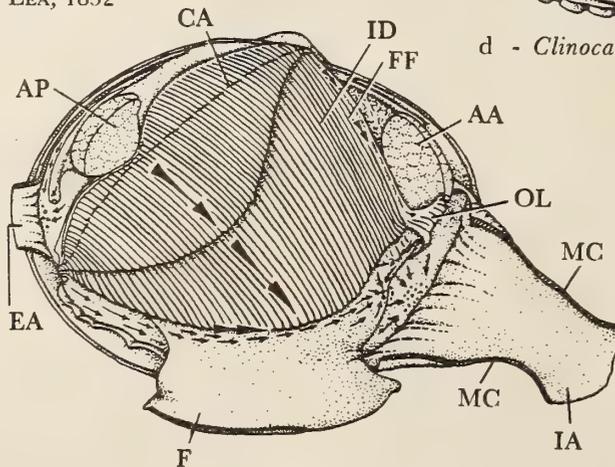
b - *Acila castrensis*: Association of ctenidium and palp



c - *Anodonta californiensis* LEA, 1852



d - *Clinocardium nuttallii* (CONRAD, 1837)



e - *Kellia laperousii* (DESHAYES, 1839)

Figure 1: Major associations of ctenidium and labial palp exemplified by *Acila* and *Anodonta* (Category I), *Clinocardium* (Category II), and *Kellia* (Category III).

up to 1 cm long (Erycinacea, Fig. 1) and *Isognomon costellatus* (CONRAD, 1837) (Pteriacea, Fig. 2). Category III characterizes the following groups: Arcacea, Pteriacea, Pectinacea, Anomiacea, and Ostreacea, as well as Crassatellidae, Sphaeriacea, Cyamacea, Lucinacea, Erycinacea, some Veneridae (*Transenella*, *Psephidia*, *Gemma*), Cooperellidae, Mactracea (in part), Tellinacea (except *Semele*), Solenacea, Saxicavacea, Myacea, Adesmacea (*Xylophaga* possibly excepted), Pandoracea (except Lyonsiidae), and Clavagellacea (in PURCHON, 1956, p. 46). The Septibranchia seem also to be in this category.

Extensive subdivision and some intergradation of these categories exist, but these will not be discussed here.

Discussion

Of the three structural levels observed in the association of ctenidia and labial palps Category I is interpreted as the most primitive, for it occurs in the widely divergent Protobranchia (Nuculidae and Nuculanidae) and in some filibranch and eulamellibranch representatives. Among the latter are the Astartidae, generally thought to be relatively conservative descendants of the group from

That there are thought to be at least two major lines of evolution in the Bivalvia was discussed in a previous summary of the literature (STASEK, 1961, p. 535). One line stemmed from the Late Cambrian ctenodonts and led to the Nuculidae, Nuculanidae, Mallettiidae, and, possibly, to the Septibranchia (PURCHON, 1963). A separate line arose from the Ordovician actinodont group, which, after early adaptive radiation, apparently gave rise to all lamellibranchiate bivalves. There are no known intermediate fossil forms demonstrating the evolution of the actinodonts from the ctenodonts, and comparative anatomical studies of their respective descendants often have demonstrated what are taken to be great differences, for example between the ctenidia (PELSENEER, 1911), the digestive systems (OWEN, 1959; PURCHON, 1963), and the dentition (COX, 1959). However, the similarities between the association of gill and palp in many of their descendants, together with the widespread presence of eu-latero-frontal cilia on the ctenidial filaments (ATKINS, 1938), is evidence establishing some close affinity between these otherwise little related and remote fossil groups.

Collation of stomach types, as described by PURCHON

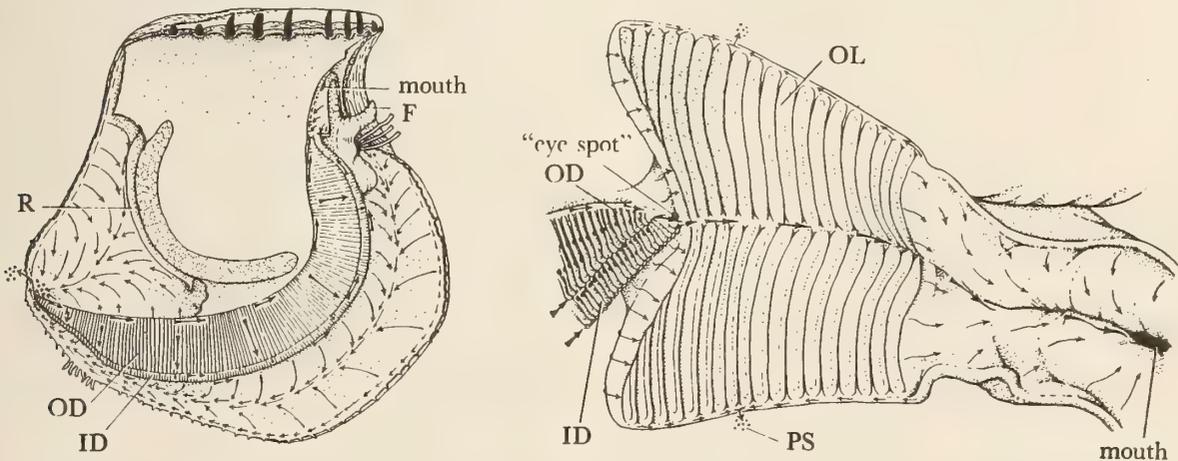


Figure 2: *Isognomon costellatus*. Mantle cavity and detail of association of ctenidium and labial palp (Category III).

which the remainder of the Heterodonta arose (NICOL, 1955). That the most primitive existing condition is one in which the filter-feeding mechanism is highly developed may be emphasized. As evidenced by the apparently minor rôle the association plays in gathering food in the Nuculidae, a rôle one can hardly envisage as having evolved if the palp proboscides were pre-existing, efficient food collectors, the presence of such similar associations in diverse and otherwise primitive families indicates that one is not here dealing with an instance of convergent evolution.

(see PURCHON, 1963) and the association of ctenidium and palp indicates that while near the bases of the major evolutionary lines the association of gill and palp has been more conservative than the structure of the stomach, the reverse is true at other levels. For example, in astartids and carditids, both with stomachs of type 4, adults of the former comprise a subgroup in Category I while adults of the Carditidae are in Category II.

Category II seems to have come about by fusion of the ctenidial filaments to the distal oral groove. All known

species in this category are culamellibranchiate. If one assumes that an association of this kind arose prior to the dichotomy leading to the development of a stomach of Type 5 from one of Type 4 (see PURCHON, 1963), the appearance of an association of Category II in groups with either type of stomach is not surprising. All groups in this category are concluded to be diversely descended from some large, common-ancestral group and to be more primitive with respect to the association of ctenidium and palp than their relatives in Category III.

Groups in which the adults are characterized by an association of Category III appear to have arisen either from groups in Category II by prolongation of the period of growth of the anterior-most filaments of the inner demibranch (e.g. *Kellia*) or from groups in Category I through extreme inhibition of the development of the anterior regions of the body (e.g. *Chlamys*, see STASEK,

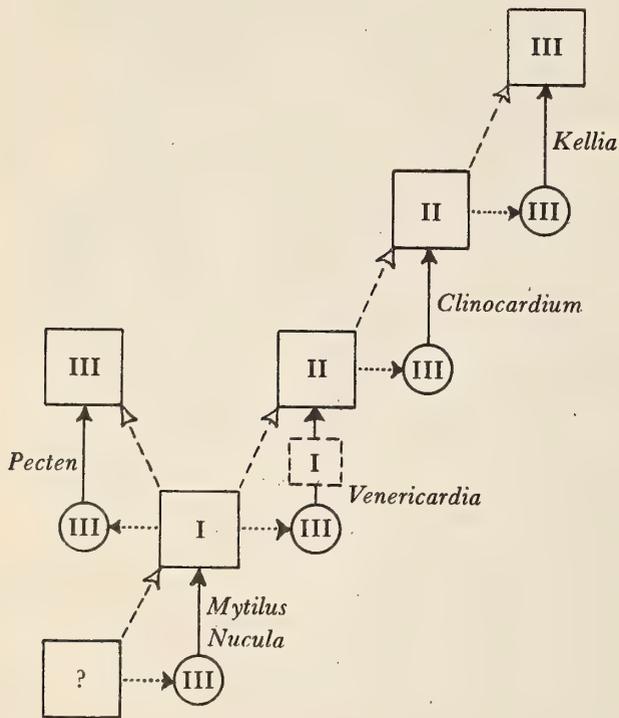


Figure 3: Phylogenetic and ontogenetic progression (dashed and solid arrows respectively) of the associations of the ctenidium and labial palp. Condition in adults indicated by large squares; probable condition in post-larval stages by circles; transient condition by small square. Dotted arrows suggest that evolutionary changes occur by modification of ontogenies through successive generations. No actual phylogenetic relationship of exemplary genera is meant to be implied.

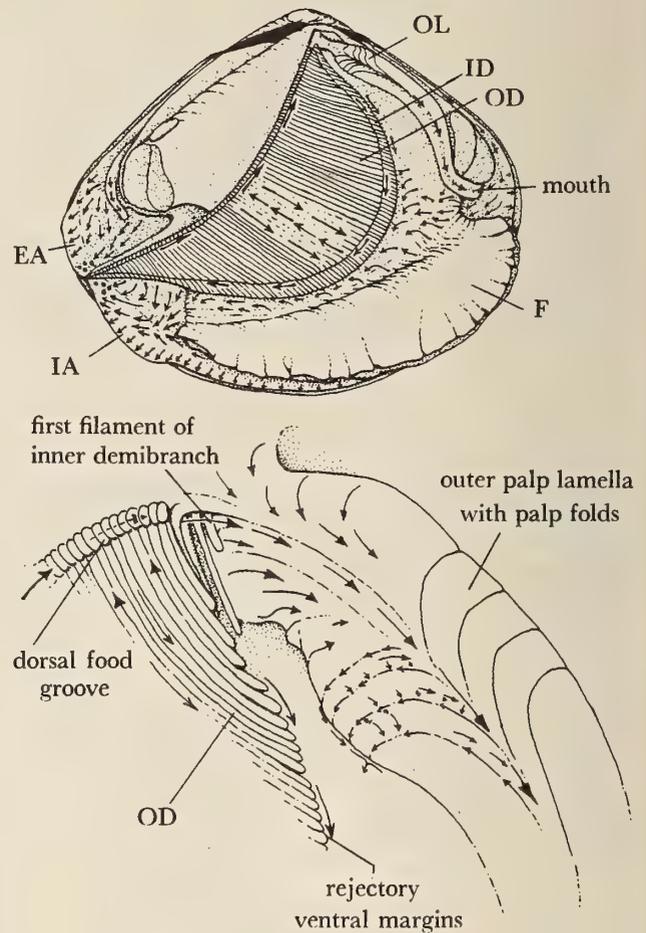


Figure 4: *Glycymeris subobsoleta*. Mantle cavity and detail of association of ctenidium and labial palp.

- Explanation of abbreviations used for all text figures:
- A - anus
 - AA - anterior adductor
 - AP - posterior adductor
 - CA - ctenidial axis
 - DG - distal oral groove
 - F - foot
 - IA - inhalant aperture
 - IL - inner palp lamella
 - Ma - mantle
 - OD - outer demibranch
 - OL - outer palp lamella
 - OL-t - outer palp lamella turned back
 - PO - palp pouch
 - PS - pseudofeces
 - S - suspensory membrane of palp
 - C - ctenidium
 - CL - cleft in foot
 - EA - exhalant aperture
 - FF - first ctenidial filament
 - K - keel of foot
 - MC - mantle cut
 - PR - palp proboscis
 - R - rectum

1963). Taxa in Category III are not necessarily related, there having been several convergent evolutionary trends. Probable phylogenetic progression of the relation of gill and palp is illustrated by dashed arrows in figure 3.

While Category III appears to be the most modified in terms of phylogeny, it seems to be the association first appearing in the ontogeny of every species for which suitable information exists. Kinds of ontogenetic progression are shown by unbroken arrows in figure 3. Wherever an association of Category III is encountered in the adult, evolutionary trends towards juvenilization are concluded to be the cause. Juvenilization may occur either through relatively unmodified prolongation of growth of the early post-larval arrangement, affecting many other organs as well (e. g. in the Erycinacea and the Lucinidae, see STASEK, 1963), or through extreme relative retardation of the formation of a distal oral groove (e. g. in the Ptericea and Pectinacea). Relative retardation, which involves the whole of the anterior regions of the body and mantle/shell (STASEK, 1963), may be lesser, as in the Mytilacea (Category I), or greater, as in *Isognomon*, and generally results in a derived condition in which both inner and outer demibranchs are embraced by the palp. Also, the ctenidial axis empties very near the juncture of the two palp lamellae (Fig. 2). The view that this is a derived condition is contrary to general belief. For example, YONGE (1939, p. 134) considered it to be an intermediate stage in the evolution of the Eulamellibranchia. Notwithstanding the very few exceptions, such as large *Mya arenaria*, the normal and primitive condition in isomyarian Bivalvia is one in which only the inner demibranch is embraced by the palp lamellae, the axis of the ctenidium passing obliquely to, and not nearly parallel with the antero-posterior axis of the body (compare figs. 1 and 2). The scheme envisaged by previous investigators may have been influenced by the prevalent concepts of PELSENEER (1911, p. 123) who mistakenly considered the Mytilidae to have given rise to all the Eulamellibranchia.

The situation seen in extreme anisomyarian families such as the Isognomonidae (Fig. 2) also characterizes the Arcacea (Fig. 4). The anatomical arrangement in the former is clearly allied with relative inhibition of growth of the anterior regions, a process leading to a heteromyarian or monomyarian condition. The very similar association of ctenidium and palp in the nearly isomyarian Arcacea, for example *Glycymeris*, is surprising, especially since neontologists usually regard that genus as an "unmodified equilateral isomyarian" (YONGE, 1962, p. 451). The probable truth of the matter emerges when the fossil record is taken into account. In a revealing paper, NICOL (1950) concluded that the Glycymeridae were derived from the Cucullaeidae (probably *Idonearca*) during Late Jurassic times. The Cucullaeidae are inequilateral and

somewhat heteromyarian. That family and the Arcidae seem to have arisen as separate stocks from the complex arcacean genus *Parallelodon* (ARKELL, 1930), the Cucullaeidae sometimes being regarded as members of the Parallelodontidae (REINHART, 1935, p. 8; DECHASEAUX, 1952, p. 270). The Parallelodontidae were probably descendants of the Ordovician actinodonts, a group showing remarkable variation in form (cf. DOUVILLÉ, 1912). Some, such as *Actinodonta acuta*, were isomyarian while others, such as *A. obliqua* and *Cyrtodonta declivis*, were heteromyarians. It was in the cyrtodont type that ARKELL (1930) and NEWELL (1954) perceived the origin of the Arcacea. If this is true, Recent Arcacea had heteromyarian ancestors in which both demibranchs were probably embraced by the palp lamellae. Through time, there seems to have been an equalization of growth rates of anterior and posterior regions of the body and mantle/shell resulting in the Glycymeridae, a secondarily derived isomyarian and equilateral type, but one in which the probably ancient association of ctenidium and palp has been retained. This process has actually carried *Glycymeris* beyond an isomyarian state to one in which the anterior adductor is somewhat larger than the posterior (ABBOTT, 1954, p. 348). Conditions in the Arcacea thus provide an example in which adaptations of the ancestors partially restricted the further evolution of their phylogenetic offspring.

Conclusion

Associations of ctenidium and palp in existing species may be correlated with time of appearance of higher taxa in the fossil record to result in a scheme illustrating the probable temporal interconnections of the three major categories (Fig. 5). Correlation with other organ systems has allowed subdivision within groups with similar ctenidium-palp associations. Basic assumptions have been that categories I and II each arose only once and that any of the taxa named have, since their appearance, retained the general original character of the association. Minor alterations have occurred but have not been discussed. A third assumption has been that all extinct and as yet unstudied existing species have been or will be characterized by one of the three major categories described. Comparative use of further characters would aid in separating groups parallel or convergent in the few features used and in bringing together groups believed on other grounds to be closely related (i. e. the Lucinidae and Dipodontidae, the Lyonsiidae and Pandoridae, etc.). Thus, too few anatomical systems have been employed in figure 5 to justify a claim that all levels of the "tree" validly depict close taxonomic relationship. I concur with RIDWOOD (1903) that in Recent species correlation of several organ systems will provide a more reasonable understanding than now exists of the past history and

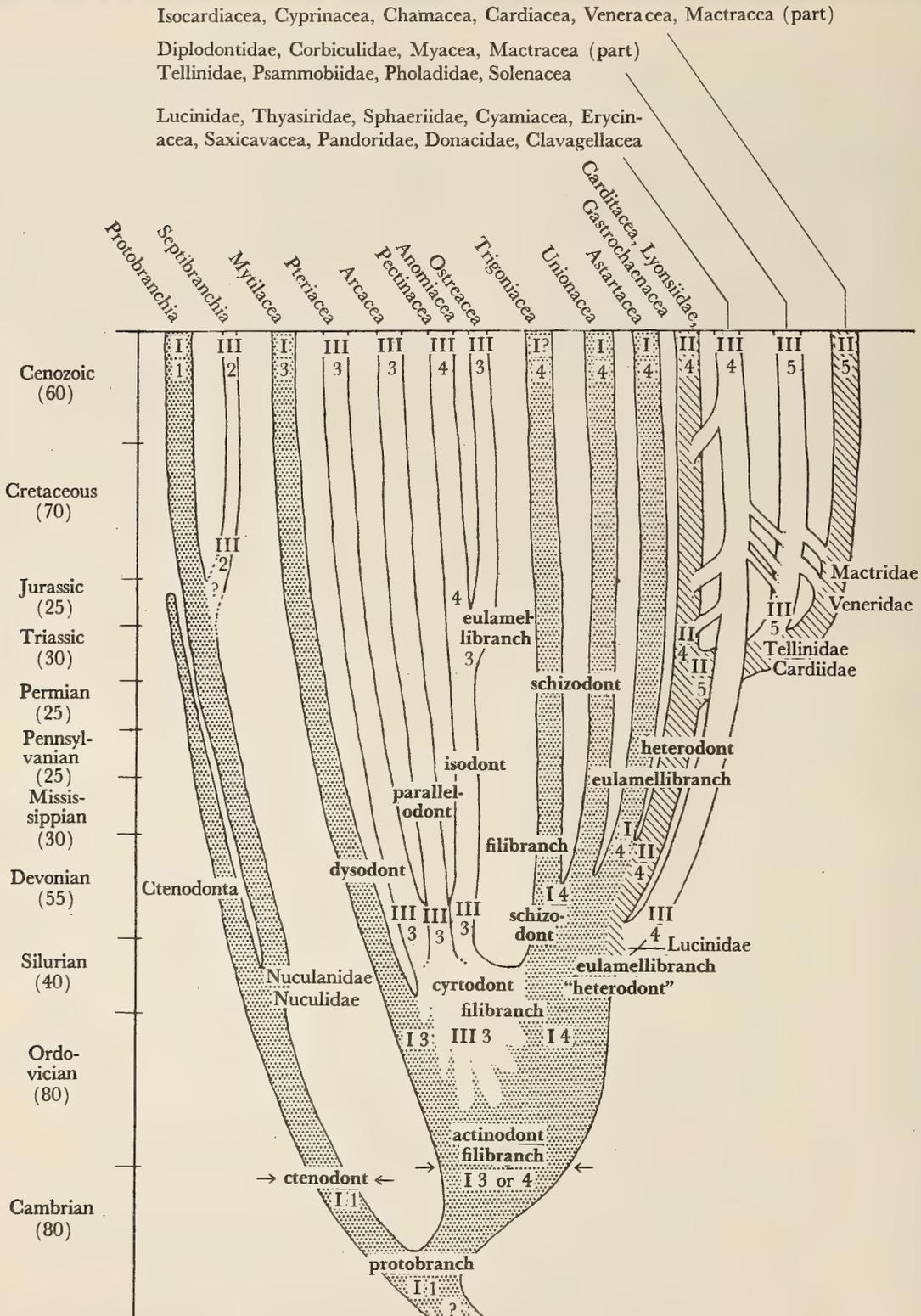


Figure 5: Tentative phylogenetic tree of the Bivalvia as obtained through correlation of the fossil record (data mainly from DECHASEAUX, 1952), the association of ctenidium and palp (Roman numerals), stomach type (Arabic numerals), dentition, and gill type. Possible interconnections of the three major associations of ctenidium and palp are indicated by stippling (Category I), cross-hatching (Category II), and blank spaces (Category III). Arrows suggest first appearance of major lines in fossil record. Duration of geological divisions is in millions of years (NICOL *et al.*, 1959, p. 353).

interrelations of the Bivalvia. There is no need to believe that changes in one system will have been simultaneous with those in other systems; the persisting search for a single most "objective" taxobasis has been, is, and probably will continue to be futile. MARCH (1912), PURCHON (1958), and COX (1960) have outlined and discussed previous attempts at phylogenetic classification in the Bivalvia.

ACKNOWLEDGMENTS

The observations upon which this synopsis is based were made at several institutions. To their staffs I extend my thanks for help and courtesy given in diverse ways. These institutions are the Department of Zoology, University of California, Berkeley; the Hawaii Marine Laboratory, University of Hawaii, Honolulu; the Friday Harbor Laboratories, University of Washington, Seattle; the Eniwetok Marine Biological Laboratories, University of Hawaii, Marshall Islands; the Stazione Zoologica, Naples, Italy; and the Department of Oceanography, Scripps Institution, La Jolla, California.

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I wish also to acknowledge the generosity of the Cocos Foundation, Inc., which paid excess cost of publication of a recent paper (STASEK, 1963). Unfortunately, notification of their grant arrived too late to include notice of it in that paper.

LITERATURE CITED

- ABBOTT, R. TUCKER
1954. American seashells. Princeton, New Jersey. D. van Nostrand Co., Inc.; xiv + 541 pp.; 100 figs.; 40 pls.
- ARKELL, W. J.
1930. The generic position and phylogeny of some Jurassic Arcidae. *Geol. Mag.* **67**: 297 - 310, 337 - 352.
- ATKINS, DAPHNE
1938. Laterofrontal cilia of the gill filaments and their phylogenetic value. *Quart. Journ. Micro. Sci.* **80**: 345 - 436.
- COX, L. R.
1959. The geological history of the Protobranchia and the dual origin of taxodont Lamellibranchia. *Proc. Malacol. Soc. London*, **33** (5): 200 - 209.
1960. Thoughts on the classification of the Bivalvia. *Proc. Malacol. Soc. London*, **34** (2): 60 - 88.
- DECHASEAUX, COLETTE
1952. Classe des Lamellibranches in *Traité de Paléontologie*, 2ième éd. Jean Piveteau. Paris. Masson et Cie.; 790 pp., illus.
- DOUVILÉ, H.
1912. Classification des Lamellibranches. *Bull. Soc. Géol. Fr.* (4) **12**: 419 - 467.
- KELLOGG, J. L.
1915. Ciliary mechanisms of lamellibranchs with descriptions of anatomy. *Journ. Morphol.* **26**: 625 - 701.
- MARCH, M. COLLEY
1912. A discussion of the general classification of the Pelecypoda. *Ann. Mag. Nat. Hist.* (8) **10**: 91 - 116.
- NEWELL, NORMAN D.
1954. Status of invertebrate paleontology, 1953. V. Mollusca: Pelecypoda. *Bull. Mus. Comp. Zool. Harvard* **112**: 161 - 172.
- NICOL, DAVID
1950. Origin of the pelecypod family Glycymeridae. *Journ. Paleont.* **24** (1): 89 - 98.
1955. Morphology of *Astartella*, a primitive heterodont pelecypod. *Journ. Paleont.* **29** (1): 155 - 158.
- NICOL, DAVID, *et al.*
1959. Paleontologic record of the primary differentiation in some major invertebrate groups. *Journ. Wash. Acad. Sci.* **49** (10): 351 - 366.
- OWEN, GARETH
1959. The ligament and digestive system in the taxodont bivalves. *Proc. Malacol. Soc. London*, **33** (5): 215 - 223.
- PELSENER, PAUL
1891. Contribution à l'étude des lamellibranches. *Arch. Biol.* **11**: 147 - 312.
1911. Les lamellibranches de l'expédition du Siboga. Partie anatomique. *Siboga-Exped.* **53 a**: 1 - 125.
- PURCHON, R. DENISON
1956. A note on the biology of *Brechites penis* (L.) (Lamellibranchia). *Journ. Linn. Soc. Zool.* **53**: 43 - 54.
1958. Phylogeny in the Lamellibranchia. *Proc. Cent. Bicent. Congr. Biol. Singapore 1958*: 69 - 82.
1963. Phylogenetic classification of the Bivalvia, with special reference to the Septibranchia. *Proc. Malacol. Soc. London* **35**: 71 - 80.
- REINHART, P. W.
1935. Classification of the pelecypod family Arcidae. *Bull. Mus. Roy. Hist. Nat. Brussels* **11** (13): 1 - 68.
- RIDEWOOD, W. G.
1903. On the structure of the gills of the Lamellibranchia. *Phil. Trans. (B)* **195**: 147 - 248.
- STASEK, CHARLES R.
1961. The ciliation and function of the labial palps of *Acila castrensis* (Protobranchia, Nuculidae) . . . *Proc. Zool. Soc. London*, **137** (4): 511 - 538.
1963. Orientation and form in the bivalved Mollusca. *Journ. Morph.* **112** (3): 195 - 214.
- YONGE, CHARLES MAURICE
1939. The protobranchiate Mollusca: a functional interpretation of their structure and evolution. *Phil. Trans. (B)* **230**: 79 - 147.
1962. On *Etheria elliptica* Lam. and the course of evolution, including assumption of monomyarianism, in the family Etheriidae (Bivalvia: Unionacea). *Phil. Trans. (B)* **244**: 423 to 458.

Morphology and Mode of Burrowing in *Siliqua patula* and *Solen rosaceus* (Mollusca: Bivalvia)

BY

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(6 Text figures)

The mode of burrowing in the Bivalvia is intimately associated with body and shell form and is also closely connected with aspects of the animal's mode of life. The morphology of many bivalves has been described, and papers by DREW (1899, 1907), JORDAN (1915), WEYMOUTH (1920), FRAENKEL (1927), STOLL (1938), QUAYLE (1949), ALLEN (1958), HOLM (1961), and ANSELL (1962) have stressed burrowing activity in the class. There is, however, little mentioned in the literature concerning the interrelationship of burrowing and morphology. This paper attempts to relate and compare these two aspects in *Solen rosaceus* CARPENTER, 1865 and *Siliqua patula* (DIXON, 1788).

Mode of Life

Solen rosaceus CARPENTER, 1865

This organism lives in a permanent burrow in which it can freely move up and down. It is found in mud flats in sheltered bays and ranges from Santa Barbara, California to Baja California, México. Its occurrence in these areas has been described by WEYMOUTH (1920) and RICKETTS (1952).

The burrowing behavior of certain species of *Solen* has been described by FRAENKEL (1927). The behavior of *Solen rosaceus* conforms to the general pattern outlined by him and is described below.

When the animal is unearthed and placed on the substratum, it first extends the foot out of the shell in an anterior direction (fig. 1a). The muscles at the tip of the foot contract causing the very tip to extend and become pointed. The foot is pushed into the soil by simultaneously extending the tip and forcing the bulk of the foot out from between the valves. This action continues until the foot is well below the soil, where it swells at the end and forms a bulbous anchor (fig. 1b). Next, the pedal retractor muscles contract, and the shell

portion of the animal is drawn into the sand toward the anchor (fig. 1c). The sequence of movements is repeated until the animal reaches the required depth in the substratum.

Movement within the burrow was not seen in *Solen rosaceus*, but it is probably the same as I have observed for *Solen sicarius* GOULD, 1846. This movement differs slightly from the movements made when the organism is re-burying itself. First, the valves open widely and grip the sides of the burrow wall (fig. 2a). Then the foot is extended to a length that is approximately equal to the shell length. Next, the tip of the foot swells and grips the burrow wall, the valves close, and the pedal retractors contract, causing the shell to move toward the anchored foot (fig. 2b).

Siliqua patula (DIXON, 1788)

This clam occurs on exposed sandy beaches, often in the zone of heavy surf, as described by WEYMOUTH (1920), QUAYLE (1941), and YONGE (1952). It ranges from the Aleutian Islands to Pismo Beach, California (BURCH, 1944). The animal lives vertically in the sand and forms no permanent burrow as do its related bay-living forms *Solen rosaceus* and *S. sicarius*. The valves are thin, but a highly developed burrowing ability keeps it from being easily unearthed and damaged by wave action. A small specimen (about 3 cm long) can rebury itself in 7 seconds, while a larger individual (about 8 cm long) takes 27 seconds. This is relatively faster than a 7 cm long *S. sicarius* which takes from 45 seconds to 11 minutes for the same operation.

Although YONGE (1952) stated that the foot of *Siliqua* functions in the same manner as that described by FRAENKEL (1927) for other genera of the Solenidae, several differences have been noted. (Compare with the description of burrowing for *Solen rosaceus*.) When burrowing, *Siliqua* first extends its foot antero-ventrally (fig.

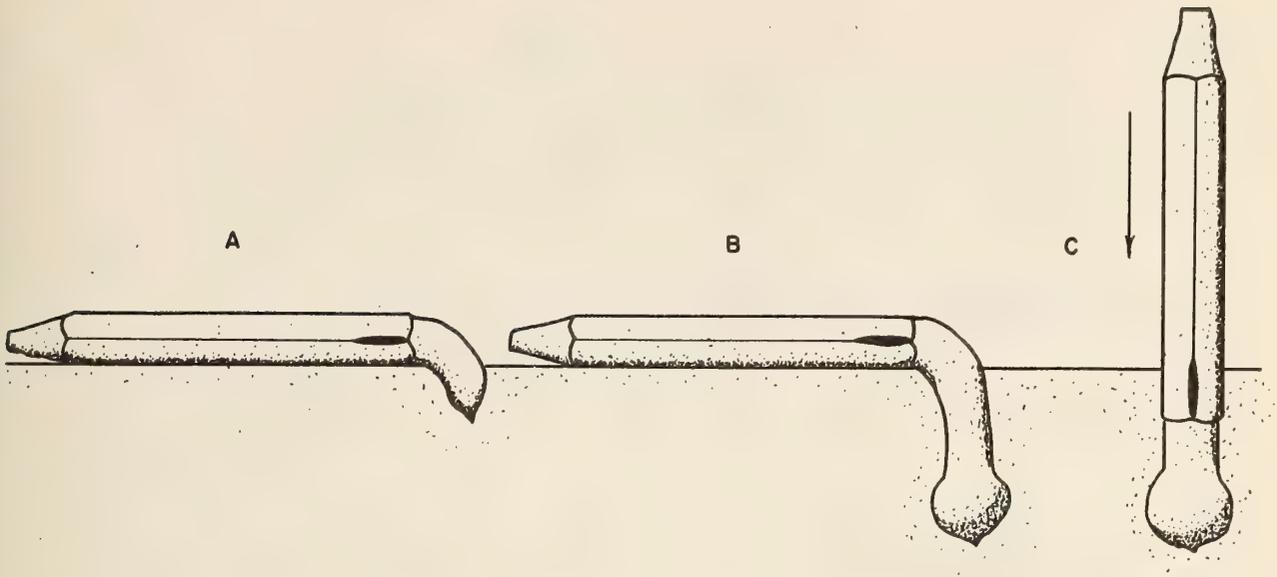


Figure 1: *Solen rosaceus*. Burrowing movements. Description in text.

3a). The foot is then thrust rapidly in an anterior direction (arrow in fig. 3a) where it is driven, pointed end first, into the sand. This one rapid motion places the foot anterior to the valves and well into the soil. The fringed margin of the foot then expands and opens out to form

an anchor in much the same way as YONGE (1959) described for *Pharus legumen* (LINNAEUS, 1758). The pedal retractor muscles then contract and pull the shell toward the anchored foot (fig. 3b). A few repetitions of this sequence are enough to bury the organism.

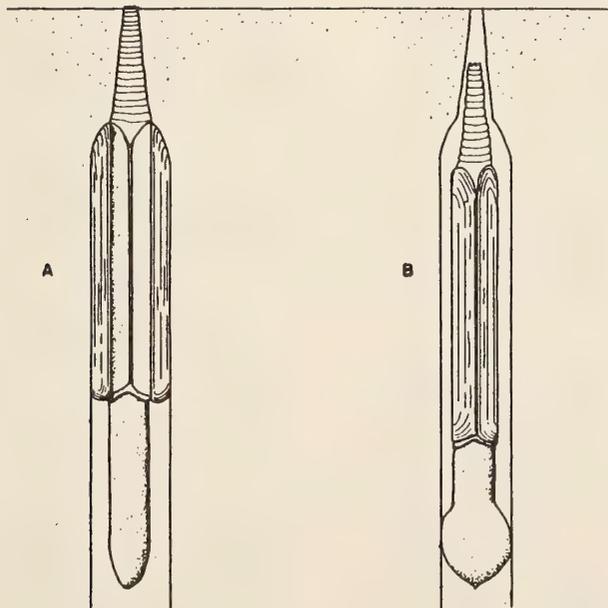


Figure 2: *Solen rosaceus*. Movement within the burrow. Description in text.

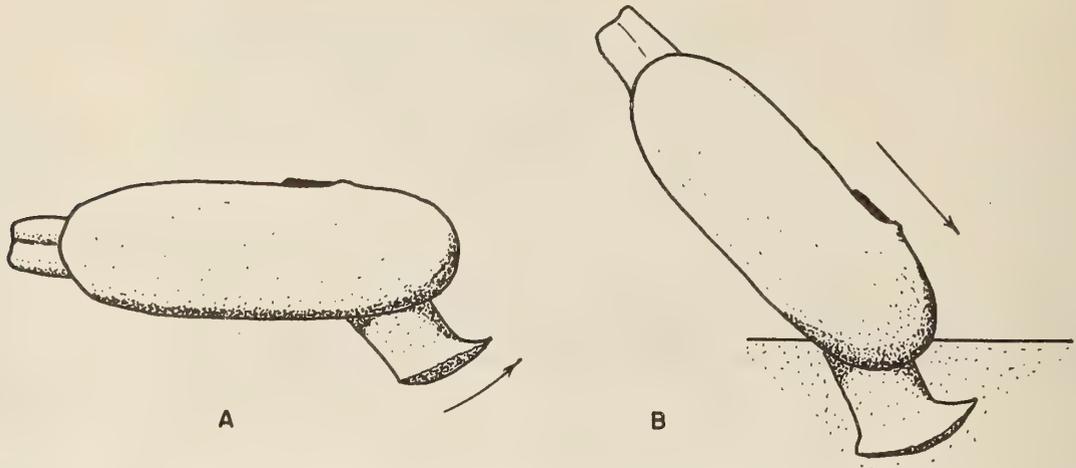


Figure 3: *Siliqua patula*. Burrowing movements. Description in text.

Morphology

Solen rosaceus CARPENTER, 1865

This animal attains a maximum length of about 6 cm (WEYMOUTH, 1920). The shell is elongated, being approximately 5 times as long as wide.

A dissection is shown in figure 4, the right valve and mantle lobe having been removed. The siphons are fused for their entire length and are about $\frac{3}{4}$ as long as the length of the shell. The inhalant siphon is protected by a ring of tentacles, while the exhalant siphon is partially enclosed by a circular flap. The siphons are annulated for their entire length, and each annulation has a fully developed set of siphonal tentacles. When the siphons are autotomized, which readily occurs when they are irritated or when the water becomes stale, a new set of tentacles is already formed and apparently ready to function.

The mantle overlying the labial palps and portions of the demibranchs is very thin, but in all other places it is muscular and thick. The edges of the mantle lobes are fused along the entire ventral margin. This restricts the pedal opening to the anterior end.

The foot is long and cylindrical, resembling a finger. It is highly mobile and can be extended to a length approximately equal to that of the shell.

The adductor muscles are inserted along the dorsal portion of the shell. The anterior adductor is large and elongated antero-posteriorly. This is not merely a posterior extension of the muscle, but as shown by OWEN (1959), the primitive dorso-ventral axis is now oriented antero-posteriorly. The posterior adductor is smaller than the anterior and its long axis runs obliquely to the long axis of the shell.

There are three attachments of the pedal muscles on each valve (fig. 4). The large anterior protractor muscle (AP) is located near the posterior margin of the anterior adductor. The fibers of this muscle extend posteriorly around the digestive diverticula and radiate out onto the foot. The anterior retractor muscle (AR) is located posterior to the anterior protractor muscle. The strands of this muscle run postero-ventrally where, near the foot, they split into two bundles and fan out onto the foot. The division of this muscle resembles the condition described for *Pharus legumen* by YONGE (1959). A small muscle (PM) is inserted onto the shell adjacent to the region of mantle thickening. The fibers pass postero-ventrally, under the anterior protractor fibers, and radiate out onto the foot. The posterior retractor muscle (PR) is the largest of the pedal muscles, being about ten times greater in area at the site of attachment than is the anterior retractor muscle. It is inserted onto the shell adjacent to and on the antero-dorsal side of the posterior adductor muscle.

Siliqua patula (DIXON, 1788)

This species attains a maximum length of about 15 cm (WEYMOUTH, 1920). The shell is elongated, being just over 2.5 times as long as high.

A dissection is shown in figure 5, the right valve having been removed. The siphons are rather short and are fused except at the very tip. Both the inhalant and exhalant openings are ringed by tentacles. The tentacles around the exhalant opening are long and thin; those surrounding the inhalant opening are short and frilled.

The mantle is fused ventrally from the siphons to a point on the margin just posterior to the umbo. Here the muscular mantle fusion is terminated and the fourth pal-

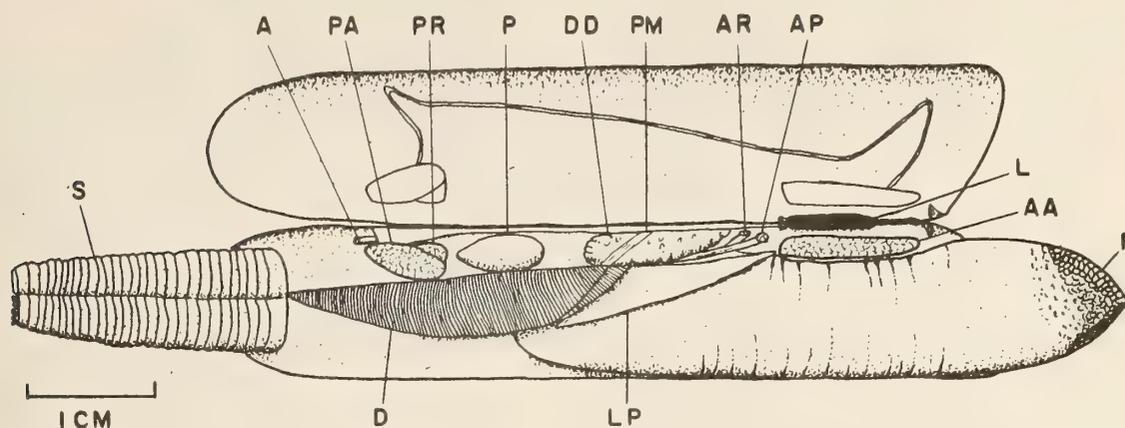


Figure 4: *Solen rosaceus*. Mantle cavity viewed from the right side.

A: anus; AA: anterior adductor; AP: anterior pedal protractor; AR: anterior pedal retractor; D: demibranchs
DD: digestive diverticula; F: foot; L: ligament; LP: labial palps; P: pericardium; PA: posterior adductor muscle;
PM: pedal muscle; PR: posterior pedal retractor; S: siphons.

lial aperture begins. The presence of this opening was first noted by OWEN (1959). He also recognized that cuticular fusion was present anterior to the fourth pallial aperture; but, because he had only preserved material with which to work, he concluded that the cuticular fusion extended to the anterior margin and that the pedal opening was there confined. The actual extent of cuticular fusion (fig. 5, CF) is very short, being about 0.8 cm in an animal 8 cm long. Thus the pedal opening is not restricted to the anterior end, but extends on the ventral edge of the shell from a point below the umbo to the anterior adductor. The entire mantle edges are fringed with tentacles, which are smaller on the postero-dorsal margin and at the site of the pedal openings.

The foot is large and oval in cross-section. Its end is pointed, and a frilled muscular fold extends from the tip to the heel.

The adductor muscles are placed near the dorsal margin. The anterior adductor is larger than the posterior, and, in both, the long axis is oriented obliquely to the long axis of the valves.

There are five insertions of the pedal muscles on each valve (fig. 5). The anterior protractor muscle (AP_1) is attached adjacent to the anterior adductor on its dorsal margin. This muscle runs postero-ventrally where it meets the muscles emanating from a second anterior attachment of the protractor muscle (AP_2). The muscles from the two insertions coalesce and continue around the digestive diverticula to the site of posterior attachment of this muscle (PP). This is in contrast to the

findings of OWEN (1959) where he stated that there is no trace of the posterior protractor muscle in this genus. The fibers emanating from the posterior protractor muscle run ventrally onto the foot and also to the anterior margins of the pericardium. The anterior retractor muscle is attached high on the shell just beneath and slightly posterior to the umbo (AR). The strands of this muscle pass ventrally to the foot. The posterior retractor muscle is large and is located adjacent to the posterior adductor on its anterior side (PR). This muscle arrangement is different than that depicted by YONGE (1952) in his study of this species, for he illustrated only two pedal insertions on each valve. He located the anterior retractor insertion posterior to the anterior adductor muscle and stated that the muscle is inserted on a rib which extends antero-ventrally from the umbo. He concluded that this rib is functionally associated with the anterior retractor muscle and serves as a strengthening ridge. This rib probably does serve to strengthen the shell, but it is not associated with the anterior retractor muscle, as this muscle is attached under the umbo.

Figure 6 shows the change in form that occurs during the ontogeny of *Siliqua patula*. Until the animal is 2.5 cm long (fig. 6a) the outline of the shell is rather oval. After attaining this size, the elongated form, characteristic of the large *Siliqua*, is assumed. YONGE (1952, 1962) stated that a byssus is present in the young post-larval stages, and this probably corresponds to the oval stage shown in figure 6a. When the byssus is lost, the animal assumes its elongated form (fig. 6b) which seems to be highly adapt-

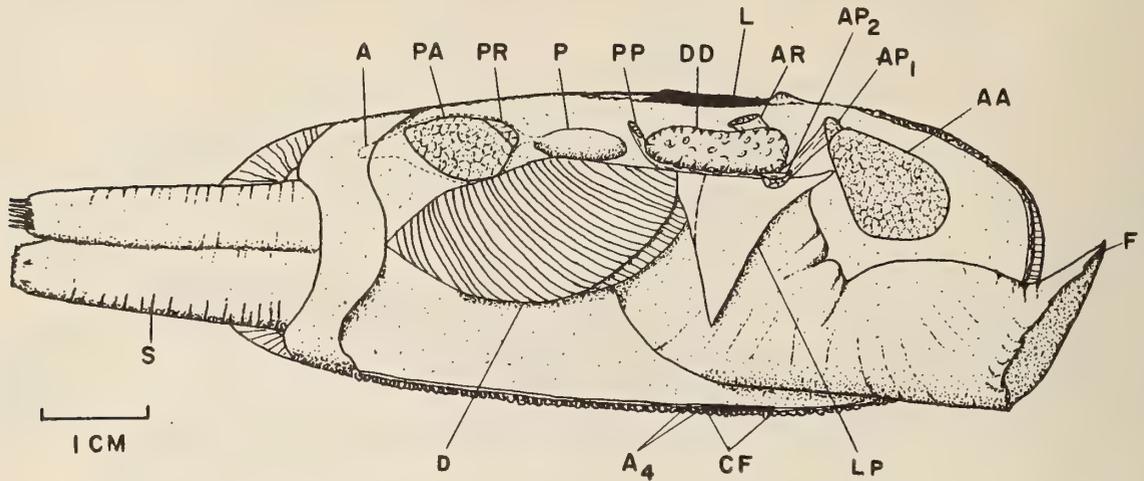


Figure 5: *Siliqua patula*. Organs seen from the right side after removal of the right valve. A₄: fourth pallial aperture; AP₁: anterior pedal protractor; AP₂: second attachment of the anterior pedal protractor; CF: cuticular fusion; PP: posterior pedal protractor. Other symbols as in Figure 4.

ed for the rapid vertical type of burrowing characteristic of the species. A phenomenon somewhat similar to this appears to occur in *Venerupis pullastra* (MONTAGU) as outlined by QUAYLE (1952), who suggested that the rapid adoption of an oval form in the early post-larval stage is advantageous for burrowing in this species.

Interrelation of Form and Burrowing

The morphology and mode of burrowing of *Siliqua patula* and *Solen rosaceus* show many differences. Both are elongated antero-posteriorly, but this condition is more pronounced in *Solen rosaceus*, the length-height ratio being approximately $2\frac{1}{2} : 1$ in large specimens of *Siliqua patula* and $5 : 1$ in *Solen rosaceus*. The elongated form is an adaptation for vertical burrowing (YONGE, 1952).

In *Solen rosaceus*, foot movements are confined to an antero-posterior direction. Hence the long axis of the shell

is parallel to the burrowing direction, which decreases resistance to the substratum. Corresponding to the movement of the foot is the growth of the anterior adductor, which extends mainly along the antero-posterior axis of the body. This muscle is located adjacent to the ligament, and, because it is in such close proximity to the ligament, a large muscle would probably be more efficient in counteracting the opening moment of the ligament. The only direction in which this muscle can grow without hampering the movements of the foot is in the antero-posterior plane.

This muscle is elongated in many species of the genus *Solen*, and it reaches its maximum extent in the genus *Ensis*. There is a correlation between the posterior extension of this muscle and the reduction in relative size of the posterior adductor muscle. In *Solen rosaceus* and *S. sicarius*, the anterior adductor is elongated so that its posterior end lies opposite the posterior end of the liga-

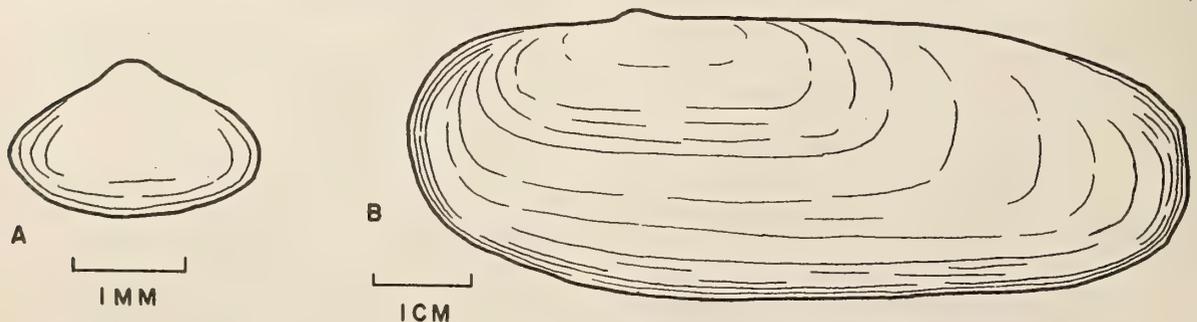


Figure 6: *Siliqua patula*. Change in form during ontogeny. Figure 6 A - a specimen 2.5 mm long; Figure 6 B - a specimen 80 mm long. Anterior end to the left.

ment (fig. 4). In these forms, the anterior adductor is about 1.5 times as large as the posterior. In species of *Ensis*, there is considerable growth of the anterior adductor posterior to the ligament and the posterior adductor is correspondingly quite small, the anterior adductor being at least three times as large as the posterior. As the growth of the anterior adductor moves posterior to the ligament, which occurs in those forms with an extreme reduction of depth, the closing moment of this muscle will tend to close the shell along its entire length; and the function of the posterior adductor is taken over, to a degree, by the anterior. OWEN (1959) stated that the reduction of the relative size of the posterior adductor is due to the extension pallial attachment in the posterior embayment of the mantle. This also appears to be a contributing factor. There are several changes in morphology that accompany the increasing loss of depth in these organisms. These include the greater growth of the anterior adductor posterior to the ligament, the reduction in size of the posterior adductor, and the occurrence of pallial attachment posterior to the posterior adductor.

In *Siliqua patula*, the foot movements differ from *Solen rosaceus*. In *Siliqua*, the foot is extended antero-ventrally, not directly anteriorly. The foot is then thrust anteriorly as shown by the arrow in figure 3a. Corresponding to the pedal movements is the placement of the anterior adductor. The direction of growth of this muscle is not confined to the antero-posterior plane, but the main growth axis is in an antero-ventral direction.

The posterior retractor muscle is larger than the anterior in both species. The size and placement of the posterior retractor is closely associated with the functioning of the foot during burrowing. When the foot is anchored, there is approximately a straight line between the anchor and the site of attachment of this muscle. When the muscle contracts, it exerts its pull nearly parallel to the long axis of the shell. This tends to keep the movements of the foot parallel to the long axis of the valve and insures that the long axis of the shell is not exposed to the resistance of the substratum.

In both species, the ventral mantle is fused. In *Solen rosaceus*, the fusion extends from the ventral edge of the inhalant siphon to a point on the ventral margin immediately under the umbo; that is, the mantle is fused along the entire ventral margin. The fused mantle aids in keeping foreign particles out of the mantle cavity and also, coupled with the rigid housing provided by the teeth and ligament articulation, confines the foot movements to the antero-posterior axis. In *Siliqua patula*, the fusion of the ventral mantle is not so extensive. Muscular cross fusion extends from the siphons to a point on the

ventral margin just posterior to the umbo (fig. 5), i. e. about two thirds of the ventral margin are fused. Tissue fusion is terminated at the fourth pallial aperture, but there is limited cuticular fusion anterior to this. The pedal gape is not confined to the anterior end as mentioned by OWEN (1959), but foot movements do occur in the antero-ventral direction as mentioned by YONGE (1952).

The shape of the foot in the two species is quite dissimilar. In *Solen rosaceus* it is finger-like, whereas in *Siliqua patula* it is cylindrical, but pointed on its dorsal and flattened on its anterior extremities (compare figs. 4 and 5). In *Siliqua patula*, a frilled muscular flap extends from the tip to the heel of the foot. This flap opens out and inflates to form an anchor, whereas in *Solen rosaceus* the end of the foot merely swells to form an anchor, there being no muscular flap present. The foot of *Solen rosaceus* is well suited for movement within a permanent burrow (fig. 2). *Siliqua patula*, which lives in the surf zone, constructs no such burrow, and its pointed foot is well adapted to the rapid type of digging characteristic of this animal. *Solen rosaceus* requires many probes of the foot to bury it sufficiently to form an anchor, whereas in *Siliqua patula* one quick thrust of the foot usually places it well into the substratum. This is an important factor contributing to *Siliqua patula*'s rapid burrowing and is a useful adaptation for maintaining positional stability in its surf habitat.

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LITERATURE CITED

- ALLEN, JOHN A.
1958. On the basic form and adaptations to habitat in the Lucinacea (Eulamellibranchia). Phil. Trans. Roy. Soc. London, Ser. B, 241: 421-481.
- ANSELL, ALAN D.
1962. Observations on burrowing in the Veneridae (Eulamellibranchia). Biol. Bull. 123: 521-530.
- BURCH, JOHN Q. (Editor)
1944 to 1946. Distributional list of the west American marine mollusks from San Diego, California to the Polar Sea. Conch. Club S. Calif., minutes; 2 parts; pagination by issue; pls. 1-3.

- DREW, GILMAN A.
 1899. Some observations on the habits, anatomy and embryology of members of the Protobranchia. *Anat. Anz.* 15: 493 to 519.
 1907. The habits and movements of the razor-shell clam, *Ensis directus*. *Biol. Bull.* 12: 127 - 140.
- FRAENKEL, G. V.
 1927. Die Grabbewegung der Soleniden. *Zeitschr. vergl. Physiol.* 6: 167 - 220.
- HOLME, NORMAN A.
 1961. Notes on the mode of life of the Tellinidae (Lamelli-branchia). *Journ. Mar. Biol. Assoc. U. K.* 41: 699 - 703.
- JORDAN, H.
 1915. Über die Art, wie *Macra inflata* sich in den Sand einwühlt. *Zool. Physiol.* 35: 289 - 300.
- OWEN, GARETH
 1959. Observations on the Solenacea with reasons for excluding the family Glaucomyidae. *Phil. Trans. Roy. Soc. London, Ser. B.* 242: 59 - 97.
- QUAYLE, D. B.
 1941. The edible molluscs of British Columbia. *Rep. Brit. Columbia Fish Dept.*, 1940: 75 - 87.
1952. The rate of growth of *Venerupis pullastra* (MONTAGU) at Millport, Scotland. *Proc. Roy. Soc. Edinb., Ser. B.* 64: 384 - 406.
1949. Movements in *Venerupis (Paphia) pullastra* (MONTAGU). *Proc. Malacol. Soc. London*, 28: 31 - 37.
- RICKETTS, EDWARD F., & JACK CALVIN
 1952. Between Pacific tides. Stanford Univ. Press, v - xiii; 3 - 502; 46 pls. Stanford, Calif.
- STOLL, EVA
 1938. Sur le mode de locomotion de quelques mollusques marins. *Trav. Stat. Biol. Roscoff.* 16: 5 - 29.
- WEYMOUTH, FRANK W.
 1920. The edible clams, mussels and scallops of California. *Calif. Fish & Game Bull.* 4: 77 pp.
- YONGE, CHARLES MAURICE
 1952. Studies on Pacific coast mollusks. IV. Observation on *Siliqua patula* DIXON and on the evolution within the Solenidae. *Univ. Calif. Publ. Zool.* 55: 421 - 438.
 1959. On the structure, biology and systematic position of *Pharus legumen* (L.). *Journ. Mar. Biol. Assoc. U. K.* 38: 277 - 290.
 1962. On the primitive significance of the byssus in the Bivalvia and its effect in evolution. *Journ. Mar. Biol. Assoc. U. K.* 42: 113 - 125.

Lumpers and Splitters

BY

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Part I: The Generic Division of Cowries

LINNAEUS (1758) has established the genus *Cypraea* for 42 so-called species, arranged in several groups according to superficial characters of the shells. The first monographer of the cowries, J. E. GRAY (1824 to 1828), has described 116 living and fossil species as members of this one genus also. The subsequent well known iconographies on living cowries, edited chiefly for use of collectors by SOWERBY (1832 to 1837), KIENER (1843 to 1845), REEVE (1845 to 1846), SOWERBY (1870), WEINKAUFF (1881), and ROBERTS (1885) also united all cowries denticulate on both lips of the shell to the genus *Cypraea*, including two species of Sulcocypraeinae (*Cypraea adamsonii* SOWERBY and *C. pustulata* LAMARCK, which anatomically approach the Amphiperatidae more than the Cypraeidae) and many species of Triviidae, which family has been removed from the Cypraeacea (= Cypraeidae and Am-

phiperatidae, both with a triangular osphradium) to the Lamellariacea (see Zoological Record 92 for 1953, p. 82). In the same way, HIDALGO (1906 to 1907) enumerated in his monograph 222 living species of "*Cypraea*" (Triviidae etc. included) in alphabetical order so that comparison of allied species becomes difficult. Even I myself lumped all cowries (Triviidae excluded) when beginning my special studies (SCHILDER 1922, 1924a).

Sixty years before, however, TROSCHEL (1863) examining the radula, divided the family "Cypraeacea" into 8 genera and subgenera, well separating them from the family "Triviacea" (genera *Erato* and *Trivia*); the Amphiperatidae had been split into several genera a long time before. Another step in splitting up the cowries has been made by JOUSSEAUME (1884) considering both living and fossil species: this "auteur mal inspiré" (CROSSE) has distinguished 36 coordinate genera, many of which

represent phylogenetic units (2 genera of these 36 contain Sulcocypracinae only, and 5 genera belong to Triviidae).

The further progress in splitting the Linnaean genus *Cypraea* is due to scientists who tried to elucidate the evolution of the phylogenetic tree of cowries: they were chiefly paleontologists, as COSSMANN (1903) and VREDEBURG (1920), whereas my own attempts (SCHILDER 1924b, 1927, 1932, 1936, 1939, 1941) relied on paleontology, zoogeography and anatomy one third each. If the subfamilies, genera, and subgenera established for the various branches, twigs, and twiglets of the most probably correct phylogenetic tree (SCHILDER, 1936, pls. 11-12; 1939, pls. 7-8) become adopted in papers treating the living offspring only (SCHILDER, 1938-1939), they often look rather arbitrary, as the fossil connecting links are omitted; whereas arrangements of cowries according to shell features of living species only (IREDALE, 1939, STEADMAN & COTTON 1946, ALLAN 1956) are condemned to be artificial from the beginning.

Therefore the phylogenetic splitting of the Linnaean genus *Cypraea* accomplished in my papers has been adopted by two eminent malacologists in their handbooks of mollusca: The anatomist THIELE (1929, p. 273-277) has divided the living true cowries (called "Cypracinae") into 6 genera, 16 subgenera, and 14 named sections which should be called infragenera according to the use of the terms infraclassis and infraordo by American mammalogists (ROMER, SIMPSON; see SCHILDER, 1955). The paleontologist WENZ (1941, p. 965-1000) has fully accepted my system of that time (SCHILDER, 1939) dividing the true cowries (Cypraeidae) into 45 genera and 23 subgenera, 29 and 20 of which include still living species.

The present status of genera and subgenera of fossil and living true cowries (Cypraeidae) published in my last catalogue (SCHILDER, 1941, p. 65-68) and kept up to date in manuscript additions enumerates 72 valid names with an additional 46 superfluous ones which must be carried along as synonyms: the latter refer to type species differing only conchologically from anatomically closely allied species (e. g. *Prolyncina*), or even to races (*Albacypraea*) or individual varieties (*Nivigena*) of species placed in other genera, or to juvenile specimens (*Ipserronea*).

On the other hand, KAY (1957, 1960) has emphasized the view that the anatomy of all living cowrie species is similar to such a degree that they should be united once more to the Linnaean genus *Cypraea*. Nevertheless, KAY divided the monster genus (now comprising almost a thousand living and fossil named species and subspecies) into several unnamed "groups" which are characterized by the female sexual organs and by the features of the radula, and which mostly correspond to named taxa in my system. This simplification in nomenclature seems to

have been welcomed mostly by conchologists collecting all families of mollusks, as it permits avoiding an excessive burden to their memory by a plethora of generic names.

* * *

"Doubtless the truth lies somewhere in between the viewpoints of the lumpers and splitters." This verdict given by HELFER (1946) seems to be a reasonable solution of our problem. "The genus, to be a convenient category in taxonomy, must in general be neither too large nor too small" (THORPE, 1940, p. 357), and "genera with 500, 1,000, or even 2,000 species are very inconvenient, and any excuse for breaking them up into smaller units should be good enough" (MAYR, 1947, p. 283). For "a genus is a systematic unit including one species or a group of species of presumably common phylogenetic origin, separated by a decided gap from other similar groups. It is to be postulated for practical reasons, that the size of the gap shall be in inverse ratio to the size of the group" (MAYR, *ibid.*). To the size of the gap we may add the length of time during which a branch or twig of the palaeontological tree has developed by itself parallel to other units.

In my last catalogue (SCHILDER, 1941, p. 65) I have divided the family Cypraeidae (= true cowries) into 4 subfamilies, 11 tribes, 22 sections, 46 genera, and 72 subgenera (undivided genera included). If one adds the cowries discovered since 1941, they contain 405 species and 503 named subspecies of various degrees (individual "varieties" and synonyms excluded), 170 and 159 of which, respectively, are still living: therefore the average ratio is about one subgeneric unit to more than a dozen of named geographical or stratigraphical races.

Surely the number of 908 species and subspecies is too large for uniting them into one genus only, even if many so-called subspecies should be rejected (see the second part of this paper): KAY's proposition evidently does not conform to MAYR's thesis quoted above. We must not only consider the number of cowries involved in the phylogenetic tree, but also the geological age of its various branches and the final differentiation of its numerous twiglets. The Cypraeidae began at least in Lower Cretaceous times as Cypraeorbiniae, which comprise the most primitive groups characterized by the concave but smooth fossula: they developed several side-branches, as the curious *Mandolina* and the giant *Gisortia*. These all became extinct in Tertiary times and very few species of other groups survived. Their immediate descendants since Tertiary times are the Cypraeinae, our well known large cowries with ribbed fossula, developed to the terminal genera *Luria* and *Lyncina* that are anatomically widely separated each from the other. More modern descendants of Cypraeorbiniae are the Cypraeovulinae; the allies of *Zonaria* flourished in the Neogene of the West (Atlantic

and West coast of America) while the allies of *Erronea* up to the highly specialised *Palmadusta* and *Bistolida* developed in the East (Indopacific), including the genera *Notocypraea* (said to have no veliger-larval stage: GRIFFITHS, 1962), *Umbilia* (males much larger than females, in contrast to all other groups), and *Cypraeovula* in its less warm Southern border areas. The Cypraeovulinae were accompanied by the Nariinae with laterally pitted shells and the median of the radula adorned by a subtending bract; the phylogenetic position of the modern *Pustularia* is less evident. The anatomical differences generally agree with this paleontological radiation (SCHILDER, 1936), as recently has been confirmed by KAY (1960) as well as by statistical differences in the radula and penis detected by ourselves (SCHILDER, 1963a, b).

The species composing such an old ramifying family cannot be encompassed by a single generic name. Besides, there is a very serious formal argument against KAY's extreme view: if one unites all living and fossil cowries into one genus *Cypraea*, it becomes necessary to rename several species for secondary homonymy (e. g. *Pustularia mariae* SCHILDER, 1927 vs. *Cypraea camelopardalis mariae* SCHILDER, 1924), and this new name is to be adopted in all papers calling all cowries "*Cypraea*", while the former name (*mariae*) has to be maintained in all papers in which the writer still prefers to split the monster genus (International Rules of Zoological Nomenclature 1958, article 57 and 59 b, c), as nobody can hinder the specialist to use well established generic names for natural groups of species according to his conscience. Therefore there will be not only a continuous double way of generic classification, but also of naming several species.

On the other hand, for approaching the views of lumpers, it seems advisable to reduce the ranks of the taxonomic units by one degree, as THIELE did in 1929; then, my catalogue (SCHILDER, 1941) would contain 4 subfamilies, 11 infra-families (see above), 22 genera and 46 subgenera, which numbers seem to be a tolerable taxonomic differentiation adequate to the age and to the multiformity of the family Cypraeidae; as the taxon infragenus is not as yet acknowledged by the International Rules of Zoological Nomenclature, the 72 still more minor taxa should be rather suppressed than treated as real subgenera in strictly taxonomic papers, but they could also be maintained as unofficial "infragenera" to replace the awkward term "group of . . . (name of typical species)" in phylogenetic studies in which exact brachiology seems to be more essential than correctness in nomenclature. Surely such a taxonomic reduction of ranks cannot be carried through without careful examination of each case by the specialist. In the Recent fauna, many monotypic groups will be maintained, as their unique living members are relics of groups of species flourishing in Terti-

ary times, e. g. *Siphocypraea mus* (LINNAEUS), *Propustularia surinamensis* (PERRY), *Umbilia hesitata* IREDALE.

There is still another alternative solution of the problem "lumpers or splitters", which has been adopted partially in applied and in taxonomic entomology: a double nomenclature for general collectors and for advanced cypraeologists! That would mean the use of one generic name *Cypraea* (embracing all species of Cypraeidae) by collectors possessing a few cowries only as Linnaeus did two centuries ago; and the use of plenty of different names for subfamilies, infra-families, genera, subgenera and infragenera for specialists who try to unravel the intricate evolution of cowries, examining anatomy as well as fossil ancestors, and who prefer to designate a natural unit of species by calling it by a well established generic name. However, I do not recommend this splitting of methods in using generic names, but prefer a moderate splitting in taxonomy.

Part II: Species and Subspecies in Cowries

I often have been asked by conchologists: what is the total number of living cowrie species? Is, for example, *Erosaria eburnea* (BARNES, 1824) a "good" species, or should it be classified as a subspecies of *E. miliaris* (GMELIN, 1791) only?

The answer depends on the definition of the category "species" used in zoological taxonomy. According to RENSCH (1929, p. 4) and SCHILDER (1952, p. 11) a species comprises all specimens the cross breeding of which produces an unlimited sequence of fertile generations showing no traces of degeneration; this definition includes also specimens living in different regions so that their crossing is possible in experiments only, but never in nature.

As this biological test, however, hardly can be practiced in marine mollusks, it must be provisionally replaced by a morphological test: "groups of similar shells should be treated as different species if they can be separated by at least one well-recognizable character showing no intermediates even in extreme specimens" (SCHILDER, 1960, p. 8), young and pathological specimens excluded. As the ranges of variation in the radula and in the color of the animal evidently are great, but hardly known as yet, this morphological test mostly will be confined to conchological characters. Rare hybrids between well established species, as between *Cypraea tigris* LINNAEUS, 1758 and *C. pantherina* SOLANDER, 1786 (SCHILDER, 1962) should be neglected, as they are comparable to those between the horse and the ass.

There is a rather traditional custom in classifying some cowries as true species or as varieties only. So, for instance, *Erosaria lamarckii* (GRAY, 1825) and *E. miliaris* (GMEL-

IN, 1791) have been treated as distinct species by most writers, whereas *Erronea adusta* (LAMARCK, 1810) has been regarded only as a "variety" of *E. onyx* (LINNAEUS, 1758), though the morphological differences are analogous in both pairs (consisting chiefly in constant differences in color) and the geographical distribution is similar (both pairs inhabit different regions touching each other in the Malacca Strait). Certainly this tradition should be infringed by treating both pairs in the same way: degrading "*lamarckii*" to subspecific rank or raising "*adusta*" to specific rank.

There are lumpers and splitters also on the species level. So, for instance, ROBERTS (1885, p. 179) thought *Monetaria moneta* (LINNAEUS, 1758) and *M. annulus* (LINNAEUS, 1758) to be possibly varieties of one species *moneta*, probably according to the development of the yellow ring, but other characters of the shell (SCHILDER, 1938, p. 140) allow separating all specimens, including young ones, and the hind corners of the median of the radula are consistently different; and RANSON (1954) proposed to unite *Pustularia globulus* (LINNAEUS, 1758), *P. bistrinotata* SCHILDER & SCHILDER, 1937, and *P. cicercula* (LINNAEUS, 1758) as one species only, though not too worn shells easily can be separated (SCHILDER, 1938, p. 125). On the other hand, CROSSE (1869) has treated all New Caledonian rostrate monstrosities as distinct species, and IREDALE established many species which proved to be single aberrant specimens of well known cowries (GRIFFITHS, 1961).

The intraspecific taxa have been discussed by SCHILDER (1960). The specimens of each species can be arranged and named according to various view-points: from morphologically and geographically well separable races down to single pathological abnormalities, not fully developed stages, and even artificial deformations. There are also other lumpers and splitters: many writers prefer to call cowries only by specific names, and reject quoting racial or varietal names, whereas other authors try to designate exactly, by particular intraspecific names, the region from which each cowrie came (SCHILDER, 1938) or the special features of each aberrant shell (ROCHEBRUNE, 1884; MELVILL, 1888).

The only taxonomic units worth to be named as subspecies (according to the International Rules of Zoological Nomenclature) are genetically isolated groups of populations, constituting geographical (in fossils also stratigraphical) "races" which live in different parts (or

geological times) of the whole area (or epoch) occupied by the species. The nomenclatorial status of "local varieties" characterizing one population only which may have spread to a very restricted area (e. g. *Palmadusta saulae siasiensis* (CATE, 1960)) is doubtful, as are evidently "ecological varieties" living in different environments (e. g. surf and lagoons) or in different depths of the sea and showing parallel characters in many species; the SCHILDERS (1938, p. 122) proposed to call these ecological variations by abbreviated homonymous terms instead of by different names. Individual aberrations, such as extremes in size, shape, or color surely do not deserve intraspecific names, nor do pathological deformations and juvenile stages.

* * *

Even if we adopt the subspecies concept restricting "races" to inhabitants of large areas in which the species are supposed to be rather uniform genetically, the matter is far from being settled and the diversity of facts justifies the controversy between lumpers and splitters.

According to the evolution of species and of their distribution we can distinguish nine degrees in development of morphological differences of single specimens and of whole populations (i. e. cowries inhabiting the same restricted place), and nine degrees in geographical separation of the areas inhabited by two allied morphological groups, as follows (Table 1):

Table 1

Nine Classes of Morphological Distinction

Class	Single Specimens	Populations
9	by several essential characters	always well
8	by few always superficial	always well
7	with few exceptions	always well
6	mostly	always well
5	often	always well
4	extremes only well	mostly
3	extremes hardly	often
2	not	hardly
1	not	not

recognizable

recognizable

Nine Classes of Geographical Separation

Class	term (SCHILDER, 1952, p. 21; 1956, p. 57	the border lines of two compared inhabited areas are
9	allopatric discon- tinuous	sejunct
8		disjunct
7		exclusive
6		indistinct
5	sympatric continuous	transgressive
4		perruptive
3		objective
2		dispersed
1		identical

practically identical

Now we can characterize each pair of allied cowries by two figures, the first of which designates its morphological affinity, the second indicates the mutual position of the areas of distribution; this plotting of morphology against zoogeography shows a continuous flow of transitions. The geographical class 9 may be illustrated by one example of each morphological class (Table 2):

Table 2

genus	typical species	class	related cowrie
<i>Bernaya</i>	<i>fultoni</i> (SOWERBY, 1903)	99	<i>teulerei</i> (CAZENAVETTE, 1846)
<i>Zonaria</i>	<i>annettae</i> (DALL, 1909)	89	<i>aequinoctialis</i> SCHILDER, 1933
<i>Umbilia</i>	<i>hesitata</i> IREDALE, 1916	79	<i>armeniaca</i> (VERCO, 1912)
<i>Erronea</i>	<i>pulchella</i> (SWAINSON, 1823)	69	<i>pericalles</i> (MELVILL & STANDEN, 1904)
<i>Mauritia</i>	<i>scurra</i> (GMELIN, 1791)	59	<i>indica</i> (GMELIN, 1791)
<i>Erosaria</i>	<i>poraria</i> (LINNAEUS, 1758)	49	<i>scarabaeus</i> (BORY, 1827)
<i>Erronea</i>	<i>adusta</i> (LAMARCK, 1810)	39	<i>melanesiae</i> SCHILDER, 1937
<i>Pustularia</i>	<i>childreni</i> (GRAY, 1825)	29	<i>lemurica</i> SCHILDER, 1938
<i>Mauritia</i>	<i>depressa</i> (GRAY, 1824)	19	<i>dispersa</i> SCHILDER, 1939

Lumpers will probably acknowledge as true species the pair 99, and the pairs 89 to 69 as subspecies at most, while 59 to 19 may be cancelled as synonyms. Splitters, on the other hand, may call 99 to 79 species, and 69 to 19 subspecies, pointing to the fact that the two members of each pair are widely separated by habitable, but uninhabited areas so that some genetic difference must have been developed during the long time of genetic separation, even if, as in 29 and 19,

clear morphological differences did not become apparent as yet.

In SCHILDER, 1960, p. 9 I proposed to divide the category "subspecies" into three degrees: semispecies, subspecies, and infraspecies. If we adopt this classification, the classes 99-89 will become species, 79-69 semispecies, 59-39 subspecies, and 29-19 infraspecies, which have been designated by figures, capitals, small letters, and exponent figures respectively in SCHILDER, 1941, p.

59. If, however, we limit ourselves to the two only terms accepted by the International Rules of Zoological Nomenclature, the classes 99 to 69 should be called species, and 59 to 19 subspecies.

Some more typical examples of pairs characterized by different morphological and geographical separation may be added (Table 3):

Table 3

genus	typical species	class	related cowrie
<i>Luria</i>	<i>lurida</i> (LINNAEUS, 1758)	98	<i>pulchra</i> (GRAY, 1824)
<i>Zonaria</i>	<i>annettae</i> (DALL, 1909)	97	<i>spadicea</i> (SWAINSON, 1823)
<i>Luria</i>	<i>isabella</i> (LINNAEUS, 1758)	94	<i>pulchra</i> (GRAY, 1824)
<i>Blasicrura</i>	<i>quadrimaculata</i> (GRAY, 1824)	91	<i>pallidula</i> (GASKOIN, 1849)
<i>Luria</i>	<i>isabella</i> (LINNAEUS, 1758)	88	<i>mexicana</i> (STEARNS, 1893)
<i>Palmadusta</i>	<i>lutea</i> (GRONOVIVS, 1781)	87	<i>humphreysii</i> (GRAY, 1825)
<i>Ovatipsa</i>	<i>chinensis</i> (GMELIN, 1791)	83	<i>tortirostris</i> (SOWERBY, 1906)
<i>Mauritia</i>	<i>arabica</i> (LINNAEUS, 1758)	76	<i>immanis</i> SCHILDER, 1939
<i>Cypraea</i>	<i>tigris</i> LINNAEUS, 1758	75	<i>pantherina</i> SOLANDER, 1786
<i>Talostolida</i>	<i>teres</i> (GMELIN, 1791)	72	<i>rashleighana</i> (MELVILL, 1888)
<i>Macrocypraea</i>	<i>cervus</i> (LINNAEUS, 1771)	68	<i>cervinetta</i> (KIENER, 1843)
<i>Erosaria</i>	<i>lamarckii</i> (GRAY, 1825)	66	<i>redimita</i> (MELVILL, 1888)
<i>Erosaria</i>	<i>helvola</i> (LINNAEUS, 1758)	56	<i>meridionalis</i> SCHILDER, 1938
<i>Mauritia</i>	<i>mappa</i> (LINNAEUS, 1758)	53	<i>montrouzieri</i> (DAUTZENBERG, 1903)
<i>Cypraea</i>	<i>tigris</i> LINNAEUS, 1758	47	<i>schilderiana</i> CATE, 1961
<i>Erosaria</i>	<i>caputserpentis</i> (LINNAEUS, 1758)	37	<i>caputophidii</i> SCHILDER, 1927
<i>Cypraea</i>	<i>tigris</i> LINNAEUS, 1758	26	<i>pardalis</i> SHAW, 1795
<i>Staphylaea</i>	<i>limacina</i> (LAMARCK, 1810)	17	<i>facifer</i> (IREDALE, 1935)
<i>Monetaria</i>	<i>moneta</i> (LINNAEUS, 1758)	42	<i>ethnographica</i> ROCHEBRUNE, 1884
<i>Luponia</i>	<i>edentula</i> (GRAY, 1825)	41	<i>alfredensis</i> SCHILDER, 1929
all species	females	31	males

These selected examples illustrate various degrees of relation, from well established species to hardly recognizable infraspecies; the pair *lamarckii* - *redimita* is a so-called "cline", as the transition from the East African *lamarckii* to the Bengalese *redimita* is gradual, but specimens coming from the border areas are quite different. However, class 53 and the three last lines of Table 3 must be excluded, as they indicate ecological varieties not worth to be named, nor is it the proper place of sexual differences.

* * *

The purpose of the present essay is not to solve the problem of "lumpers" versus "splitters" in the taxonomy of cowries, but to illustrate the difficulties opposing a satisfactory general solution.

LITERATURE CITED

ALLAN, JOYCE

1956. Cowry shells of world seas. Georgian House, Melbourne. i-x; pp. 1-170; pls. 1-15.

CATE, CRAWFORD NEILL

1960. A new subspecies of *Cypraea saulae* GASKOIN, 1843. The Veliger 3 (2): 34-37; plt. 5; 1 map; 1 table. (1 Oct. 1960)

COSSMANN, MAURICE

1903. Essais de paléonconchology comparée. (Paris) 5: 143 to 148; 3 pls.

CROSSE, H.

1869. Catalogue des *Cypraea* de la Nouvelle Calédonie. Journ. de Conchyl. 17: 36-50.

GRAY, JOHN EDWARD

1824. Monograph on the Cypraeidae, a family of testaceous mollusca. Zool. Journ. 1: 71-80; 137-152; 367-391; (1825:) 489-518; - (1827) 3: 363-371; (1828) 3: 567 to 576; - 4: 66-88.

GRIFFITHS, R. JOHN

1961. Iredale's Cypraeidae names. The Cowry 1 (2): 21-24.
1962. *Notocypraea* on eggs. The Cowry 1 (4): 64.

HELPER, J. R.

1946. Classification of Cypraeidae. Nautilus 60 (2): 49 to 53.

- HIDALGO, J. G.
1906. Monografía de las especies vivientes del género *Cypraea*. Mem. Acad. Cienc. Madrid, 25: 1-240; (1907) 241-588; I to XV.
- IREDALE, TOM
1939. Australian cowries: Part II. Austr. Zoolog. 9 (3): 297-322; 3 pls.
- JOUSSEAUME, F.
1884. Étude sur la famille Cypraeidae. Bull. Soc. Zool. France, 9: 81-100.
- KAY, ALISON
1957. The genus *Cypraea*. Nature 180: 1436-1437. (21 Dec. 1957)
1960. Generic division of the Cypraeinae. Proc. Malacol. Soc. London, 33 (6): 278-287; 8 text figs.; 1 table.
- KIENER, L. C.
1843. Species général et iconographie des coquilles vivantes: Genre Porcelaine. (Paris) 57 pls.; (1844): 1-32; (1845): 33-186.
- LINNAEUS, CAROLUS
1758. Systema naturae: 10th ed. (Holmiae). 1: 824 pp. (*Cypraea*: pp. 718-725).
- MAYR, ERNST
1947. Systematics and the origin of species. (New York) 334 pp.; 29 text figs.
- MELVILL, JAMES COSMO
1888. A survey of the genus *Cypraea* (LINN.). Mem. Manchester Lit. Phil. Soc. (4) 1 (5): 184-252; 2 pls.
- RANSON, GILBERT
1954. Note sur *Cypraea cicercula* LINNÉ 1758. Bull. Mus. Hist. Nat. Paris (2) 26: 612-619.
- REEVE, LOVELL AUGUSTUS
1845. Conchologia Iconica vol. 3: Monograph of the genus *Cypraea*. 16 pls: (1846:) 11 pls.
- RENSCH, BERNHARD
1929. Das Prinzip geographischer Rassenkreise und das Problem der Artbildung. (Berlin) 206 pp.; 27 text figs.
- ROBERTS, S. RAYMOND
1885. Monograph of the family Cypraeidae in: GEORGE W. TRYON, Manual of Conchology (Philadelphia) 7: 153-240; 23 pls.
- ROCHEBRUNE, ALPHONSE TRÉMEAU DE
1884. Monographie des formes appartenant au genre *Monetaria*. Bull. Soc. Malacol. France 1: 73-93; 2 pls.
- SCHILDER, FRANZ ALFRED
1922. Contributions to the knowledge of the genera *Cypraea* and *Trivia*. Proc. Malacol. Soc. London, 15 (2-3): 98 to 122.
1924 a. Kritisches Verzeichnis der rezenten und fossilen Cypraeen. Abhandl. Arch. Molluskenk. 1 (2): 192 pp.
1924 b. Systematischer Index der rezenten Cypraeidae. Arch. für Naturgesch. 90 (A. 4): 179-214; 1 diagram.
1927. Revision der Cypraeacea (Moll. Gastr.). Arch. für Naturgesch. 91 (for 1925) (A. 10): 171 pp.; 1 diagram
1932. Cypraeacea. In Fossilium Catalogus I: Animalia, part 55: 276 pp.
1936. Anatomical characters of the Cypraeacea which confirm the conchological classification. Proc. Malacol. Soc. London, 22 (2): 75-112; 2 pls.
1939. Die Genera der Cypraeacea. Arch. Molluskenk. 71 (5-6): 165-201; 2 pls.
1941. Verwandtschaft und Verbreitung der Cypraeacea. Arch. Molluskenk. 73 (2-3): 57-120; 2 pls.
1952. Einführung in die Biotaxonomie (Fomenkreislehre). Jena, 162 pp.: 121 maps.
1955. Ein Reformvorschlag zur Nomenklatur. Zool. Anz. 155 (7-8): 173-177.
1956. Lehrbuch der allgemeinen Zoogeographie. Jena, 150 pp.: 134 maps and diagrams.
1960. Intraspecific taxonomy. The Cowry 1 (1): 8-10.
1962. Hybrids between *Cypraea tigris* LINNAEUS, 1758 and *Cypraea pantherina* SOLANDER, 1786. The Veliger 5 (2): 83-87, 1 diagram. (1 Oct. 1962)
- SCHILDER, FRANZ ALFRED, & MARIA SCHILDER
1938. Prodrôme of a monograph on living Cypraeidae. Proc. Malacol. Soc. London, 23 (3): 119-180; (1939) 23 (4): 181-231; 1 text fig.; 9 maps.
1963 a. Statistical studies on cowrie radulae. The Veliger 5 (3): 106-111; 2 text figs.; 3 tables. (1 Jan. 1963)
- SCHILDER, FRANZ ALFRED, MARIA SCHILDER & GARFIELD HOUSTON
1963 b. The cowrie fauna of Penrith Island. The Veliger 6 (2): see this issue
- SOWERBY, GEORGE BRETtingham (second of name)
1832. Conchological illustrations (London) fig. 1-61; (1836) fig. 63-112; (1837) fig. 113-181.
1870. Thesaurus conchyliorum; 26-28: *Cypraea*. (London) 58 pp.; 37 pls.
- STEADMAN, W. R., & BERNARD C. COTTON
1946. A key to the classification of the cowries (Cypraeidae). Records South Austr. Mus. 8: 503-530; 6 pls.
- THIELE, JOHANNES
1929. Handbuch der systematischen Weichtierkunde. (Jena, Gustav Fischer, 1929-1935); 1154 pp.; 893 text figs.
- THORPE, W. H.
1940. Ecology and the future of systematics. in JULIAN HUXLEY, The new systematics. (Oxford): 341-364.
- TROSCHEL, FRANZ HERMANN
1863. Das Gebiss der Schnecken (Berlin)
- VREDENBURG, E.
1920. Classification of the recent and fossil Cypraeidae. Rec. Geol. Surv. India 51 (2): 65-152.
- WEINKAUFF, H. C.
1881. *Cypraea*. . . in MARTINI & CHEMNITZ: Systematisches Conchyliencabinet, 2nd ed. (Nürnberg) 5 (3): 166 pp.; 44 plates.
- WENZ, WILHELM
1941. In: SCHINDEWOLF, O. H., Handbuch der Paläozoologie, 6: Gastropoda (Berlin 1938-1944) xii + 1639 pp.; 4211 text figures.

NOTES & NEWS

Erroneous Records of Freshwater Clams (Sphaeriidae) from California

BY

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Three species of small freshwater clams of the genus *Pisidium* (Sphaeriidae) that have been recorded from California by Herrington (1962) are dubious members of the fauna. This note presents the relevant evidence.

"Hunt Lake, California," with no more precise data, is the locality assigned to the following species in the University of Michigan Museum of Zoology catalogue and on the labels. Most were supposedly collected by E. G. Berry on September 4, 1931. The label on lot 169705 reads 9-3-1931, but this may be an error. So far as one can tell from examination of adjacent entries in the catalogue no species except Sphaeriidae were recorded from the locality. In the following list museum catalogue numbers precede the names of the species as identified by H. B. Herrington. An asterisk (*) marks species unrepresented from California in the collection save for these lots from "Hunt Lake."

UMMZ 169703 *Pisidium nitidum* JENYNS
 UMMZ 169704 **Sphaerium nitidum* CLESSIN
 UMMZ 169705 *Pisidium nitidum* JENYNS
 UMMZ 169706 **Pisidium obtusale* form *rotundatum*
PRIME
 UMMZ 187570 *Pisidium variabile* PRIME
 UMMZ 188222 *Pisidium insigne* GABB
 UMMZ 189774 *Pisidium nitidum* JENYNS
 UMMZ 190162 **Pisidium ferrugineum* PRIME
 UMMZ 190509 *Pisidium casertanum* (POLI)
 UMMZ 192444 **Pisidium subtruncatum* MALM
 UMMZ 195780 **Pisidium lilljeborgi* CLESSIN

E. G. Berry (personal communication) was in southern California on September 4, 1931, and could have collected in the mountains of Riverside or San Diego

counties. He has no precise memory of the collection, no records, and his inquiry to the Department of Zoology, University of Utah, where duplicate specimens might have been preserved, yielded no information. No "Hunt Lake" was found in Riverside or San Diego counties on road maps of the Automobile Club of Southern California, or on topographic maps of the U. S. Geological Survey. The Sphaeriidae of this area are reasonably well known through collections by W. O. Gregg, especially, and include only *Pisidium casertanum* (POLI), *P. compressum* PRIME, and *P. insigne* GABB. Southern outliers of northern species in the higher mountains are certainly possible, as for example the isolated occurrence of *P. obtusale* in the San Bernardino Mountains, San Bernardino County (TAYLOR & HERRINGTON, 1962). Yet to find so many hitherto unrecorded species in this region is exceedingly improbable. A more likely explanation is that the specimens were mislabeled. The citations by HERRINGTON (1962: 40, 44, 49) of *P. ferrugineum*, *P. lilljeborgi*, and *P. subtruncatum* from California are hence almost certainly erroneous.

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LITERATURE CITED

- HERRINGTON, H. B.
 1962. A revision of the Sphaeriidae of North America (Mollusca: Pelecypoda). Michigan Univ. Mus. Zool. Misc. Publ. 118: 1-74; pls. 1-7.
- TAYLOR, DWIGHT W., & H. B. HERRINGTON
 1962. The fresh water clam *Pisidium tromperi* (HANNIBAL). The Veliger 4 (3): 129-131; pl. 28. (Jan. 1, 1962)

A. M. U.

Pacific Division

The meeting of the Pacific Division in 1964 will be held at Asilomar near Pacific Grove on the beautiful Monterey Peninsula from June 18 through June 21. Details will be announced at a later date. Dr MYRA KEEN of Stanford University will be Chairman; other officers of the organization, elected at the meeting in Santa Barbara this year are: EDWIN C. ALLISON, of San Diego State College, Vice-Chairman; Mrs. LUCILLE ZELLERS, El Cerrito, Secretary; Mrs. MAE DEAN RICHART, San Francisco, Treasurer.

Report of Non-Indigenous Marine Shells Collected in the State of Washington

BY

ELEANOR P. DUGGAN

4722 Baker Drive, Everett, Washington 98202

Small colorful specimens of *Nassarius* were found on the mud flats of Padilla Bay, Skagit County, Washington, on July 23, 1960. Mr. James H. McLean, graduate student at Stanford University, has identified these as *Nassarius fraterculus* (DUNKER, 1859), a species native to Japan. When or how this species was introduced into the Puget Sound area is unknown. It seems reasonable to assume that they were included with seed oysters from Japan before the Washington State Fisheries Department began the program of prior inspection of seed oyster shipments.

The collection was made in a portion of Padilla Bay near Bay View where there are no commercial oyster beds. *Ocenebra japonica* (DUNKER, 1860) and *Batillaria zonalis* (BRUGUIÈRE, 1792) were also present at this locality.

Nassarius fraterculus was also found in Samish Bay, Skagit County, Washington, in May 1963 in an area where *Crassostrea gigas* (THUNBERG, 1793) are grown commercially.

A new locality in Puget Sound for the Truncatellid, *Cecina manchurica* A. ADAMS, 1861, is the northeast corner of Birch Bay, Whatcom County, Washington. Specimens obtained April 25, 1963 were identified by Mr. R. R. Talmadge of Willow Creek, California, together with *Assiminea translucens* (CARPENTER, 1864) and *Phytia myosotis* (DRAPARNAUD, 1801). All three mollusks were found under *Salicornia* and driftwood at Cottonwood Beach.

A distinct species heretofore thought endemic only to Humboldt Bay, California, was collected on May 25, 1963 in Willapa Bay, Pacific County, Washington. Beautifully banded, small, smooth *Littorina* were found beneath an abandoned oyster cannery at Nahcotta. Comparison with the type specimens by Drs. G Dallas Hanna and Leo G. Hertlein indicated that the specimens were *Littorina newcombiana* (HEMPHILL, 1876). They were located in abundance among discarded oyster shells during a search for *Assiminea translucens* and *Phytia myosotis*.

Not in Washington State waters, but contiguous thereto, was a find off Vancouver Island, British Columbia, Canada, which considerably extends the range of an apparently rare species. A number of small iridescent blue shells were brought up from 250 fathoms west of the Island by a commercial drag boat in April 1962. Dr. Myra Keen of Stanford University identified these as *Solariella nuda* DALL, 1896. Dr. Harald A. Rehder, Curator, Division of Mollusks, Smithsonian Institution, concurs but believes these may represent the genus *Margarites*. In either case, relevant literature indicates that this species hitherto has not been found north of Monterey, California, ranging southward from there to off Lower California.

REFERENCES CONSULTED

DALL, WILLIAM HEALEY

1921. Summary of the marine shell-bearing mollusks of the north-west coast of America from San Diego, California, to the Polar Sea, mostly contained in the collection of the U. S. National Museum. Smithsonian Inst., U. S. Nat. Mus. Bull. 112: pp. 1-217; pls. 1-22.

KEEN, A. MYRA

1958. Sea shells of tropical west America; marine mollusks from Lower California to Colombia. Stanford Univ. Press, xi + 624 pp.; illus. Stanford, Calif.

MORRISON, JOSEPH PAUL ELDRED

1963. *Cecina* from the State of Washington: a new record for North America. Nautilus 76 (4): 150-151.

BOOKS, PERIODICALS, PAMPHLETS

Proceedings of the Malacological Society of London
volume 35, part 4, April 1963

T. SOOT-RYEN - "Some nomenclatural changes in the family Mytilidae." [Notes availability of a generic name, *Vilasina* SCARLATO, 1960, ex BARTSCH MS, for *Modiolaria vernicosa* MIDDENDORFF, 1851; of *Geukensia* VAN DE POEL, 1959, for *Mytilus demissus* DILLWYN, 1817; and of *Mytilus charruanus* ORBIGNY, 1846 to replace the preoccupied *M. falcata* ORBIGNY, now allocated to *Mytella*. *Modiolus fornicatus* (CARPENTER, 1865) also is preoccupied. SOOT-RYEN proposes *Modiolus carpenteri*, nom. nov. as a replacement.]

R. K. DELL and S. P. DANCE - "The molluscan genus *Ranella* and the distribution of *Ranella olearium* (LINNAEUS)."

MK

Author Index to the NAUTILUS, volumes 3-75 and its predecessor, the Conchologists Exchange, volumes 1 and 2.

compiled by **Aurèle La Rocque**

Loose leaf; 279 pages. Available from Dr. A. La Rocque, University of Ohio, Columbus, Ohio. - Price \$ 2.-

This very valuable author index was prepared as a "milestone" in the "life" of the Nautilus. Dr. La Rocque plans to compile and publish, in a similar manner and format, a cumulative subject index covering the same period, if this cumulative author index is received in a manner which shows the need and the wish for the subject index.

The present index has many valuable features and it should be in the hands of all serious students of malacology and conchology, whether or not they themselves own the full set or only a part of the Nautilus. Even if the journal is available only through a library, it is most convenient for the worker to check in this index, at his convenience and in his laboratory or home; to make this generally possible, the compiler has kept the price at this extremely reasonable figure.

RS

Results of the Puritan-American Museum of Natural History Expedition to Western Mexico.

17. The Recent Mollusks: Gastropoda, Cypraeaacea.

WILLIAM K. EMERSON & WILLIAM E. OLD, Jr.

American Museum Novitates No. 2136. 32 pp.; 18 figs.

This is a continuation of the report on the Expedition into west Mexican waters some years ago. Of a possible 26 species of Cypraeaacea reported from the area before, the Expedition obtained 16, as well as three species not previously reported from the area. Many of the species are figured and in several instances similar species from other areas are shown for comparison.

RS

The Cephalopod papers of Japetus Steenstrup

a translation into English by AGNETE VOLSØE, JØRGEN KNUDSEN and WILLIAM REES

Danish Science Press, Ltd., Copenhagen (1962); about \$ 12.-; 330 pp., 1 frontispiece, 8 pls. and many text figures.

Steenstrup, in a long career - from 1849 to 1897 - made some of the most fundamental contributions to malacology, especially to the knowledge of the cephalopods. Because his papers, for the major part, were published in Danish, they were not as widely circulated as they should have been. The present volume fills an important gap,

making the 24 papers available to all those who could not read them in the original. The flavor of Steenstrup's personality which was mirrored in his particular manner of writing - and in his attacks upon his opponents - is well preserved in these masterfully handled translations. Some of the relatively awkward sentences were kept thus intentionally, so as to convey at least in some measure the original style of Steenstrup. It may also be of interest that Steenstrup's 24 papers on cephalopods represent probably his most important contributions to zoology - out of well over 200 papers published.

It will be interesting to see, in the next few years, what influence Steenstrup's papers will have on the writings of our present-day cephalopod specialists. In any event, we think that the Danish Science Press is to be congratulated on having rendered this important service.

RS

Contribution to the Biogeography of Cocos Island, including a Bibliography.

by LEO G. HERTLEIN. Proceedings of the California Academy of Sciences, Fourth Ser., Volume 32, No. 8, pages 219 to 289, 4 figures. May 20, 1963.

G DALLAS HANNA Anniversary Volume

This paper contains a general account of Cocos Island, Costa Rica, its biogeography, and an extensive bibliography. Nine phyla are represented in the faunal lists of species reported from this island; the significance of their distribution is discussed.

The list of marine and brackish water mollusks includes 88 species and subspecies, namely 12 Bivalvia, 57 Gastropoda, 4 Pteropoda, 4 Amphineura, and 11 Cephalopoda. Of these, only five species (three bivalves and two cephalopods) have not been reported from elsewhere. All but 14 of the total have been reported from waters of the west American mainland. At least 38 of the total have been reported from the Galapagos Islands and 33 from the Gulf of California. Nine species of land snails are listed; seven of these are endemic on Cocos Island; one or two occur in the Indo-Pacific region.

Very few species of the invertebrate fauna are identical with Caribbean or Atlantic forms, but many closely related species occur in that region. - The percentage of Indo-Pacific species in the invertebrate fauna of Cocos Island is small except in the assemblage of corals and holothurians, but even in these groups the eastern Pacific element predominates.

It is concluded from the study that the biota of Cocos Island was derived chiefly from the American mainland, fortuitously by the agencies of wind, ocean currents, birds, or marine mammals.

RS

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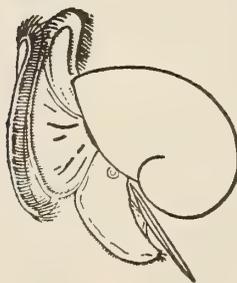
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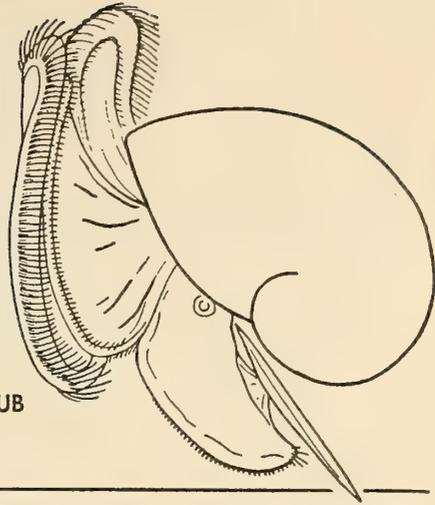
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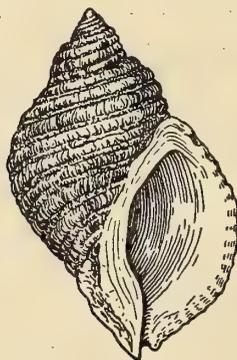
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Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION**, **Subdivision**, SECTION,
 SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).
New Taxa

Amimopina, An Australian Enid Land Snail

BY

ALAN SOLEM

Curator of Lower Invertebrates

Chicago Natural History Museum, Chicago 5, Illinois

(Supported in part by National Science Foundation Grant G-16419)

(4 Text figures)

IN AN EARLIER publication (SOLEM, 1959) I suggested that *Bulimus macleayi* BRAZIER, 1876, variously referred to the Partulidae, Bulimulidae, and Camaenidae, probably was an enid. Through the courtesy of Dr. D. F. McMichael of the Australian Museum, Sydney, it was possible to study the anatomy of specimens of "*Bulimus*" *macleayi* from the bank of the Little Stewart River, Silver Plains, Cape York Peninsula, Queensland, Australia. They were collected from the leaves of trees by J. L. Wassell on March 15, 1959. The specimens and dissections are preserved in the Australian Museum, Sydney. Drawings of the pallial region and genitalia are by Harry Cleaver, a student at Antioch College, those of the radula and jaw by Miss Marcia Oddi, Temporary Summer Assistant, Chicago Natural History Museum.

Examination of the pallial region, genitalia, jaw and radula confirmed my earlier suggestion that *Bulimus macleayi* is an enid, belonging to the subfamily Cerastuinae (= Pachnodinae), but it is obviously distinct from the other genera that have been dissected. In having the very long atrium and vagina possessing heavy internal padding and being bound to the body wall, a very short spermatheca and the renal fold forming a closed ureter, it is immediately differentiated.

A brief discussion of the systematically important features follows:

Pallial region (Figure 1): Lung with strong venation, weaker between hindgut and rectal fold. Kidney (K) very long, tapering, only slightly broadened at base. Renal orifice (KO) near anterior tip, opening into a closed tube formed by appression of the upper edge of the renal fold to the surface of the kidney. Just before the lateral basal extension of the kidney the closed tube ends and the renal ridge (KR) rapidly decreases in size, ending just before the posterior margin of the pallial cavity. There is a small gap between the end of the renal fold and start of the rectal fold (HGR). The latter seems to vary in position, lying near the hindgut (as in the figured specimen) or midway between the hindgut (HG) and kidney. Low at first, the rectal ridge becomes a quite high, thin plate

paralleling the hindgut and ending just beside the rectum near the pneumostome, forming a ureteric sulcus (KS).

The presence of at least a short renal fold is characteristic of many orthurethrans (for examples, see STEENBERG, 1925), while in the enids many species have developed pallial folds. SESHAIYA (1932: 4, fig.3) shows well developed, free rectal and renal folds in *Rachis punctata* (ANTON) and WIEGMANN (1901: 223) mentions an apparently long renal fold in several West China species. I am not, however, aware that any orthurethran with a pseudo-sigmurethrous urinary system has been reported. The formation of a tube by attachment of the renal fold duplicates the normal sigmurethrous condition. Almost certainly the rectal fold then serves as a channel through which the excretory products pass before leaving the mantle cavity. Many sigmurethrans have the portion of the ureter lying along the hind gut partly or almost completely an open groove. Available material was limited in numbers and not preserved in a suitable condition for determination of the microscopic anatomy of the pallial region. A comparison between the tissue structures in typical sigmurethrans and the pseudo-sigmurethrous *Bulimus macleayi* might yield quite interesting information on the origin of the sigmurethrous condition.

Genitalia (Figure 2): Ovocystis poorly preserved, apparently a linear series of clumped clavate alveoli. Hermaphroditic duct (GD) highly convoluted, slender. Talon reduced to a very short lobe deeply imbedded in albumen gland (GG). The latter is relatively large, thick at the base, tapering to a flat sheet posteriorly. Carrefour region not clearly differentiated. Prostate (DG) and uterus (UT) normal, short, approximately equal in length to the vagina (V). Free oviduct (UV), a short, coiled, moderately thick tube sculptured inside with weak pilasters. Spermatheca (S) a short, unstalked sac, very thin walled, lateral to the free oviduct and vagina, separated from them by a small muscular collar. Weak connective tissue binds it to the side of the free oviduct and it is too short to reach even the lower end of the uterus. Upper third of vagina weakly pilastered, lower portion

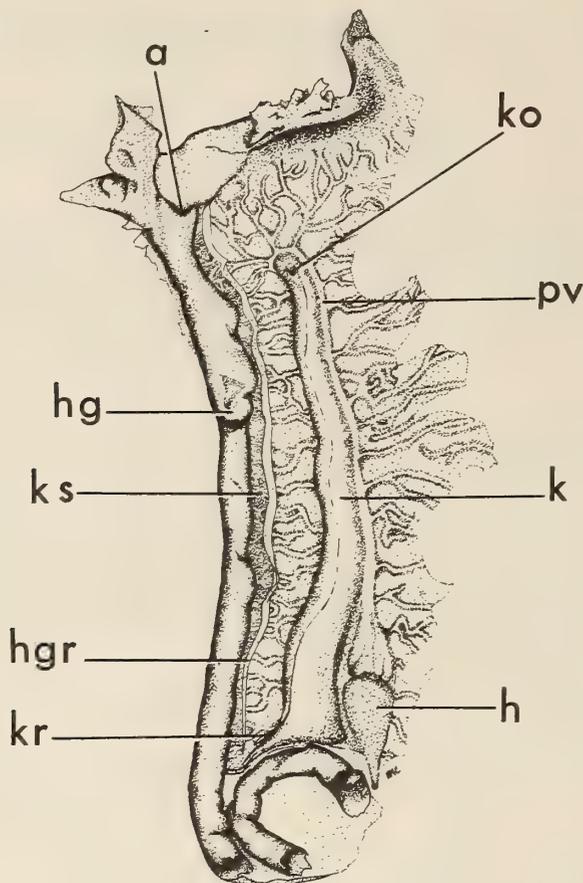


Figure 1: *Amimopina macleayi*. Pallial region, showing kidney (K), renal orifice (KO), pulmonary vein (HV), pericardium and heart (H), renal ridge (KR), hindgut (HG), rectal fold (HGR), anus (A) and ureteric sulcus (KS)

with a ring of thick, brown spongy tissue terminating above in a blunt arm. Below the insertion of the male system, the spongy mass is restricted to the outer wall and upper portion of the atrium (Y), leaving the inner wall free of glandularized tissue and consisting of a thin, muscular sheath. Atrium and vagina closely bound to body wall by muscular tissue. Atrium very long, wide.

Vas deferens (D), a thin white tube, loosely bound to free oviduct and vagina by connective tissue, tightly tied in to penioviducal angle. Shortly after starting up the penis, it passes into the thicker walled, larger epiphallus (E). The latter is largest in its midsection (incorrectly shown in drawing), tapering slightly before reflexing and lying bound to the penis (P), for slightly more than one-third length of the latter. Epiphallus longitudinally ribbed

internally, entering penis laterally and subapically through a large, soft, very pliable pilaster occupying nearly all of the upper penial bulb. A thin penial flagellum (PF) with alveolar cells inserts just above entrance of epiphallus. Upper portion of thin walled penis with weak corrugations inside, gradually coalescing into small longitudinal pilasters in lower two-thirds. Penial retractor muscle (PR) inserts laterally just below entrance of epiphallus, arising on diaphragm, split near apex with other arm attaching to penial appendix (PL). Base of penis uniting with the larger duct of the appendix and opening into atrium at point where the ring of brown tissue forms only two-thirds of a circle. Lower portion of penial appendix thinwalled, with weak internal pilasters. Branch of penial retractor muscle (PRA) inserts transversely at lower edge of a

heavy muscular collar that separates the upper and lower portions of the appendix. Upper portion of penial appendix with very thick, muscular walls. From tip of the penial appendage, a very long, tubular flagellum (PLF) arises, becoming broader and flatter above. Upper end of flagellum lying next to diaphragm along base of pericardium and kidney, tip reaching hindgut.

Gonopore below and in front of right ommatophore, the same distance above the foot as the lower tentacle and equidistant from tentacle and ommatophore. Opening a vertical slit. Mass of atrial and vaginal brown tissue clearly visible through body wall, lying parallel to plane of foot.

The penial appendage with its long flagellum, the split penial retractor muscle, lateral entrance of the epiphallus

and form of these organs is typically enid. In having a long, slender, penial flagellum and lacking an epiphallic caecum, plus the extremely short, unstalked spermatheca without a diverticulum, *Bulimus macleayi* immediately differs from the European-Asian genera (see HESSE, 1933 and FORCART, 1940). The few African and Asian genera that have been dissected show slightly longer, but similar, spermathecae and have a penial or epiphallic flagellum. For this reason, plus the similarities in radula and pallial folds, I have placed *B. macleayi* in the Cerastuinae.

Most land snails have a relatively short atrium which usually has some muscular or connective tissue extending from it to the body whorl. *Bulimus macleayi* seems unique, however, in having such a great extent of the atrium and

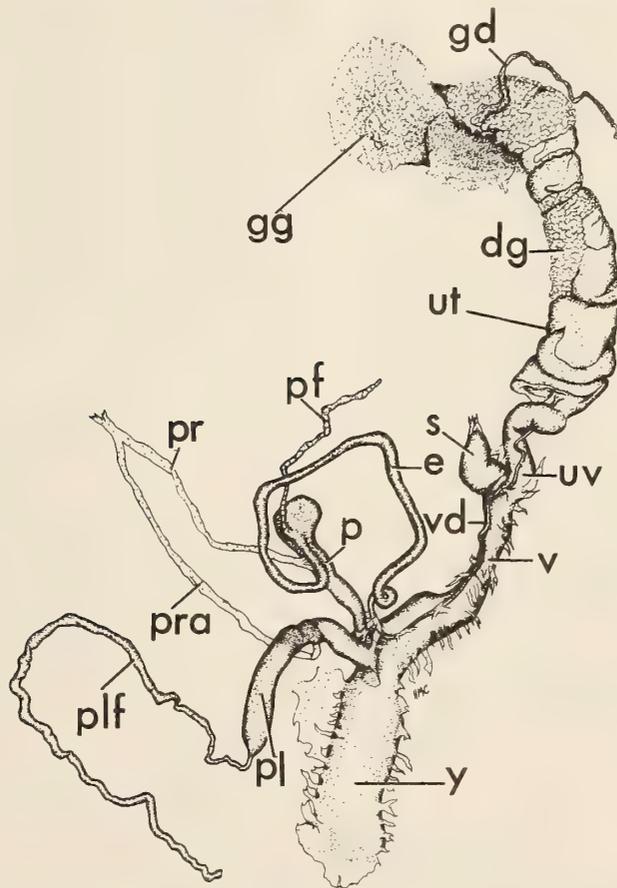


Figure 2: *Amimopina macleayi*. Genitalia, showing hermaphroditic duct (GD), albumen gland (GG), prostate (DG), uterus (UT), free oviduct (UV), vagina (V), spermatheca (S), atrium (Y), vas deferens (D), epiphallus (E), penis (P), penial retractor (PR), penial flagellum (PF), penial appendix (PL), penial appendix retractor (PRA), and flagellum of penial appendix (PLF).

vagina solidly bound to the body wall, and also in possessing such peculiar brown spongy padding inside the atrium and vagina. Normally the interior of these organs will



Figure 3: *Amimopina macleayi*. Jaw.

have weak pilasters, as are found in the penis and free oviduct of *B. macleayi*, but I know of no similar development in other land snails. Its function could conceivably involve dissolving of spermatophores, or it could be only a stimulatory pad.

Amimopina SOLEM, gen. nov.

Amimopina IREDALE, 1933, Rec. Austral. Mus., 19, p. 42 (*nomen nudum*).

Pseudosigmurethrous orthurethra, the ureter formed by apposition of the renal fold, pallial region with heavy venation. Spermatheca very short, free oviduct long with internal spongy tissue. Penis with flagellum and lateral entrance of the epiphallus. Penial retractor muscle arising on diaphragm, split with part inserting just above middle of penis and other part attaching below middle of penial appendix. Penial appendix with long flagellum, retractor muscle attaching to muscular collar. Atrium long, broad, tightly bound to body wall, internally with brown spongy tissue. Jaw of narrow, partially fused plates. Radula with central tooth unicuspid, six laterals and 43 marginals. Marginal teeth with progressive splitting of cusps. Basal plates moderately elongated. Shell conic, brownish-yellow, with faint radial striations. Lip simple, not expanded or reflexed.

Type species: *Bulimus macleayi* BRAZIER, 1876.

Serious doubts exist concerning the availability for nomenclatural use of many generic names proposed by Tom Iredale. A strong case can be made that many of his names were never published in the technical sense of the word. Following Article 13 of the International Code of Zoological Nomenclature (p. 42 of the 1961 edition), in order for a name published after 1930 to be available, it ". . . must be either (i) accompanied by a statement that purports to give characters differentiating the taxon; or (ii) accompanied by a definite bibliographic reference

to such a statement; or (iii) proposed expressly as a replacement for a pre-existing available name." Iredale's casualness in introducing new names is legendary among zoologists. His descriptions, when present, are apt to be sketchy, at best. It is impossible to evaluate the systematic position of his names from the publications, since he seldom gave comparisons or adequate diagnoses of new taxa. ZILCH (1960, pp. 725 - 730) listed 265 generic and subgeneric names proposed by Iredale that he could not evaluate and place in his supraspecific monograph of the Euthyneura. Many Iredalean names are validly proposed from a nomenclatural viewpoint, however *scientifically inadequate* their descriptions. Other names "diagnosed", for example, as "It, however, seems more like the former (*Georissa*) than the latter (*Omphalotropis*), and as it is conchologically neither, the new name *Omphalorissa* is introduced for it" could hardly be considered as adequately differentiated. Such names I consider to be *nomina nuda*. Subsequent studies may show that generic names are needed for many species groups covered now only by Iredalian *nomina nuda*. When this happens, formal descriptions, preferably utilizing the same names can be published, with the names being validated from the later study. Each one of Iredale's names will have to be judged separately, and it will be many years before their status can be settled. In previous studies I have been guilty of

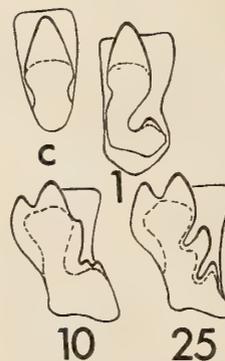


Figure 4: *Amimopina macleayi*. Radular teeth, showing central tooth, first lateral, fourth marginal (tenth tooth) and 19th lateral (25th tooth).

accepting his names as being validly proposed, although reducing them to synonymy, without testing whether they meet the requirements for publication.

Amimopina is a case in point. After mentioning a referral of *Bulimus macleayi* to *Papuina* (Camaenidae) that he considered incorrect, IREDALE (1933, p. 42) states "It may be noted that KOBELT (Conch. Cab., ed. KUSTER [sic], Bd. i, Abth.13, ante Sept., 1901) referred the species *macleayi* to *Bothriembryon* (Bulimulidae), a worse selec-

tion than *Papuina*, so the new generic name *Amimopina* is proposed, the Australian *B. (ulimus) beddomei* BRAZIER being the type." IREDALE did not (i) have "a statement that purports to give characters differentiating the taxon", (ii) give "a definite bibliographic reference to such a statement", and (iii) no generic name had ever been proposed for *Bulimus beddomei*, so he was not proposing a substitute name. Therefore, *Amimopina* does not meet the criteria of availability of the International Code of Zoological Nomenclature. Subsequent mention of the name in the literature is restricted to listing in check lists (IREDALE, 1938, 1941) or in publications without any diagnostic characters (SOLEM, 1959 a, p. 59 and SOLEM, 1959 b, pp. 154, 157). Since the animal does possess quite distinctive characteristics, the shell differs from most enids, and it obviously can not be placed in a previously described genus, I have formally described *Amimopina* at this time. I consider previous references to be *nomina nuda* and the genus *Amimopina* will have to date from publication of this article.

No genus seems to be closely related. The Indian-African *Rachis* (see SESHAIYA, 1932) has a similar pallial structure, except for the appression of the renal ridge to the kidney, but the much larger spermatheca, presence of an epiphallal caecum, quite different radular teeth and colorful, much thicker shell immediately separates them generically. The conic, brown, rather featureless shell is reminiscent of the South African *Pachnodus*, but the latter have not been dissected and most species are more broadly conic with a peripheral keel which is lacking in *Amimopina macleayi*.

A synonymy of the single species follows.

Amimopina macleayi (BRAZIER, 1876)

Bulimus macleayi BRAZIER, 1876, Proc. Linn. Soc. New South Wales, 1: 108 - Yule Island, Papua; BRAZIER, 1880, *op. cit.*, 4: 395 - east side of Yule Island, Papua; TAPPARONE-CANEFRI, 1883, Ann. Mus. Civ. Storia Nat., Genova, 19: 104, pl. 2, figs. 16, 17; HEDLEY, 1891, Proc. Linn. Soc. New South Wales, 16: 97; PILSBRY, 1909, Man. Conch., (2) 20: 319; IREDALE, 1933, Rec. Austral. Mus., 19 (1): 42; SOLEM, 1959, Arch. f. Mollusk., 88(4-6): 154, pl. 12, fig. 6.

Bulimus beddomei BRAZIER, 1876, Proc. Linn. Soc. New South Wales, 1: 127 - Mt. Ernest Island, Torres Strait, Australia (*nomen nudum*); BRAZIER, 1880, *op. cit.*, 4: 395 - Mt. Ernest Island, Torres Strait; Thursday Island, Torres Strait; Fanny Bay, Port Darwin; Andromache River, between Bowen and Cape Palmerston; TATE, 1882, Trans. Proc. Rep. Roy. Soc. S. Australia, 5: 50; HEDLEY, 1888, Proc. Roy. Soc. Queensland, 5: 64; IREDALE, 1933, Rec. Austral. Mus., 19 (1): 42.

Partula macleayi (BRAZIER), HEDLEY, 1894, Proc. Linn. Soc. New South Wales, (2) 19: 387, pl. 26, figs. 22, 23 - Rigo, Papua (radula and jaw figured).

Papuina macleayi (BRAZIER), PILSBRY, 1900, Manual Conch., (2) 13: 121, 122, pl. 4, figs. 66 - 68.

Bothriembryon macleayi (BRAZIER), KOBELT, 1901, Syst. Conch. Cab., I (13) 2: 767, 768, pl. 112, figs. 10, 11.

Amimopina beddomei (BRAZIER), IREDALE, 1938, Austral. Zool., 9 (2): 93.

Amimopina macleayi (BRAZIER), IREDALE, 1941, *op. cit.*, 10 (1): 64.

Aminopina (sic) macleayi (BRAZIER), SOLEM, 1959, Arch. f. Mollusk., 88 (4-6): 154, 157.

Range: South coast of New Guinea in the vicinity of Port Moresby (Rigo and Yule Island), islands in Torres Strait and coastal Queensland as far south as Cape Palmerston (22° 20' S), and Northern Territories near Port Darwin.

Remarks: Although IREDALE (1933: 42) states that "there are differences" between Brazier's two forms and that another form lives near Port Essington, material I have examined belongs to one species. No large series of specimens exist in collections, but available specimens show such minor differences that specific separation is very unlikely.

LITERATURE CITED

FORCART, LOTHAR

1940. Monographie der türkischen Enidae (Moll. Pulm.). Verhandl. Naturforsch. Gesellsch. Basel 51: 106 - 263; 3 pls.; 13 text figs.

HESSE, P.

1933. Zur Anatomie und Systematik der Familie Enidae. Arch. f. Naturgesch., N. F. 2 (2): 145 - 224; 43 figs.

IREDALE, TOM

1933. Systematic notes on Australian land snails. Rec. Austral. Mus. 19 (1): 37 - 59.

1938. A basic list of the land Mollusca of Australia. Austral. Zool. 9 (2): 83 - 124; pls. 12 - 13.

1941. A basic list of the land Mollusca of Papua. Austral. Zool. 10 (1): 51 - 94; pls. 3 - 4.

SESHAIYA, R. V.

1932. Anatomy of *Rachisellus punctatus* (ANTON). Annamalai Univ. Journ. 1 (1): 72 - 90; 16 figs.

SOLEM, ALAN

1959 a. Systematics of the land and fresh-water Mollusca of the New Hebrides. Fieldiana: Zoology 43 (1): 1 - 238; 34 pls.; 8 figs.; 17 tables.

1959 b. On the family position of some Palau, New Guinea, and Queensland land snails. Arch. f. Molluskenk. 88 (4-6): 151 to 158; pls. 12 - 13; 2 text figs.

STEENBERG, C.-M.

1925. Études sur l'anatomie et la systématique des maillots. Videns. Medd. Dansk naturh. For. 80: viii, 211; 34 pls.; 50 figures.

WIEGMANN, FRITZ

1901. Binnen-Mollusken aus Westchina und Central-Asien.

Zootomische Untersuchungen II. Die Bulimuliden. Ann. Musée Zool., St. Petersburg 6: 220-297; pls. 10-11.

ZILCH, ADOLF

1960. Gastropoda Euthyneura. Handb. Paläozool., Band 6, Teil 2, Lief. 4: 601-834; figs. 2112-2515.

Foxidonta, A Solomon Island Trochomorphid Land Snail

BY

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(Supported in part by National Science Foundation Grant G-16419)

(5 Text figures)

CLENCH (1950) described *Foxidonta stevensoni* as an endodontid land snail. Examination of paratypes had convinced me that it was not an endodontid, since the characteristic endodontid reticulated microsculpture was absent. I had surmised that it might be a camaenid near *Coliolum*, but this was only on the basis of shell features.

Through the kindness of Rev. H. E. J. Biggs, I obtained several preserved specimens and was able to study the gross anatomy. Rather to my surprise, *Foxidonta* is a trochomorphid land snail very near to *Videna* and *Brazieria* in anatomical structures, although obviously differing in shell form and sculpture.

For providing the material to be dissected, I am deeply indebted to Rev. Biggs. The drawings of the foot, pallial region and genitalia are by Harry Cleaver, a student at Antioch College. The other drawings are by Miss Marcia Oddi, Temporary Summer Assistant, Chicago Natural History Museum.

A redescription of the genus follows:

Genus *Foxidonta* CLENCH, 1950

Aulacopod sigmurethra, radular teeth with elongated basal plates, marginals bicuspid. Spermatheca inserting on base of penis. Epiphallus entering penis apically, penial retractor muscle inserting at junction of epiphallus and penis. Penis with a simple pilaster apically, lower portion with several small pilasters radiating in a fan shape from base of a groove. Pallial region without distinct venation, some scattered black and white color patches.

Shell very elevated, conical, strongly carinated. Apex with weak spiral lines above, developing radial growth striae near its end. Lower whorls with irregular, prominent, low, triangular ribs, usually with very long periostacal extensions. Umbilicus narrowly open, columellar lip moderately reflected.

The lack of distinct pallial venation, sausage-shaped kidney, bicuspid lateral radular teeth with elongated basal plates, presence of pedal grooves, and insertion of the spermatheca on the penial side of the penioviducal angle at once relate *Foxidonta* to the *Videna*, *Brazieria*, *Hogolua*, *Kondoa* complex of Indonesia and the Caroline and Palau Islands. *Foxidonta* differs primarily in the simple internal structures of the penis. The other genera have much more complicated penial structures. Conchologically, *Foxidonta* differs by its larger size, conical shape, lack of parietal dentition, the presence of heavy radial growth ribs and the very elevated spire. The most similar shell is the much smaller *Videna* (*Peleliua*) *pagodula* (SEMPER, 1870).

A brief description of the systematically important anatomical features follows.

Foot with undivided sole, pedal grooves (Figure 1) moderately prominent, uniting across the tail. No caudal foss or horn. Pallial region (Figure 2) with sausage-shaped kidney (K) about twice as long as the pericardium (H) and one third the length of the pallial cavity. Hindgut (HG) and secondary ureter (KD) opening at base of pneumostome. Principal pulmonary vein (HV) without branches, surface of pallial wall with weak

striation and scattered color patches. A triangular lobe of the mantle gland intrudes onto the pallial surface

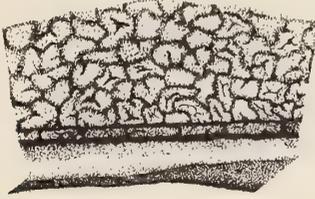


Figure 1: *Foxidonta stevensoni*. Portion of foot showing pedal grooves and the foot sole forming lower part of lateral margin.

from the mantle edge. Genitalia (Figure 3) typically trochomorphid with ovotestis (not shown) of groups of

clavate alveoli imbedded in the liver. Hermaphroditic duct (GD) long and convoluted, carrefour (X) sacculate and distended. Uterus (UT) with many folds, prostate (DG) normal. Free oviduct (UV) with upper portion a swollen, glandular sac with internal groove that lies next to the vas deferens. After an abrupt narrowing of the glandular portion, the moderately swollen lower free oviduct is thin walled with strong internal pilasters before joining the spermatheca and penis to form the common atrium. Spermatheca (S) a short, apical sac loosely bound to glandular zone of free oviduct, base entering on penial side of penioviducal angle. Vas deferens (D) a narrow tube running from the prostate to epiphallus, moderately connected by tissue to the walls of free oviduct and penis, tightly bound to penioviducal angle. Epiphallus (E) abruptly enlarged, entering penis apically without sharp differentiation. Penial retractor

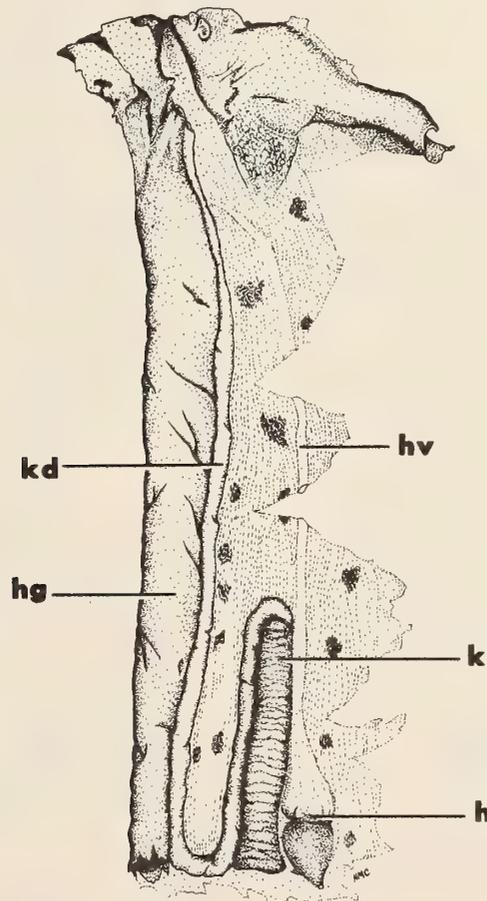


Figure 2: *Foxidonta stevensoni*. Pallial region showing kidney (K), pericardium and heart (H), hindgut (HG), secondary ureter (KD) and pulmonary vein (HV).

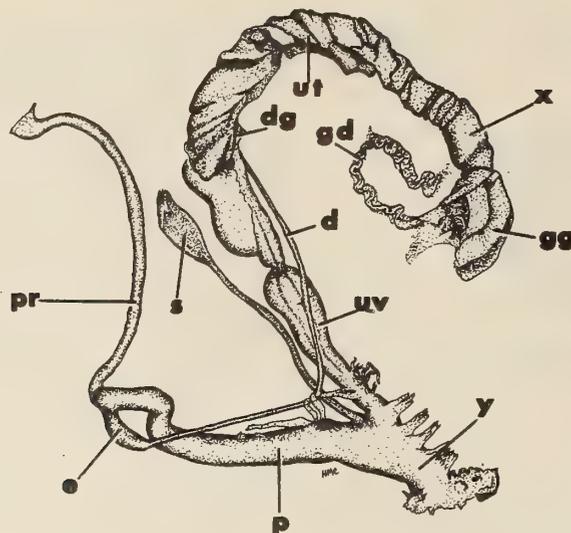


Figure 3: *Foxidonta stevensoni*. Genitalia showing hermaphroditic duct (GD), albumen gland (GG), carrefour (X), uterus (UT), prostate (DG), free oviduct (UV), spermatheca (S), vas deferens (D), epiphallus (E), penial retractor (PR), penis (P), atrium (Y).

(PR) arising on diaphragm, inserting on apex of penis. Penis (P) a slim, slightly twisted, muscular tube. Upper portion with one narrow, prominent, crenulated pilaster running from entrance of epiphallus down to slightly above the midpoint of penis. There it fans out into a series of small, radially arranged pilasters. Atrium (Y) short, muscular with irregular pilasters inside, possessing strong muscular attachment to the body wall.

Jaw (Figure 4) with low median lobe, weakly transversely striate, without longitudinal markings. Radula

Remarks: The extension of the videnoid series of Trochomorphinae into Melanesia is not surprising. Discovery that *Foxidonta* is a trochomorphid does suggest that some of the New Guinea *Coliulus* may prove to be trochomorphids rather than camaenids, since the shells of such New Guinea species as *C. arfakiensis* (TAPPARONE-CANEFRI, 1887), *C. canefriana* E. A. SMITH, 1895



Figure 4: *Foxidonta stevensoni*. Jaw with part of attachment membrane.

with 122 rows on mounted example, 10 laterals and 37 marginals. Radular teeth (Figure 5) typically trochomorphoid, central with barely visible ectocones, laterals weakly bicuspid, marginals strongly bicuspid.

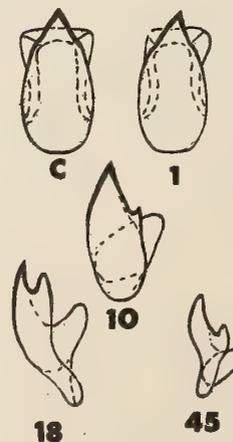


Figure 5: *Foxidonta stevensoni*. Radular teeth showing central, first lateral, tenth lateral, and the 18th and 45th teeth, both marginals.

and *C. weiskei* (FULTON, 1902) are quite similar in shape, sculpture and form of the aperture to *Foxidonta stevensoni*. Possibly *Paratrochus dalbertsi* (BRAZIER, 1876) from Yule Island, New Guinea may prove to be related.

LITERATURE CITED

CLENCH, WILLIAM JAMES

1950. A new genus and species of Endodontidae from the Solomon Islands. *Revista Socied. Malacolog.* 7 (2): 59 to 60; 3 figs.

Morphological and Behavioral Concealing Adaptations of *Lamellaria stearnsii*, a Marine Prosobranch Gastropod

BY

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(Plate 16)

THE LAMELLARIIDAE are a family of mesogastropods which prey upon tunicates. Although a number of writers have remarked upon the close resemblance between lamelliariids and the tunicates on which they feed (HERDMAN, 1893; ANKEL, 1935), there has been little consideration of the relationship of this similarity to other aspects of the biology of lamelliariids, and knowledge of the natural history of these gastropods is largely confined to a single species, *Lamellaria perspicua* (LINNAEUS, 1758). The following is an account of a lamelliariid occurring in Monterey Bay, California which displays a remarkable similarity to a tunicate.

Lamellaria stearnsii DALL, 1871 may be found on the compound ascidian *Trididemnum opacum* (RITTER, 1907), which occurs intertidally on the under surfaces of rocks. The snail's mantle almost covers the entire shell, and the animal is rather flat, so that it is shaped very much like a bulge in the tunicate colony (see plate 16). The pinkish-white color of the snail matches that of the tunicate closely, and the pattern of acid glands on the snail's dorsum closely resembles the pattern of oral apertures of the zooids. Finally, the siphonal notches of the snail may be compared to the common cloacal apertures of the tunicate.

The behavior of *Lamellaria stearnsii* includes further adaptations which render it inconspicuous. In the laboratory I have observed that the snails remain stationary on the tunicate during the day. If they are removed from the tunicate colony, they crawl about, displaying a pronounced

negative phototaxis. Animals resting on a tunicate colony in the light become active at once when placed in the dark. These facts suggest that the snails are active only at night, and that they remain concealed on the tunicate colony during the day.

These concealing adaptations probably do not occur to an equal degree in all species of *Lamellaria*. MARCUS (1956) has denied the existence of a close association between tunicates and *Lamellaria perspicua mopsisicolor*. I have collected *L. stearnsii* only on tunicates, but *L. rhombica* DALL, 1871, which also resembles a tunicate colony and which also occurs in Monterey Bay, is often found in more conspicuous positions.

In neither *Lamellaria stearnsii* nor *L. rhombica* is the shell completely internal, as has been reported for other species (FRETTER & GRAHAM, 1962, p. 555). Instead, the mantle covers the shell, but a small pore is left which enlarges to expose the shell when the animal is irritated. This pore was noted by ROGERS (1908) for *L. rhombica*, but not for *L. stearnsii*.

ACKNOWLEDGMENTS

I wish to thank Andrew Todd Newberry for locating some of the animals used in this study, Welton Lee for assistance with photography, James H. McLean for help with identification of the lamelliariids, and Dr. Donald P. Abbott for identifying the tunicates and for criticizing the manuscript.

LITERATURE CITED

- ANKEL, W. E.
1935. Das Gelege von *Lamellaria perspicua*. Zeitschr. Morphol. Ökol. Tiere 30: 635-647.
- DALL, WILLIAM HEALEY
1871. Description of sixty new forms of mollusks from the west coast of North America and the north Pacific Ocean, with notes on others already described. Amer. Journ. Conch. 7 (2): 95-159; pls. 13-16.
- FRETTER, VERA, & ALASTAIR GRAHAM
1962. British prosobranch molluscs; their functional anatomy and ecology. London, Ray. Soc.; xvi + 755 pp.; 317 figs.
- HERDMAN, W. A.
1893. "Mimicry" of *Lamellaria perspicua*. Conchologist 2: 129-130.
- MARCUS, EVELINE DU BOIS-REYMOND
1956. On some Prosobranchia from the coast of São Paulo. Boll. Inst. Oceanogr. Univ. São Paulo 7 (1-2): 3-28; pls. 1-3.
- ROGERS, JULIA ELLEN
1908. The shell book. New York, Doubleday, Page & Co.; xii + 485 pp.; 104 pls.

Studies on the *Mytilus edulis* Community in Alamitos Bay, California: I. Development and Destruction of the Community¹

BY

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(5 Text figures)

INTRODUCTION

SCHEER (1945) STATED in his paper dealing with the development of marine fouling communities that it is important to distinguish between seasonal progression and true succession. He cited the work of McDougall (1943) at Beaufort, N. C. as an example of seasonal progression, and his work in Newport Bay, California, as true succession. He found experimental plates suspended during different times of the year went through the same sequence of development in forming the climax community of *Mytilus edulis* LINNAEUS, 1758.

The study of marine fouling organisms has attracted a considerable amount of attention throughout the world and especially along the Pacific Coast of North America. Much of the world data have been summarized in the U. S. Naval Institute publication on marine fouling (ANONYMOUS, 1952). Along the eastern Pacific Ocean studies have been conducted at Friday Harbor, Washington (JOHNSON & MILLER, 1935), San Francisco Bay (GRAHAM & GAY, 1945), Los Angeles - Long Beach Harbors (BARNARD, 1958; REISH, 1961 b), Newport Bay

(SCHEER, 1945), La Jolla (COE & ALLEN, 1937; ALEEM, 1957), and San Diego Bay (WHEDON, 1937, 1943, in ANONYMOUS, 1952). In the majority of these studies, test panels were placed periodically in the sea in order to obtain data on the seasonal settlement of marine organisms. With the construction of a large boat harbor in Alamitos Bay in 1959, it was possible, in an area never before exposed to sea water, to determine whether or not the establishment of the *Mytilus edulis* community is a seasonal progression or a true succession.

MATERIALS AND METHODS

Alamitos Bay (Figure 1) is a small body of water located within the city of Long Beach, California, which is used primarily for recreational purposes. The details of the dredging and construction of the marina area of the bay have been described elsewhere (REISH, 1961 a, 1963).

In order to ascertain whether seasonal progression or true succession occurred, the study was conducted in two

¹ This study was supported by research grant NSF G-8914 from the National Science Foundation.



Figure 1

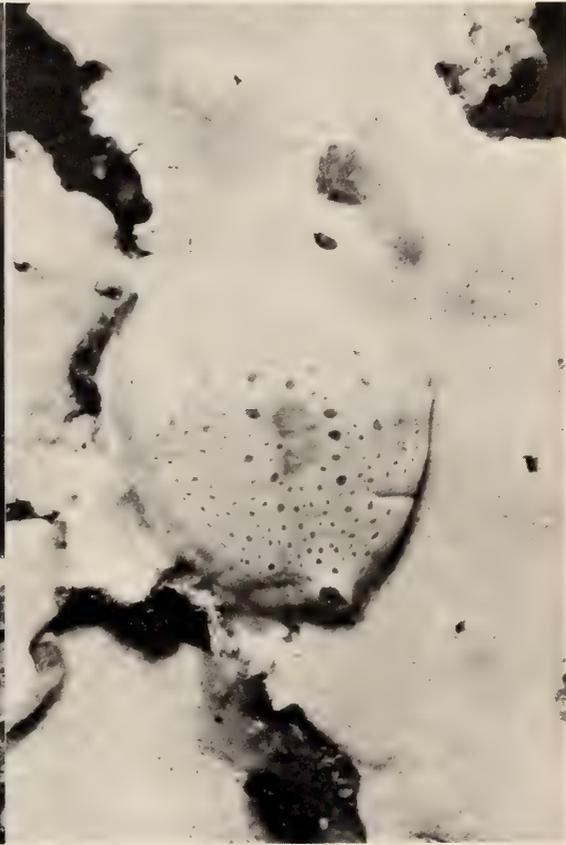


Figure 2

Figure 1: *Lamellaria stearnsii* crawling on the bottom of a dish.

Figure 2: *Lamellaria stearnsii* at rest on *Trididemnum opacum*.

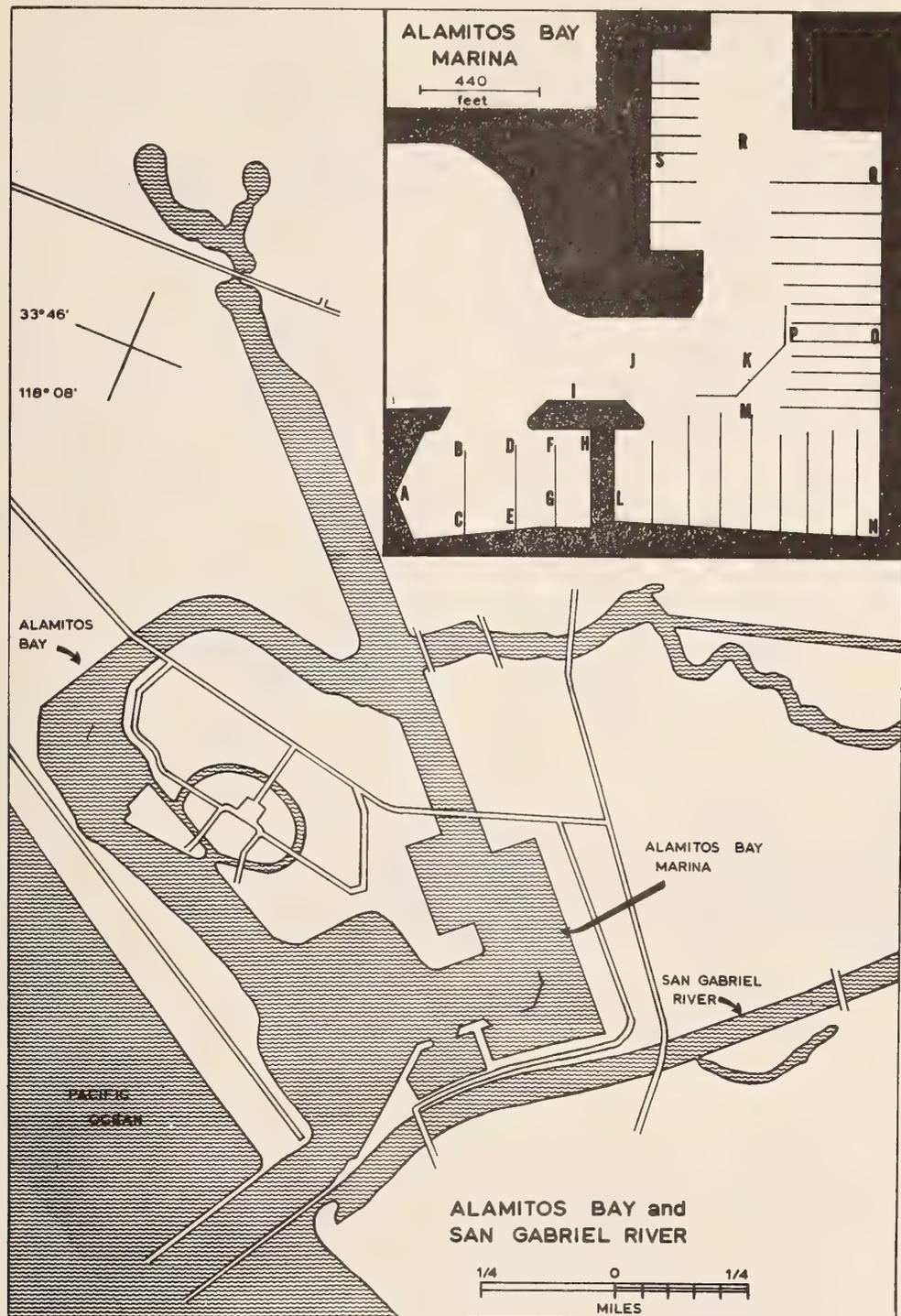


Figure 1: Map of Alamos Bay, California. Collection site located at Station P (see inset map.)

ways: (1) collections were made monthly for three years from the sides of boat docks beginning two weeks after they were first placed in the water, and (2) scraping the sides and bottom of one different float free from all macroscopic organisms approximately each season of the year and then making bimonthly collections from the sides and bottom for the next 1.5 years.

The individual boat dock (Figure 2) is constructed of wooden decking which is buoyed by a reinforced molded fiber glass plastic pontoon. The docks are held in position by concrete pilings but are free to move up and down with the tides. Each pontoon is divided by constructions into eight sections with the two outer ones being slightly larger. The first collection made on October 21, 1959, was taken from the left section (Figure 2, Number 1), the following month from the adjacent section (Number 2), etc. Collections 7 to 12 were made from the adjacent pontoon at the next dock (a distance of about 5 meters); collections 13 to 18 from a third pontoon, etc. Thus, each successive collection had been exposed one month longer than the preceding one. The study was terminated October 19, 1962. The pontoons from which collections were made all had the same exposure (west) and were within a few meters of each other. Each section of the pontoon measured 13 by 25 cm giving a surface area of 325 cm².

In the second study the floats were scraped on March 3, July 12, September 28, 1961, and February 2, 1962. Collections were made bimonthly. This study was terminated August 15, 1962. Collections from the side of the floats were made in the same manner as described above. Samples of the bottom of the float covering the same surface area were made by an aqualung-diver.

The fouling organisms were preserved in formalin in the field and then sorted, identified, weighed, and measured in the laboratory.

The water temperatures were summarized from the daily readings taken of the ocean by the City of Long Beach. These figures compared with those obtained by the author within the marina.

ACKNOWLEDGMENTS

The author wishes to thank Dr. Donald P. Abbott and Dr. John D. Soule for identifying some of the tunicates and bryozoans, respectively, encountered in this study. The author wishes to thank also Miss Emilie Bender, Mrs. Bettye Byrne, Miss Janet Budnick, Miss JoAnn Loper, Miss Ruth Zakem and Mr. Harold Pope for sorting the organisms collected in this study.

DATA

Settlement of Principal Organisms.

The data on the settlement of the principal organisms are summarized in Figure 3. The initial inhabitant consisted of the bacterial-algal scum as reported by others (SCHEER, 1945; ALEEM, 1959). The ectoproct *Bugula neritina* (LINNAEUS, 1758) was the first macroscopic organism to settle on the floats. It first settled about one month after the floats were submerged and reached its maximum development by November 1959. The tube-building polychaete *Hydroides norvegica* (GÜNNERUS, 1768) replaced *B. neritina* as the dominant organism by December 1959. A month later the green alga *Ulva lobata* (KÜTZING, 1849) SETCHELL & GARDNER became the dominant organism, a position it maintained throughout the first half of 1960. The climax organism, *Mytilus edulis*, first appeared in February 1960, but it was not until June 1960, that its biomass exceeded that of *U. lobata*. This pelecypod dominated the community until the entire association was affected by the red tide outbreak in the fall of 1962.

Growth of the Principal Organisms.

Following its initial dominance, *Bugula neritina* was taken frequently, but never abundantly, except during July and August 1962. The settlement of this species always occurred when the water temperature was between 15.6° and 19.4° C. *Bugula neritina* was not taken in November 1960 nor in December 1961, when the water temperatures were within this range. Elsewhere (ANON-

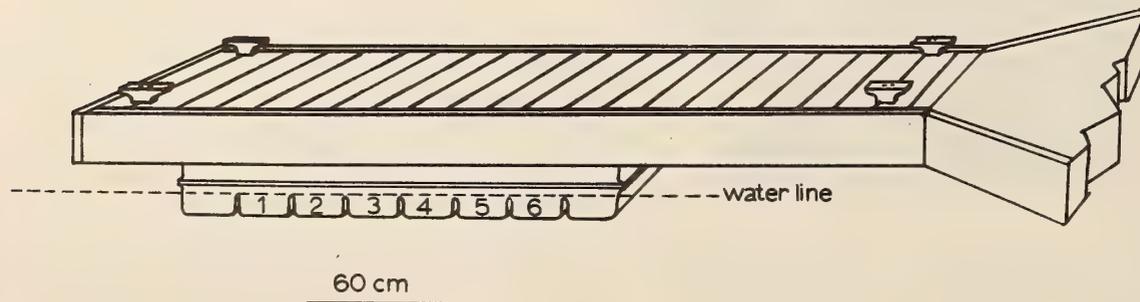


Figure 2: Diagram of boat dock and float. Numbers indicate site and order of collection.

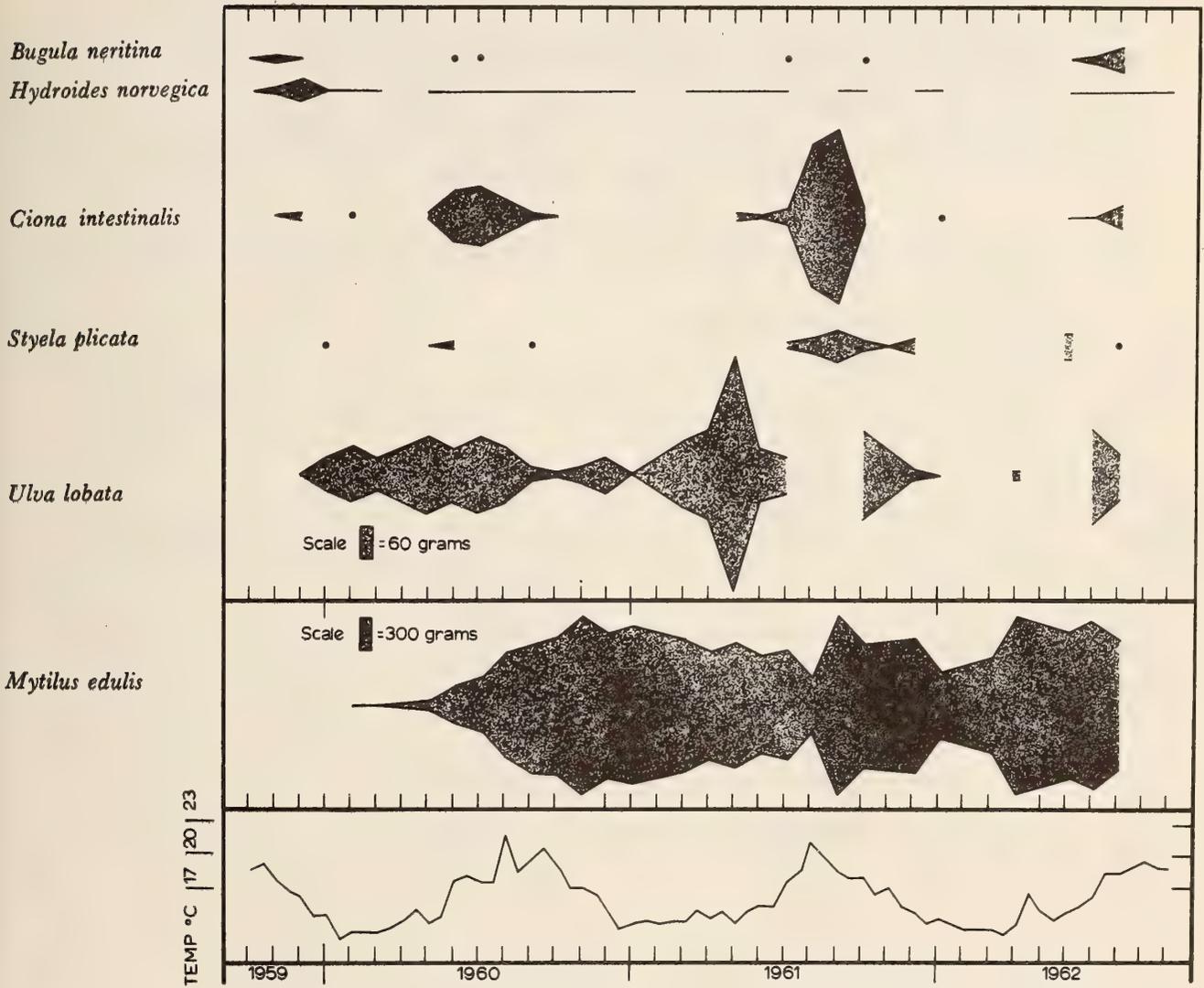


Figure 3: Diagrammatic representation of the appearance and growth in biomass of the principal organisms of the *Mytilus edulis* community. Temperature data from the records of the City of Long Beach, California.

YMOUS, 1952) it has been found to attach when the water temperature ranged from 15° to 18° C.

Hydroides norvegica was present on the floats most of the time throughout the three year period. The population peak occurred during November and December 1959 when the water temperature ranged from 16.7° to 18.9° C. In nearby Los Angeles Harbor heavy settlement of *H. norvegica* was noted when the water temperatures were above 18.4° C; however, the volume of the polychaete tube growth in Alamitos Bay never approached the quantity observed in Los Angeles Harbor. Growth of the polychaete, as measured by tube length, increased from 5 to 8 mm in October 1959 to 10 to 22 mm in December

1959. This is far short of the 100 to 150 mm lengths observed on the hulls of ships by WISELY (1958).

The population of *Ulva lobata*, as measured by weight, fluctuated considerably after its development in spring 1960. The fluctuations are apparently correlated with optimal temperature ranges between 13° and 18.5° C, giving a spring and fall peak in growth.

The changes in the population of *Mytilus edulis* are represented by weight (Figures 3 and 4) and by the number of individuals present (Figure 4). The first few specimens appeared on the floats in February 1960, with additional ones attaching during the spring months. Following the peak of 352 specimens in June 1960, the

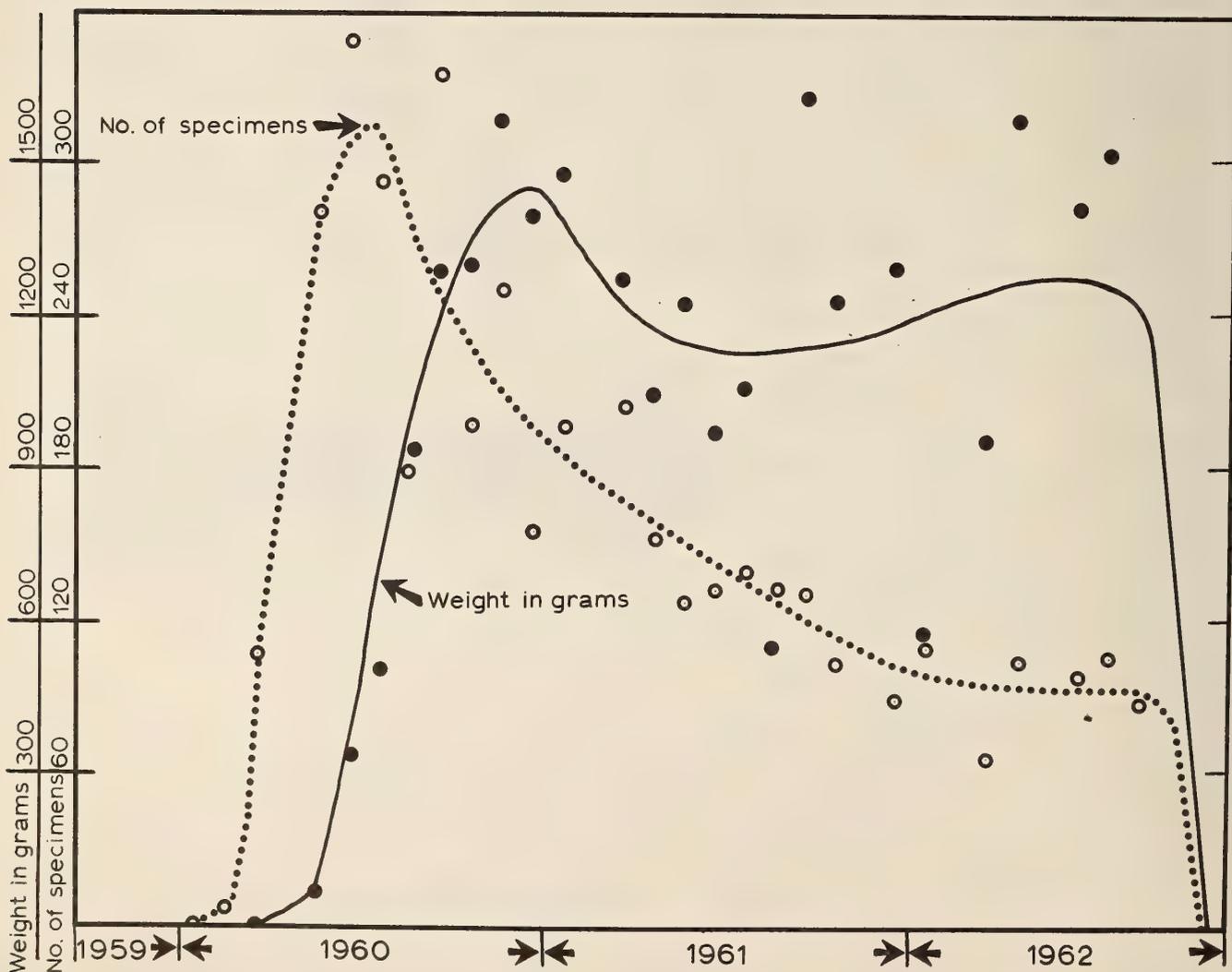


Figure 4: Graph showing the settlement, growth rate, and destruction of the *Mytilus edulis* community.

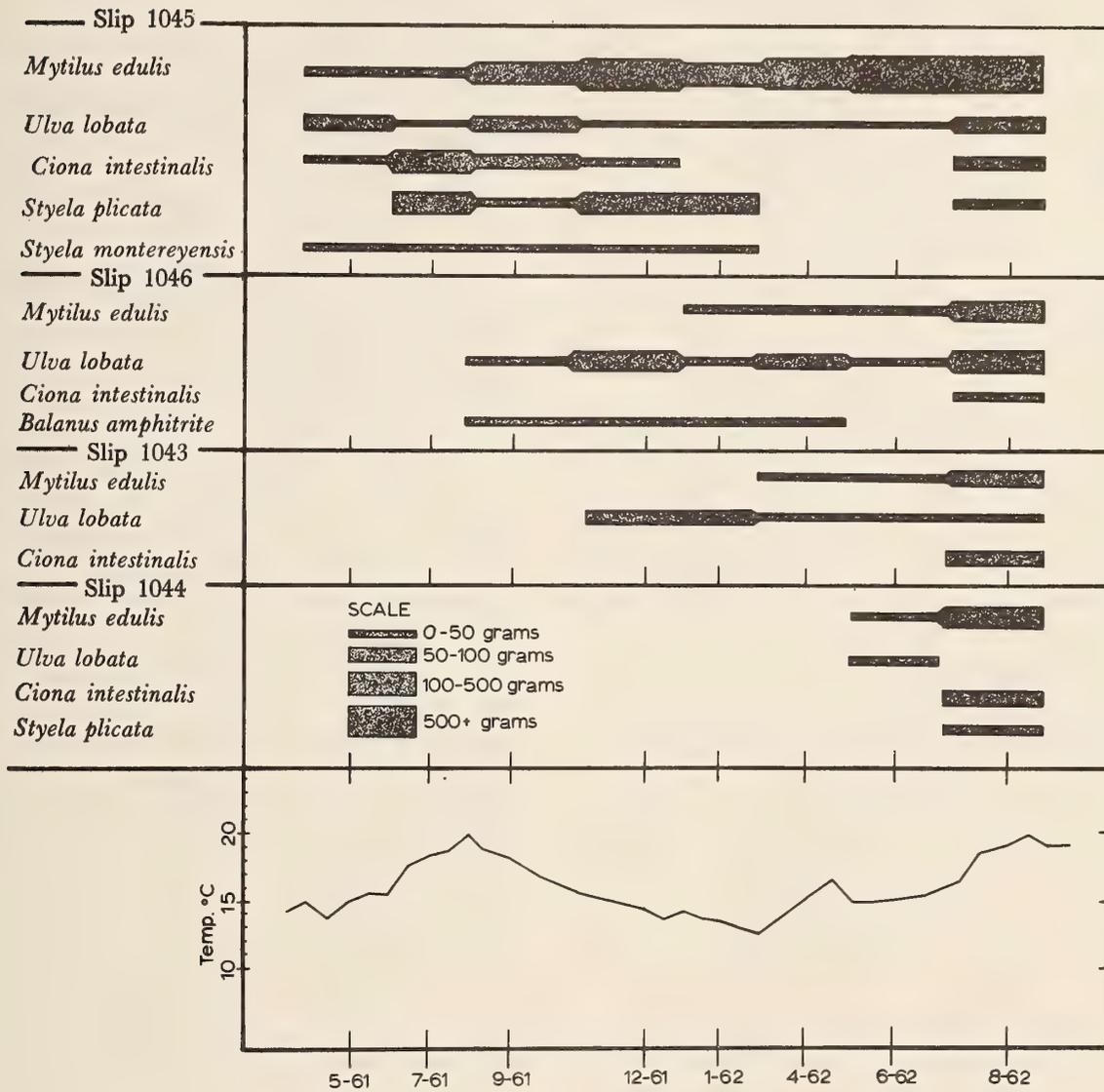


Figure 5: Diagrammatic representation of the appearance and growth in biomass of the principal organisms settling on floats scraped seasonally. Slip 1045 scraped March 3, 1961; slip 1046 on July 12, 1961; slip 1043 on September 28, 1961; slip 1044 on February 2, 1962. Dates at bottom of chart indicate time of collection. Temperature data as in Figure 3.

number of mussels gradually declined over the next two years until the entire population was killed by the red tide (Figures 3 and 4). The rate of growth of the population as determined by the weight was rapid after the initial lag of three months. A maximum of 1690 grams was measured in November 1960. For the ensuing two years the weight of *M. edulis* remained relatively constant until the mass mortality of the community in October 1962.

Growth of *Mytilus edulis* as determined by shell length was rapid. A maximum length of 82 mm was noted nine months after the first mussels were observed on the floats; this gave a minimal growth average of 9 mm per month. This is the fastest growth rate recorded for *M. edulis*. GRAHAM & GAY (1945) measured a monthly increment of 6 mm over a six month period in San Francisco Bay. STUBBINGS (1954) stated 5 mm per month growth rate in British waters. However, the growth rate of *M. meridionalis* KRAUSS in South African waters was nearly identical with the present findings (MILLARD, 1961). The amount of tidal exposure and availability of food have been cited as important ecological factors governing the rate of growth of *M. edulis* (GRAHAM & GAY, 1945; SAVAGE, 1956). Undoubtedly, the warmer waters of southern California also play a rôle in rapid growth. DEHNEL (1956) has shown that the growth rate of *M. californianus* CONRAD, 1837 is faster in a population in southern California than in Alaska.

While apparently not dominant members in the temporal sequence of the *Mytilus edulis* community, the tunicates *Ciona intestinalis* (LINNAEUS, 1767) and *Styela plicata* (LESUEUR, 1823) are important sporadic inhabitants of the floats. The settlement of *C. intestinalis* appeared to be seasonal with the heaviest attachments occurring in the spring months and extending into late summer before dying and dropping from the floats. The water temperature ranged from 15° to 16° C during the period of attachment of *C. intestinalis*. *Styela plicata* did not occur frequently, and its occurrence could not be related to either the time of the year or water temperature.

Settlement of Principal Organisms on Floats

Scraped Seasonally.

One float was scraped free of all macroscopic life approximately each season of the year to ascertain whether or not seasonal progression or true succession is involved in the establishment of the *Mytilus edulis* community. These data are summarized in Figure 5 for the side of the floats. The first appearance of *M. edulis* occurred as early as two months after the float was scraped in late winter (Slip 1045) but as late as six to seven months on floats scraped in summer or early fall (Slips 1046, 1043). The biomass of the mussel increased with time and in

all cases the largest quantity was collected at the termination of the study on August 15, 1962. *Ulva lobata* was an early inhabitant, and, with one exception, was always present on these four floats. The tunicates *Ciona intestinalis*, *Styela plicata*, and *S. montereyensis* (DALL, 1872) developed the largest biomass on Slip 1045 during 1961. The barnacle *Balanus amphitrite* DARWIN, 1854 was an important inhabitant only on Slip 1046 during late 1961 and early 1962. Collections from the undersurface of the float were made at the same time and the results are similar to these with the exception of the lack of *U. lobata* and the greater development of *C. intestinalis*.

DISCUSSION

The serial stages in true succession in the development of the *Mytilus edulis* community has been shown by SCHEER (1945) in nearby Newport Bay. The initial stage was characterized by bacteria - algae (small forms) - hydroids. This is followed by the bryozoan - serpulid phase and then with the climax community of *Mytilus edulis*. Additional paths may involve a *Balanus*, *Ciona intestinalis*, or a *Styela montereyensis* - sponge phase.

MILLARD (1951) found in protected South - African waters that following the initial diatom layer the stages consisted of a *Balanus* phase, *Ciona intestinalis* phase, and climaxing with *Mytilus meridionalis*. BARNARD (1958) found in highly turbid waters of Los Angeles - Long Beach Harbors that the mat-forming, tube-building amphipods and polychaetes developed early and apparently excluded the establishment of a *Mytilus edulis* community.

When the data for the collections from the floats collected for over a three year period (Figures 3 and 4) are compared with the data from the floats scraped seasonally (Figure 5), it is evident that seasonal progression rather than true succession occurred in Alamitos Bay Marina. It is the time of the year when the float is first submerged which determines what organisms will attach. For example, if the surface was first exposed (or scraped) during the winter and spring, then *Mytilus edulis* will settle soon and the mature community will develop rapidly (Figure 5, Slip 1045). If, on the other hand the initial exposure is in the second half of the year, then other organisms may settle on the surface. Additional species, such as *Ciona intestinalis* or *Styela plicata* may settle on the surface following their particular period for reproducing and settling during the time that *M. edulis* is present and increasing in biomass (Figures 3 and 5).

Settlement of *Mytilus edulis* in Alamitos Bay in 1960 to 1962 occurred during the winter and spring months during which the water temperature ranged from 12.8° to 18.3° C. This compares with the findings of 14.0° to 19.5° C by GRAHAM & GAY (1945) in Oakland, Cali-

foria, and of 12.5° to 22.0° C by ENGLE & LOOSANOFF (1944) in Milford Harbor, Connecticut. Spawning of *M. edulis* in British waters occurred in April and May, when the water temperatures were 9.5° to 12.5° C (CHIPPERFIELD, 1953). The spawning season for *M. edulis* in local waters is unknown.

It was impossible to ascertain how long any individual specimen of *Mytilus edulis* would live within this community. A few empty shells of adult size were noted during the study. A few specimens of less than 10 mm in length were measured in every collection. It is possible that as the adult specimens die additional space would then be available and some of these smaller mussels would increase in size. The mass mortality of the fouling organisms in the fall of 1962 following a red-tide bloom of *Gonyaulax polyedra* STEIN was widespread throughout much of the marina. While this cause of death among the mussels was extensive, it probably is a rare occurrence and exerts only a minor influence upon the *M. edulis* community over the years. This red tide was the most extensive one observed in Alamitos Bay by the author during the past eleven years (REISH, 1963 - in press).

SUMMARY

1. The growth, development and destruction of the *Mytilus edulis* community in Alamitos Bay Marina, California was described.
2. Data collected periodically from floats exposed the entire time and from floats following seasonal scraping indicate seasonal progression rather than true succession occurs. *Mytilus edulis* settled on new surfaces within two months following late winter scrapings but as late as seven months on floats scraped in summer or early fall.
3. The other major organisms of the community include *Ulva lobata*, *Hydroides norvegica*, *Bugula neritina*, *Ciona intestinalis*, and *Styela plicata*. The occurrence of these species and the relationship to the community structure and other factors are discussed.

LITERATURE CITED

- ALEEM, ANWAR ABDEL
1957. Succession of marine fouling organisms on test panels immersed in deep-water at La Jolla, California. *Hydrobiologica* 11: 40 - 58.
- ANONYMOUS
1952. Marine fouling and its prevention. U. S. Naval Inst. Annapolis; 388 pp.
- BARNARD, J. LAURENS
1958. Amphipod crustaceans as fouling organisms in Los Angeles - Long Beach harbors, with reference to the influence of sea water turbidity. *Calif. Fish and Game* 44: 161 - 170.
- CHIPPERFIELD, PHILIP N. J.
1953. Observations on the breeding and settlement of *Mytilus edulis* (L.) in British Waters. *Journ. Mar. Biol. Assoc. U. K.* 32: 449 - 476.
- COE, WESLEY R., & W. E. ALLEN
1937. Growth of sedentary marine organisms on experimental blocks and plates for nine successive years at the pier of the Scripps Institution of Oceanography. *Bull. Scripps Inst. Oceanogr., Univ. Calif. Tech. Ser.* 4: 101 - 136.
- DEHNEL, PAUL A.
1956. Growth rates in latitudinally and vertically separated populations of *Mytilus californianus*. *Biol. Bull.* 110: 43 - 53.
- ENGLE, J. B., & VICTOR L. LOOSANOFF
1944. On season of attachment of larvae of *Mytilus edulis* Linn. *Ecology* 25: 433 - 440.
- GRAHAM, H. W., & H. GAY
1945. Season of attachment and growth of sedentary marine organisms at Oakland, California. *Ecology* 26: 375 - 386.
- JOHNSON, MARTIN W., & ROBERT C. MILLER
1935. The seasonal settlement of shipworms, barnacles, and other wharf-pile organisms at Friday Harbor, Washington. *Univ. Washingt. Publ. Oceanogr.* 2: 1 - 18.
- MCDUGALL, KENNETH D.
1943. Sessile marine invertebrates at Beaufort, North Carolina. *Ecol. Monogr.* 13: 321 - 374.
- MILLARD, NAOMI
1951. Observations and experiments on fouling organisms in Table Bay Harbor, South Africa. *Trans. Roy. Soc. South Africa* 33: 415 - 446.
- REISH, DONALD J.
1961 a. A study of benthic fauna in a recently constructed boat harbor in southern California. *Ecology* 42: 84 - 91.
1961 b. The relationship of temperature and dissolved oxygen to the seasonal settlement of the polychaetous annelid *Hydroides norvegica* (GUNNERUS). *Bull. So. Calif. Acad. Sci.* 60: 1 - 11.
1963. Further studies on the benthic fauna in a recently constructed boat harbor in southern California. *Bull. So. Calif. Acad. Sci.* 62: 23 - 32.
1963. Mass mortality of marine organisms attributed to the "Red Tide" in southern California. *Calif. Fish and Game*, 49 (4): (in press)
- SAVAGE, R. E.
1956. The great spatfall of mussels (*Mytilus edulis* L.) in the River Conway estuary in spring 1940. *Ministry Agric., Fish and Food, Fish. Invest. ser.* 2, 20 (7): 22 pp.
- SCHAEER, BRADLEY T.
1945. The development of marine fouling communities. *Biol. Bull.* 89: 103 - 121.
- STUBBINGS, H. G.
1954. Biology of the common mussel in relation to fouling problems. *Research, London* 7: 222 - 229.
- WISELY, B.
1958. The development and settling of a serpulid worm, *Hydroides norvegica* GUNNERUS (Polychaeta). *Austral. Journ. Mar. and Freshwater Res.* 9: 351 - 361.

New Terebrid Species from the Eastern Pacific

(Mollusca : Gastropoda)

BY

G. BRUCE CAMPBELL

Contribution from the
"SEA OF CORTEZ MARINE RESEARCH CENTER"
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(Plate 17)

PILSBRY AND LOWE (1932) were the last to describe a large assemblage of new terebrid species from the Eastern Pacific, bringing the number of known Recent species and subspecies in this province to approximately 45; but they made no attempt to revise any of the previously described species except to refer occasionally to one or more in their comparisons. Of the eleven new species they described, only two are found within the confines of the Gulf of California, *Terebra ligyrus* and *T. ira*. Their study included primarily material collected by H. N. Lowe from Mazatlán to Panama with the exception of some material from Guaymas, Sonora and La Paz, Baja California, both in the southern half of the Gulf of California. The three additional species that are subsequently described were collected from the northern half of the Gulf of California with Guaymas as the southern limit. They were discovered in the course of a general review of the family as it occurs in the Eastern Pacific. Since PILSBRY & LOWE's work, little has been done with the Eastern Pacific terebras until the last five years, a period that has produced six new taxa and several significant extensions of range. Of these six new taxa only one falls within the scope of this paper, *Terebra fitchi* BERRY, 1958, a species described from the outer coast of Baja California.

The family Terebridae is almost exclusively distributed in tropical waters with very few species occurring in the temperate zones; only one species ranges as far north as Santa Barbara, California (34° 20' 21" North Latitude) where it is reported as "rare". The bathymetric range for this group includes the intertidal zone with the probable lower limit at several hundred meters. DALL (1908) records the depth for a specimen of *Terebra lingualis* HINDS, dredged in Panama Bay, as 590 meters with a bottom temperature of 7.7° C. He hastened to point out that he did not consider the species living at that depth. On several occasions I have been on expeditions in the Gulf of California and out of Mazatlán

where living specimens of *T. lingualis* were trawled at depths in excess of 250 m. The optimum habitat for most of the Eastern Pacific species appears to be from mid-tide line to a depth of about 30 m. They seem to prefer a fine sandy bottom where they move about just under the surface, leaving a fairly typical groove behind them. An experienced diver, upon locating one of these trails across the sea floor will usually find the *Terebra* hidden under a small mound at one end of the trail; occasionally an uncovered apex will betray its location.

It is not my intention to review the numerous generic and subgeneric allocations of this family as it would require a complete taxonomic revision to correct the present confused and unsatisfactory arrangement. There is an adequate number of supraspecific taxa from which to choose should such a revision be attempted.

Most workers accept at least three fairly well defined divisions of the family on a generic level. These are based primarily on anatomical studies of the animal. *Terebra*, *sensu stricto* is typified by having a proboscis that forms a large muscular, evertible sac, in which the prey may be engulfed. There is evidence to suggest that some use a secretion from their poison gland to paralyze their prey. The radula is edentulous; eyes and tentacles are present. *Hastula* ADAMS may be differentiated by finding a radula with toxoglossate teeth as in *Conus*, pierced for the passage of the secretion of the poison gland. Eyes and tentacles are present. *Duplicaria* DALL* has a radula with a double row of arcuate solid teeth; no poison gland; and the eyes and tentacles are lacking. The species covered in this paper fall into the group *Terebra*, used in a generic sense. Since the supraspecific taxonomy of the family is in such a hopeless state, I have followed previous authors and conservatively as-

*DALL mistakenly believed that his *Duplicaria* of 1908 was a homonym of *Duplicaria* RAFINESQUE, 1833 and renamed it *Diplomeriza* in 1919. Since *Duplicaria* DALL, 1908 is not an exact homonym, it must be used and *Diplomeriza* DALL, 1919 placed in synonymy.

signed the species under discussion to the subgenus *Strioterebrum* SACCO, 1891.

The group is fairly well represented in the fossil record with a geologic range from the Cretaceous to Recent. A number of the Recent Eastern Pacific species has been recorded from the Pleistocene and a lesser number is represented in the Pliocene of the area. The common Recent species from the Western Atlantic, *Terebra dislocata* (SAY) has been reported by DALL, 1890 from the Miocene to Recent along the Atlantic Coast and as the variety *tantula* CONRAD from the Mississippi Eocene. This same species has been recorded from the Pliocene of Coyote Mountain, Imperial County, California (*vide* GRANT & GALE) by HANNA, 1926 as *T. gausapata* BROWN & PILSBRY; it has also been reported (*vide* GRANT) from the lower Pleistocene of Ventura, California. Since the Atlantic and Pacific Oceans were connected during the Miocene, it is not particularly surprising to find this form, known to have lived along the Atlantic Coast during the Miocene, in the Pliocene and lower Pleistocene of the Pacific Coast.

Only six species have been described from the Tertiary of California. One of these, *Terebra cooperi* ANDERSON, from the Temblor Formation, appears to be a Miocene representative of *Terebra*, *s. s.* PILSBRY & OLSSON (1946) described six new species and one new subspecies from the Jama and Canoa Formations (Pliocene) of Peru. This is an important work to take into account since many of the species described have analogous counterparts living in the Eastern Pacific.

TEREBRIDAE H. & A. ADAMS

Terebra BRUGUIÈRE, 1789

Terebra BRUGUIÈRE, Encyclop. Méthod., Vers, vol. 1, p. XV, 1789. (No species cited.) LAMARCK, Mém. Soc. Hist. Nat. Paris, 1799, p. 71. Sole species cited, *Buccinum subulatum* LINNAEUS. (A complete review of systematics concerning the genus *Terebra* may be found in HANNA & HERTLEIN, 1961, and will not be repeated here.) Type (by monotypy, LAMARCK, 1799), *Buccinum subulatum* LINNAEUS, Syst. Nat., Ed. 12, pp. 1205, 1767; Indo-Pacific; Recent.

(Subgenus) *Strioterebrum* SACCO, 1891

Strioterebrum SACCO, Molluschi dei Terreni Terziarii del Piemonte e della Liguria, Pt. 10, p. 33, 1891; DALL, Nautilus, vol. 21, p. 249, 1908; Bull. Mus. Comp. Zool., Harvard College, vol. 43, pp. 246, 248, 1908; WOODRING, Carnegie Inst., Publ. No. 385, p. 137, 1928.

"*Myurella* HINDS," COSSMAN, Ess. Paléo. Com., vol. 2, p. 49, 1896, not of HINDS, in SOWERBY'S Thes. Conch., vol. 1, *Terebra*, p. 171, 1845 (*vide* GRANT & GALE).

Type (by original designation), *Terebra basteroti* NYST; Mediterranean region, Miocene.

Shell small or medium sized with a distinct subsutural band and whorls sculptured with axial ribs and spiral threads or grooves throughout.

Geologic range: Cretaceous (*vide* COSSMAN, "*Myurella*"), Eocene (*vide* GRANT & GALE) to Recent.

Terebra (*Strioterebrum*) *adairensis* CAMPBELL, spec. nov.

(Plate 17, figures 3 to 5)

Shell medium in size, of a uniform light tan color; though beginning with the protoconch of 3½ to 4 black glassy whorls, the ensuing whorls are darker tan lightening anteriorly; early sculpture consists of a subsutural band with prominent tubercles and arched axial ribs; the ribs soon develop into a row of tubercles which, on the later whorls of the shell, are located just above the suture; on the last whorl, these tubercles lengthen to become axial ribs with residual tubercles; the shell has a narrow incised subsutural groove and whorls that are generally flat; it is covered by microscopic spiral striulae with nine to eleven raised spiral cords that intercept the axial sculpture to produce small nodes; there are eight to nine additional cords on the base; siphonal fasciole concave, anterior canal recurved, columella without plicae, aperture elongate.

Holotype: California Academy of Sciences, Department of Geology, Type Collection No. 12539

Paratypes: Two paratypes, collected with the holotype, are in the collection of Dorothy Brown, Los Angeles; two additional paratypes are in the collection of Mark Rogers, Loma Linda, California. See Table 1.

Type Locality: Bahía de Adair, approximately 15 miles north of Puerto Peñasco, Sonora, México (31° 24' North Latitude; 113° 43' West Longitude).

Range: Three specimens from San Luis Gonzaga Bay extend the range of this species to the eastern shore of Baja California, México, though it still appears to be limited to the northern portion of the Gulf of California.

Terebra adairensis belongs to a group of related species which includes *T. tuberculosa* HINDS, 1844 (Plate 17, figures 6 and 7), *T. cracilenta* LI, 1930 (Plate 17, figures 8 and 9), and *T. roperi* PILSBRY & LOWE, 1932 (Plate 17, figures 1 and 2). These species have in common one or more rows of tubercles sculpturing the whorls below the subsutural band. The most elaborately ornamented is *T. cracilenta* which may have up to nine primary and secondary rows of tubercles on the body whorl. *Terebra tuberculosa* is similar to *T. cracilenta* but has fewer rows and the tubercles are further apart.

With the exception of *Terebra cracilenta* the protoconchs of all are quite similar, consisting of 3½ to 4 whorls. That of *T. cracilenta* is more inflated and has traces of axial ribs on the last 1½ whorls as seen through a microscope. The early sculpture of *T. roperi* shows a

narrow subsutural band of nodes which lacks a well-defined subsutural groove and prominent axial ribs which end peripherally in tubercles. In contrast, *T. adairensis* has a greater apical angle and wide subsutural bands set off by subsutural grooves. The axial ribs are low with the peripheral tubercles less prominent. The axial ribs of *T. tuberculosa* are sharply protruding and only later do they develop into two rows of tubercles, the peripheral row appearing first. *Terebra cracilenta* displays similar axial ribs, but very early there appears a small row of nodes two-thirds the way down the axial ribs; within three or four more whorls a row of nodes develops below and two or more rows above this initial row thus allowing for quick identification of this species.

Terebra (Strioterebrum) churea CAMPBELL, spec. nov.

(Plate 17, figures 17, 18 and 24)

Shell small and slender, of white to light cream color, initial portion of the protoconch is dome-shaped and continues as a smooth glassy whorl of one and one-half turns followed by twelve whorls of the teleoconch; early sculpture of sharp axial ridges much narrower than the interspaces, later whorls convex with an impressed subsutural band on which there are axially lengthened curved nodes with convex portion to the left; there are nine axial cords distributed between the 22 to 24 axial ribs which are narrower than the interspaces and arched with the convex portion to the right; the last whorl contains twelve axial cords with two additional cords confined to the anterior canal; siphonal fasciole concave, columella with a faint suggestion of a fold; aperture elongate, anterior canal recurved.

Holotype: Santa Barbara Museum of Natural History Type Collection No. 03461.

Paratypes: One paratype is in the Type Collection of the Santa Barbara Museum of Natural History (No. 03462); two in the Type Collection of the San Diego Society of Natural History (Nos. 45222 and 45223); four in the John Q. and Rose Burch collection; two in the LeRoy Poorman collection; one in the B. Campbell collection; and one in the Mark Rogers collection.

Type Locality: The holotype was collected from the shore of Ensenada San Francisco, Guaymas, México, a long shallow bay that joins Bacochibampo Bay with San Carlos Bay. All of the paratypes were collected within a three mile radius of this area with the exception of Lowe's material for which the locality is merely given as "Guaymas". "La Grassa Id." is a small island just off the shore and within Ensenada San Francisco (27° 58' North Latitude; 111° 03' West Longitude). See Table 2.

This rare species shares several features with a group of small *Terebra* described by PILSBRY & LOWE (1932), *T. polypenus*, *T. corintoensis*, *T. montijoensis* and *T. sanjuanensis*. They are all generally less than 20 mm in length, with convex whorls sculptured by numerous axial ribs and spiral cords or grooves. I am indebted to Mr. Emery Chacé for the opportunity to compare *T. churea* with paratypes of the PILSBRY & LOWE species in the Type Collection of the San Diego Society of Natural History.

I have at hand photographs of the holotypes of most of the species described from the Eastern Pacific; with these and the comparative material, *T. churea* can be readily distinguished from the previously described species.

Explanation of Plate 17

- Figure 1: *Terebra roperi* PILSBRY & LOWE. (ex Campbell Collection) Chamela Bay, México. (x 3)
 Figure 2: Protoconch of Paratype SDSNH No. 502 b (x 5). Figure 3: *Terebra adairensis* CAMPBELL, spec. nov. Holotype, CAS No. 12539. (x 1½) Figure 4: *Terebra adairensis*. Paratype 2 (ex Brown Collection) Protoconch. (x 5) Figure 5: Same shell as in previous figure (x 2½) Figure 6: *Terebra tuberculosa* HINDS. (ex Campbell Collection) El Salvador; Protoconch (x 5) Figure 7: Same shell as in previous figure (x 2)
 Figure 8: *Terebra cracilenta* LI. (ex Campbell Collection) Tonalá, Chiapas, México. Protoconch (x 5)
 Figure 9: Same shell as in previous figure. (x 2) Figure 10: *Terebra ninfae* CAMPBELL. Puerto Madero, Chiapas, México. (x 5) Figure 11: Same shell as in previous figure. Protoconch (x 6) Figure 12: *Terebra dushanae* CAMPBELL, spec. nov. Holotype, CAS No. 12532 (x 5) Figure 13: Same shell as in previous figure. Protoconch (x 6) Figure 14: *Terebra bridgesi* DALL. (ex Campbell Collection) Puerto Madero, Chiapas, México (x 5½) Figure 15: Same shell as in previous figure. Protoconch (x 6) Figure 16: *Terebra bridgesi*. DALL. Lectotype USNM 9404 (James McLean, photo) (x 4) Figure 17: *Terebra churea* CAMPBELL, spec. nov. Paratype SDSNH 45222. Protoconch (x 5) Figure 18: *Terebra churea*. Paratype SBMNH No. 03462 (x 3)
 Figure 19: *Terebra tiarella* DESHAYES. Paratype of *T. fitchi* BERRY (ex Campbell Collection) (x 2)
 Figure 20: Same shell as in previous figure. Protoconch (x 5) *Terebra tiarella*. Holotype of *T. fitchi* BERRY. (ex Stanford Collection, No. SU 24715. Stanford University, photo. (x 1½) Figures 22, 23: *Terebra tiarella*. Co-types British Museum (Natural History) Dr. Robert Robertson, photo. (x1½) Figure 24: *Terebra churea*. Holotype. SBMNH No. 03461 (x 3) All photos by B. Campbell, except as otherwise noted.

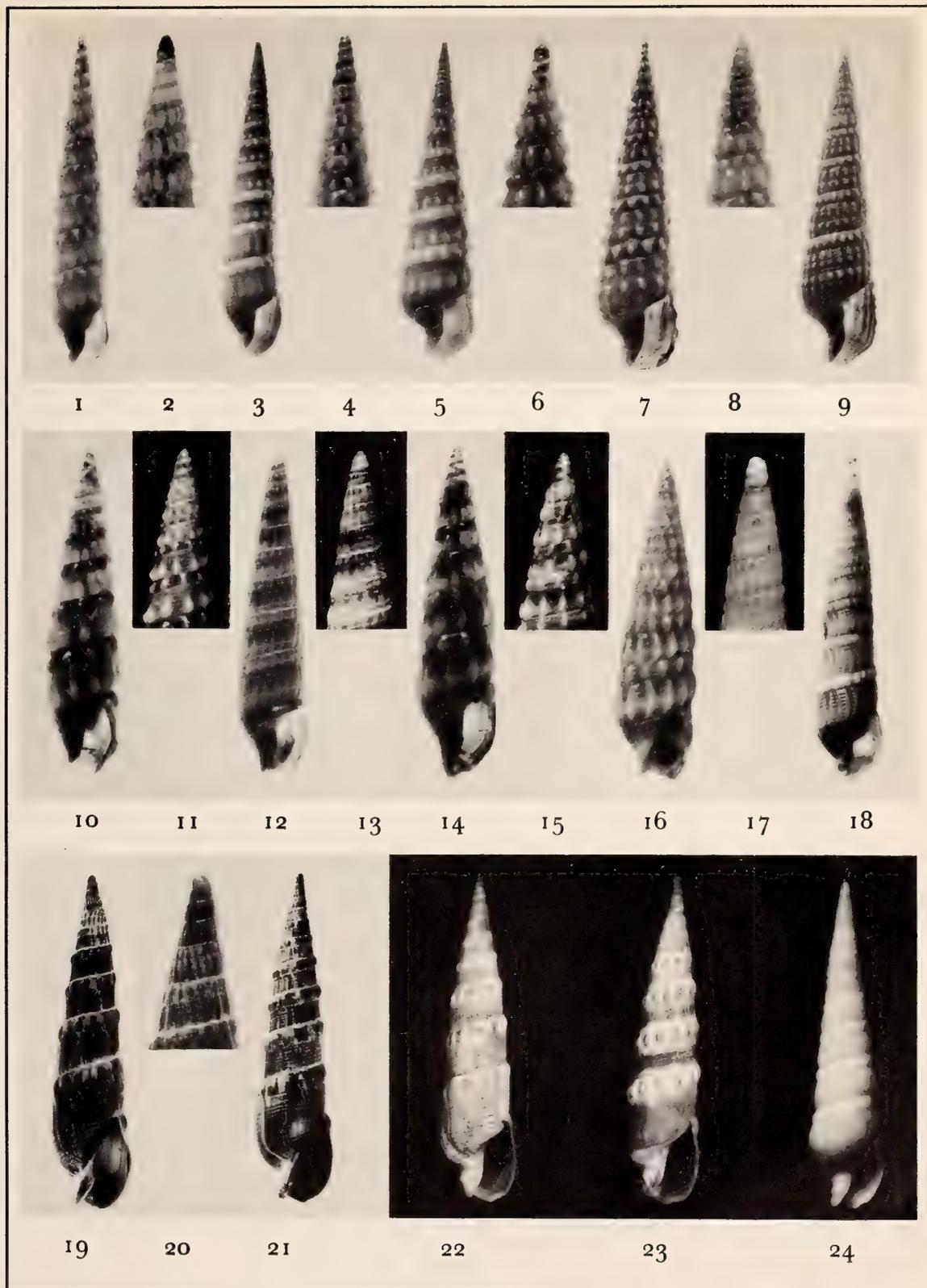


Table 1

Terebra (Strioterebrum) adairensis CAMPBELL, spec. nov.
(measurements in millimeters)

Specimen	Collection	Locality	Collector	width	length
Holotype	CAS 12539	Bahía de Adair, Sonora, México	Dorothy Brown	29.5	5.7
Paratypes 1 - 2	Brown coll.	Bahía de Adair, Sonora, México	Dorothy Brown	28.2	5.6
				19.7	4.8
Paratype 3	Rogers coll.	Bahía de Adair, Sonora, México	Mark Rogers	15.6	3.8
Paratype 4	Rogers coll.	Puerto Peñasco, Sonora, México	Mark Rogers	23.4	5.3
Hypotypes 1 - 2	Campbell coll.	San Luis Gonzaga Bay, B. C., México	B. Campbell	22.4	5.1
				20.6	5.2
Hypotype 3	Burch coll.	San Luis Gonzaga Bay, B. C., México	J. Q. Burch	15.4	3.9

The protoconch of *Terebra churea* serves as a differentiating character between it and the other small Panamic terebras; initially it is an eccentric dome followed by 1 to 1½ whorls. The protoconchs of the other small terebras have the usual 3 to 4 enlarging whorls usually associated with *Strioterebrum*. Since the remaining characters of *T. churea* are compatible with an assignment to *Strioterebrum* it is tentatively allocated to this subgenus.

Terebra (Strioterebrum) dushanae CAMPBELL, spec. nov.
(Plate 17, figures 12 and 13)

1961 *Terebra bridgesi* DALL, G. B. CAMPBELL, The Veliger 4 (1): 28, fig. 11 (not *T. bridgesi* DALL, 1908).

1961 *Terebra (Microtrypetes) sp.* J. H. McLEAN, Trans. San Diego Soc. Nat. Hist. 12 (28): 471. "Probably new".

1962 *Terebra cf. T. bridgesi* DALL, H. DuSHANE, The Veliger 5 (1): 49.

Shell minute, color brown with a light tan peripheral band which, on the earlier whorls, includes all but the subsutural band that remains brown; protoconch of 4½ glassy whorls of which the upper one third of each whorl

is brown and the remainder clear; the third whorl is the most inflated and usually the largest; the teleoconch consists of nine whorls; initial sculpture of straight axial ribs that are sharp and although separated by a fine line, are continuous and usually in line with the subsutural nodes; nodes and ribs are white; spiral sculpture indistinct other than the subsutural groove that divides the posterior third of the whorl; there may be one or two fine lines on the whorl proper, or none; the last whorl has 18 axial ribs; aperture elongate, anterior canal short and open; animal white.

Holotype: California Academy of Sciences, Department of Geology Type Collection No. 12532.

Paratypes: Since this species has been taken in number by several collectors, paratypes will be deposited in a number of major institutions. Other paratypes will remain in the collections cited in Table 3.

Type Locality: Specimens were collected at a low tide on sandbars, at Puertecitos, Baja California, México (30° 25' North Latitude; 114° 39' West Longitude).

This species belongs to a small group of minute terebras which are found in the Eastern Pacific among which are

Table 2

Terebra (Strioterebrum) churea CAMPBELL, spec. nov.
(measurements in millimeters)

Specimen	Collection	Locality	Collector	width	length
Holotype	SBMNH 03461	Ensenada San Francisco, Guaymas, México	Churea Expedition	17.4	3.9
Paratype 1	SBMNH 03462	dredged in 20 m, Bacochibampo Bay, Guaymas	Churea Expedition	15.7	3.6
Paratypes 2 - 5	Burch coll.	"La Grassa Id.", Guaymas, México	Rose Burch	14.4	3.2
				10.2	2.4
Paratypes 6 - 7	SDSNH 45222	Guaymas, México	H. N. Lowe	13.9	2.9
	SDSNH 45223			11.0	2.6
Paratypes 8 - 9	Poorman coll.	dredged in 20 m, off San Carlos Bay, Guaymas	LeRoy Poorman	8.8	2.5
				8.6	2.3
Paratype 10	Campbell coll.	dredged in 20 m, Bacochibampo Bay, Guaymas	B. Campbell	11.2	2.6
Paratype 11	Rogers coll.	dredged in 50 m, off Cabo Haro, Guaymas	Mark Rogers	7.4	1.8
			Ariel Expedition		

Terebra bridgesi DALL (Plate 17, figures 14 to 16) and *T. ninfae* CAMPBELL, 1961 (Plate 17, figures 10 and 11). *Terebra dushanae* has been recorded on several occasions in check lists of the Gulf of California as "*T. bridgesi* DALL", a species described from Panama. It was Mrs. Faye Howard who first recognized that this shell, living in the northern Gulf, was new to science and JAMES McLEAN (1961) reported it in his Bay of Los Angeles check list as "*Terebra (Microtrypetes) sp.*" A photograph of the lectotype of *T. bridgesi* DALL (Plate 17, figure 16), supplied by James McLean, and specimens of *T. bridgesi* from the Guatemala border provided the evidence that showed *T. dushanae* to be a distinct species. *Terebra dushanae* has consistently 50% more axial ribs, which are narrower, straighter, and less convex than in *T. bridgesi*. *Terebra bridgesi* has eight to ten spiral lines on each whorl and prominent subsutural grooves in contrast to *T. dushanae* which may have one to two spiral lines per whorl and ill-defined subsutural grooves. The remaining minute Panamic species, *T. mariato* PILSBRY & LOWE, 1932, has been placed in the subgenus *Microtrypetes*, which lacks a subsutural band altogether.

This species is named in honor of Mrs. Helen DuShane who was the first to compile and publish a complete check-list of the Puertecitos molluscan fauna.

Terebra (Strioterebrum) tiarella DESHAYES, 1857
(Plate 17, figures 19 to 23)

- 1857 *Terebra tiarella* DESHAYES. Jour. Conchyl. 6: 91, pl. 5, fig. 7.
1859 *Terebra tiarella* DESHAYES. Proc. Zool. Soc. London, p. 276. Not figured.
1860 *Terebra tiarella* DESHAYES, L. REEVE, Conch. Icon., 13, pl. 21, sp. 109 a, b.
1885 *Terebra tiarella* DESHAYES, G. W. TRYON, Jr., Man. Conch., 7: 8; pl. 12, figs. 38, 39.
1931 "*Terebra (Strioterebrum) albocincta* (CARPENTER) variety *hindsii* (CARPENTER)", U. S. GRANT, IV & H. R. GALE, Mem. San Diego Soc. Nat. Hist. 1: 469; pl. 32, fig. 35.
1958 *Terebra (Strioterebrum) fitchi* BERRY, Leaflets in Malacol., 1 (15): 89, 90. Not figured.
1958 *Terebra (Strioterebrum) fitchi* BERRY, A. M. KEEN, Sea shells of tropical west America, p. 491, fig. 962 a.

(these citations are only those considered to be pertinent, hence the list is not complete.)

Shell of medium size, slender, slopes nearly straight. Whorls about thirteen; protoconch smooth, glassy, and dark red, of 1½ whorls with an initial eccentric dome

Table 3

Terebra (Strioterebrum) dushanae CAMPBELL, spec. nov.
(measurements in millimeters)

Specimen	Collection	Locality	Collector	width	length
Holotype	CAS 12532	Puertecitos, Baja Calif., México	Donald Shasky	9.2	1.9
Paratypes 1 - 13	Shasky coll.	Puertecitos, Baja Calif., México	Donald Shasky	11.4 6.8	2.5 1.7
Paratypes 14 - 51	DuShane coll.	Puertecitos, Baja Calif., México	Helen DuShane	11.5 5.0	2.5 2.0
Paratypes 52 - 54	Sphon coll.	Puertecitos, Baja Calif., México	Gale Sphon, Jr.	7.2 4.8	2.0 1.2
Hypotype 1	SBMNH 03463	Bahía de Los Angeles, B. C., México	Faye Howard	6.9	1.8
Hypotypes 2 - 4	Burch coll.	San Luis Gonzaga Bay, B. C., México	J. Q. & R. Burch	7.3 7.0	1.9 1.8
Hypotypes 5 - 25	Campbell coll.	Agua de Chale, B. C., México	B. Campbell	10.0 6.6	2.1 1.7
Hypotypes 26 - 39	Shasky coll.	Agua de Chale, B. C., México	Donald Shasky	8.1 6.8	2.0 1.7
Hypotype 40	Howard coll.	Agua de Chale, B. C., México	Faye Howard	7.0	1.8
Hypotypes 41 - 50	DuShane coll.	Agua de Chale, B. C., México	Helen DuShane	9.0 6.5	2.0 2.0
Hypotypes 51 - 59	Sphon coll.	San Felipe, Baja California, México	Gale Sphon, Jr.	10.8 6.7	2.6 1.6

followed by a larger convex whorl; early whorls with 16 to 20 straight axial ribs which on later whorls usually fade to become almost imperceptible; subsutural band becomes wide and heavily nodose; spiral sculpture consists of six to eight minutely pitted incised lines between sutural fascioles, which on the last whorl number about 18; surface with microscopic striulae; aperture elongate, anterior canal short, open and recurved; siphonal fasciole rough and concave; columella twisted to left anteriorly, with a single weak fold; periostracum satiny reddish black and with the exception of the light siphonal fasciole and subsutural nodes the shell is an intense maroon.

After examining several hundred specimens of this species it became apparent that the species is quite variable. The color of the shell may be dark maroon and range through all shades to white. The axial ribs may persist on the later whorls and in some cases develop a small peripheral row of nodes.

Types: The two cotypes of *Terebra tiarella* DESHAYES are in the British Museum (Natural History). The holotype of *T. fitchi* BERRY is in the Type Collection of the Department of Paleontology, Stanford University. A paratype of *T. fitchi* is in my own collection and additional paratypes are in the collection of Dr. S. S. Berry under the number 24715.

Terebra tiarella was described by DESHAYES from the Cuming collection and the locality cited was Cape Natal (South Africa). DESHAYES' original figure of *T. tiarella* is so strikingly similar to specimens of *T. fitchi* from Bahía Santa María, Baja California, México, that a search was made to see if *T. tiarella* could be an earlier name for *T. fitchi*. Review of the literature disclosed that *T. tiarella* was listed by several authors as a species not found in the South African fauna. Pursuing this further, I sent several specimens of *T. fitchi*, including a paratype, to Mr. R. N. Kilburn at the University of Natal. His conclusions were (*in litteris*, October 25, 1962): "1. *Terebra tiarella* DESHAYES was based on shells in the Cuming collection, a notorious source of incorrect localities (Cuming did not keep labels with his specimens). 2. This species has never been 'rediscovered' in South Africa, let alone at the type locality, Cape Natal (=Durban). Nor have I seen any reference to its discovery elsewhere in the Indo-Pacific region. 3. All the specimens that you sent agree, in my opinion, very well indeed with the figures and description given by Reeve (Conch. Icon.). The large oblong aperture, prominent nodules and axial ribs on early whorls only seem unmistakable characters."

Although this appeared to be sufficient evidence for regarding *Terebra fitchi* a synonym of *T. tiarella*, I was certain only after receiving negatives from Dr. Robert Robertson of photographs he made at the British Museum (Natural History) of the cotypes of *T. tiarella* DES-

HAYES. Since *T. tiarella* is the older name it must be adopted for this Eastern Pacific species.

The locality of Cape Natal cited by Deshayes must be regarded as in error; therefore the type locality for *Terebra tiarella* is herein designated as Bahía Santa María, Baja California, México (24° 44' North Latitude; 112° 11' West Longitude).

Range: Long series of specimens studied in the collections at the San Diego Society of Natural History, Los Angeles County Museum, Stanford University, and the California Academy of Sciences appear to limit this species to the West Coast (Pacific) of Baja California. Several lots of specimens suggest that it may range as far north as San Diego, California.

GRANT & GALE (1931) figured a shell from Magdalena Bay (which is a few miles north of Bahía Santa María) and assigned it to "*Terebra (Strioterebrum) albocincta* (CARPENTER) variety *hindsii* (CARPENTER)". CARPENTER'S *T. hindsii* was described from Mazatlán and included in his "*T. albocincta*" complex together with his *T. subnodosa* and *T. rufocinerea*. I have at hand photographs of a paratype and a group of four specimens of *T. albocincta* CARPENTER and I fully agree with the notation on the museum label, ANSP No. 212190: *T. (Myurellina) variegata albocincta*; Paratype of *Myurella albocincta* CARPENTER. To substantiate this further I have on loan from the Santa Barbara Museum of Natural History 41 specimens of "*T. albocincta* (CARPENTER)" collected at Matanchen, Nayarit, México on the Churea Expedition. The majority of these are of the same form as the paratype of *T. albocincta* (CARPENTER), but the group as a whole intergrades with typical *T. variegata* GRAY, 1834. *Terebra albocincta* appears to be merely a darker color form of *T. variegata*. I include these facts because of GRANT & GALE'S suggestion that the shells from Magdalena Bay (those that I have assigned to *T. tiarella*) represent Carpenter's variety, *T. hindsii*. Should they in fact prove to be conspecific with *T. hindsii* then the name *T. hindsii* would have to be adopted for this species since it has nine months priority over *T. tiarella*. I am convinced that this is not the case. I have shells from Mazatlán which fit Carpenter's description of *T. hindsii* very well, and although morphologically they resemble the shells from the outer coast of Baja California, they belong to the *T. variegata* complex, a group in which the protoconch has approximately four smooth glassy whorls (see protoconch illustrations, Plate 17, figures 2, 4, and 6). The protoconchs of *T. tiarella* and its variations consistently have a paracentral nucleus and 1 to 1¼ subsequent whorls.

In the description of *Terebra fitchi* Dr. Berry pointed out that he knew of no species sufficiently similar to warrant special comparison with the possible exception

of *T. hindsii* (CARPENTER), but that color differences and CARPENTER's denial of microscopic striulation precluded that assignment. The final decision on *T. hindsii* will only be possible when the type material is studied.

ACKNOWLEDGMENTS

It takes the cooperation and help from many people and institutions to carry to completion a study of this nature, and to them I am sincerely grateful.

I am indebted to Mr. Emery Chace and the San Diego Society of Natural History, Drs. G Dallas Hanna and Leo G. Hertlein and the California Academy of Sciences, Mr. George Kanakoff and the Los Angeles County Museum, and Dr. A. Myra Keen and Stanford University for making available their time and material for study. I acknowledge with thanks the help of Mr. R. D. Burch, Mr. R. N. Kilburn, and Dr. Robert Robertson in tracking down Deshayes' elusive *Terebra tiarella*. I wish to thank Mr. James McLean for many "type" photographs he provided, and Mrs. Dorothy Brown, Mr. John Q. and Mrs. Rose Burch, Mrs. Helen DuShane, Mrs. Faye Howard, Capt. Xavier Mendoza, Mr. LeRoy Poorman, Mr. Mark Rogers, Dr. Donald Shasky, Mr. Gale Sphon and the Santa Barbara Museum of Natural History, and Dr. Norman Tebble and the British Museum (Natural History) for the loan of material and help in various other ways.

LITERATURE CITED

- BARTSCH, PAUL
1915. Report on the Turton Collection of South African marine mollusks, with additional notes on other South African shells contained in the United States National Museum. Bull. U. S. Nat. Mus. 91: 1-305; pls. 1-54
- BERRY, S. STILLMAN
1958. Notices of new Eastern Pacific Mollusca. — II. Leaflets in Malacol. 1 (15): 83-90
- CAMPBELL, BRUCE
1961. Four new Panamic gastropods. The Veliger 4 (1): 25-28; plt. 5 (1 July 1961)
- CARPENTER, PHILIP PEARSALL
1855-1857. Catalogue of the collection of Mazatlan shells in the British Museum collected by Frederick Reigen. London, xvi + 552 pp.
- DALL, WILLIAM HEALEY
1890. Contributions to the Tertiary fauna of Florida. Pt. 1, Pulmonate, opisthobranchiate and orthodont gastropods. Trans. Wagner Free Inst. Sci., 3: 1-200; pls. 1-12.
1908. Reports on the dredging operations off the west coast of Central America to the Galapagos, to the west coast of Mexico, and in the Gulf of California. . . . XIV. The Mollusca and Brachiopoda. Bull. Mus. Comp. Zool., Harvard 43 (6): 205-487; 22 pls.
- DESHAYES, GERARD PAUL
1857. Descriptions d'espèces nouvelles du genre *Terebra*. Journ. de Conchyl. 6: 65-102; pls. 3-5
1859. A general review of the genus *Terebra*, and a description of new species. Proc. Zool. Soc. London, 270-321
- DUSHANE, HELEN
1962. A checklist of mollusks for Puertecitos, Baja California, Mexico. The Veliger 5 (1): 39-50; 1 map (1 July 1962)
- GRANT, ULYSSES S., IV & HOYT RODNEY GALE
1931. Catalogue of the marine Pliocene and Pleistocene Mollusca of California and adjacent regions. Mem. San Diego Soc. Nat. Hist. 1: 1-1036; 15 figs.; pls. 1-32
- HANNA, G DALLAS
1926. Paleontology of Coyote Mountain, Imperial County, California. Proc. Calif. Acad. Sci., ser. 4, 14 (18): 427 to 503; 1 text fig.; pls. 20-29
- HANNA, G DALLAS & LEO G. HERTLEIN
1961. Large species of *Terebra* (Mollusca) from the Eastern Pacific. Proc. Calif. Acad. Sci., ser. 4, 30 (3): 67-80; pls. 6-7
- KEEN, A. MYRA
1958. Sea shells of tropical west America; marine mollusks from Lower California to Colombia. Stanford Univ. Press, xi + 624 pp.; illus. Stanford, Calif.
- LOWE, HERBERT N.
1935. New marine Mollusca from West Mexico, together with a list of shells collected at Punta Penasco, Sonora, Mexico. Trans. San Diego Soc. Nat. Hist. 8 (6): 15-34; pls. 1-4
- MCLEAN, JAMES H.
1961. Marine mollusks from Los Angeles Bay, Gulf of California. Trans. San Diego Soc. Nat. Hist. 12 (28): 449 to 476; figs. 1-3
- PILSBRY, HENRY AUGUSTUS
1931. The Miocene and Recent Mollusca of Panama Bay. Proc. Acad. Nat. Sci. Philadelphia 83: 427-440; 5 figs.; plt. 41
PILSBRY, HENRY AUGUSTUS & HERBERT N. LOWE
1932. West American and Central American mollusks collected by H. N. Lowe 1929-31. Proc. Acad. Nat. Sci. Philadelphia 84: 33-144; 6 figs.; pls. 1-17; 2 photographs
PILSBRY, HENRY AUGUSTUS & AXEL A. OLSSON
1941. A Pleiocene fauna from western Ecuador. Proc. Acad. Nat. Sci. Philadelphia 93: 1-79; pls. 1-19; 1 photograph
REEVE, LOVELL AUGUSTUS
1860. Conchologia Iconica. Monograph of the genus *Terebra*. 13: pls. 1-27
TRYON, GEORGE WASHINGTON, JR.
1885. Manual of Conchology. Monograph of the family Terebridae. 7: 1-64; pls. 1-12. Philadelphia

Mitridae and Terebridae
(Mollusca : Gastropoda)
of Malaita, Fiji, and Bileau Island, New Guinea

BY

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(1 Map)

RECENTLY THE SENIOR AUTHOR was sent large samplings of Mitridae for identification, almost simultaneously from three different Melanesian localities. These places are all situated within approximately 13 degrees of latitude and 33 degrees of longitude — a considerable distance, to be sure, but with no apparent barriers to hinder the free movement of mollusks, such as uncommonly great ocean depths completely separating the areas, or a wide thermal range. A striking recurrence of species in the different localities prompted the investigation of other studies concerning the same general area, as it seemed an unusual opportunity to make, for this group, an up-to-date survey of a comparatively limited geographical region.

During the early stages of this project, it was discovered that the junior author, studying Terebridae, had been paralleling the work on the mitrids from the same localities; coincidentally, with one exception he had been concerned with specimens from the same collectors. In order to avoid duplication of accounts and to conserve space, the two studies have been combined here.

Two major checklists were used for comparison, both compiled by Dr. Alan Solem of the Chicago Natural History Museum. One of these (SOLEM, 1953) not only concerns species from one of the islands where our collections were made (Malaita, British Solomon Islands), but also amounts to a revision of several earlier works on Solomon Islands mollusks — namely those by E. A. SMITH (1876, 1885), H. B. GUPPY (1887), DALL (1910), DAUTZENBERG (1910), and EYERDAM (1951). Therefore this paper (and its sequel: SOLEM, 1958) seemed a logical starting point on which to base a more modern list. An

other faunal list from the Solomon Islands (ABBOTT, 1958) was examined, but as it includes only a few common, widely-dispersed species in the groups with which we are concerned and since it added nothing new, this work has not been incorporated into our study.

Subsequent correspondence with Dr. Solem resulted in his generous offer to lend the specimens of Mitridae and Terebridae on which he had based his studies. Through careful comparison with that part of Solem's original material which is now in the Chicago Natural History Museum, we are reasonably well assured of the correct identities for those species appearing on all the lists. The more recently collected specimens are now in the possession of the original collectors, or in the collections of the authors of the present study.

The first of the three groups of shells studied was an assemblage of over 150 lots of Mitridae, comprising more than 70 species; the Burch material in *Terebra* contained 23 species. These were collected in 1930 by Mr. Walter J. Eyerdam from drift along a small beach at Suu, Malaita. Another series was sent by Mrs. Isobel Pert, who collected her shells on the shore of Bileau Island, Madang Harbor, New Guinea; her collection numbered about 60 species of *Mitra* and 30 of *Terebra* (see BURCH, 1963). The third group was from Mr. A. Jennings of Nadi, Fiji, who has been dredging and shore collecting in that area for several years. Approximately 75 mitrid species and 40 of *Terebra* have been identified from his material. Since the *Mitra* collection of Mr. Ditlev Thaanum is also temporarily on loan to the senior author for study, the 43 species he collected in

1940 with T. T. Dranga have been included also, in a separate column which does not appear in the *Terebra* list.

All of our identifications, whether among those on the published lists or not, have been carefully checked with the type figures and original descriptions. Since many of these figures are poorly delineated, certain of the species are difficult to identify positively by this method alone. Only a study of the holotypes would enable a worker to differentiate among some of the species as depicted in the monographs — if, indeed, some are not synonymous. However, due to Dr. Solem's cooperation in sending his material for comparison, the final outcome should present a minimal number of misidentifications.

The results of our work have been tabulated for easy comparison among the different localities, and the species cited on the earlier lists have been included. It will be noted that many species have been added to the published records through material used in this study; there are 46 species of *Mitra* and 15 of *Terebra* not previously recorded from the Solomon Islands. This does not necessarily mean that ranges have been extended, but only that certain species had not formerly been recorded from some of the localities.

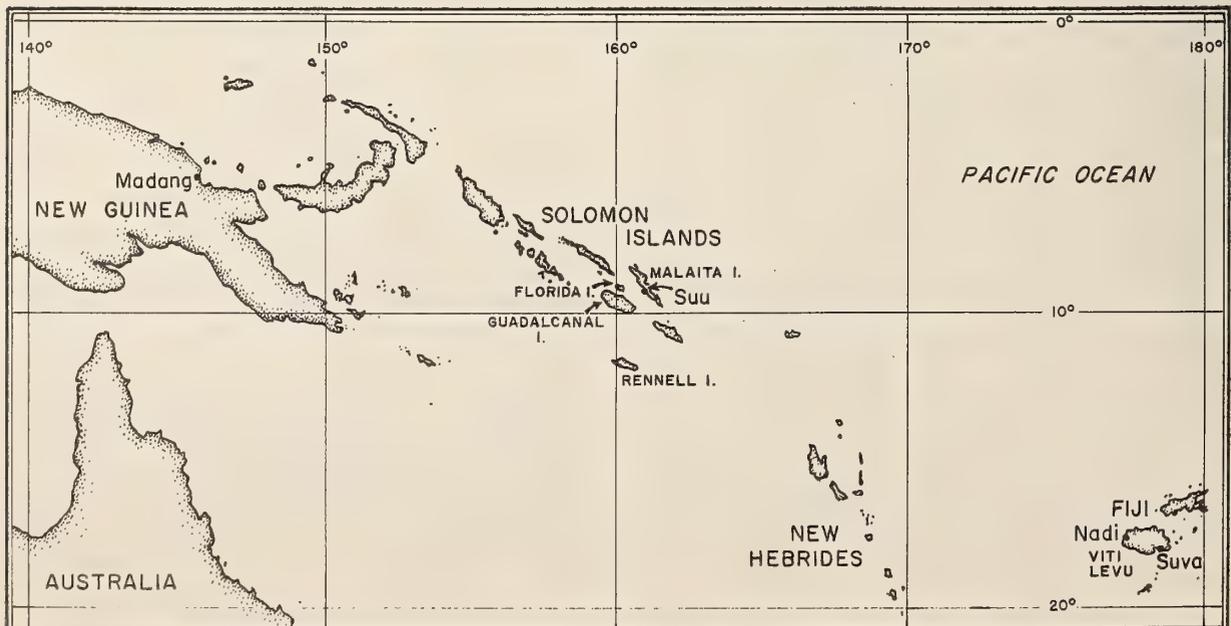
We wish to point out that none of the lists in this paper is intended as a complete checklist for its respective area; each group represents only a typical sampling by an individual within a comparatively limited time.

In order to simplify the alphabetical listing of species, they have been assigned to as few generic groups as

possible; most collectors, with relatively small collections of *Mitra* and *Terebra*, find a more specialized classification confusing. Since no systematic work is intended in this paper, we have therefore adopted approximately the same minimal taxa mentioned by KURODA and HABA (1952), using for the Mitridae only the broad groups *Pusia*, *Vexillum*, *Mitra*, *Strigatella*, *Imbricaria* and *Cylindromitra*; for the Terebridae we have used only *Terebra*, *Duplicaria* and *Hastula*. This is roughly the same classification used by GARRETT (1880) in his similar study of the Polynesian Mitridae, and it facilitates the locating of species-names on an alphabetical list.

We have followed Dr. Solem's example in listing in parentheses only the more obvious synonyms, to assist collectors in correlating their specimens with our tables. In some instances, nomenclatural changes have taken place since the SOLEM papers were published; all species appear here under what we believe to be the presently valid names, with the invalid names cited as synonyms. A few species misidentified in the SOLEM material are listed here under the correct names, with the incorrect names added in brackets. The catalog number of the Chicago Natural History Museum is given for each lot examined from that source. Unidentified species have been omitted, as they serve no useful purpose in a faunal study.

Even if it were not premature to do so, it would be unwise to attempt to make satisfactory conclusions from a checklist of this sort. The conditions under which the separate collections were made are certain to have



differed widely; for example, Mr. Jennings has been dredging intensively for a number of years in Fiji, in both shallow and relatively deep water. Mr. Thaanum also dredged there, but only for a comparatively short time, and probably not more than once at each station. Mrs. Eyerdam's — but even these two apparently similar circumstances differ, because the former collection was made throughout an entire year, while the latter was probably completed within a few days. Some of the earlier collections tabulated by Solem could have been made within a few hour's time — perhaps during one tide, though one of these (Fox collection) was made over a period of thirty years while Dr. Fox was doing medical missionary work in the Solomon Islands. Conditions of weather, season, ecology, length of time spent in making the collection, and many other important factors must be considered in evaluating any faunal study. Since the circumstances necessarily vary so widely in these instances, it would be inappropriate to consider the present tabulation as anything more than a checklist of authenticated species that have been collected at each of the localities. Only a few broad trends may be noted, such as the occurrence of some species at all stations, or the relative scarcity of certain others that are reported at only one or two localities.

The tabulations are interesting, though again it should be stressed that no conclusions as to the relative rarity of species, or to their general distribution, should be drawn at this time. The arrangement of plus (+) and minus (—) signs in the various columns, indicating the presence or absence, respectively, of species at different localities, offers 64 possibilities for different combinations of the symbols for the six columns of Mitridae, while the number of possible combinations for the five-column list of Terebridae is 32 (based on the binomial theorem). The appearance of only one or two plus signs for any species might be interpreted as indicating its relatively restricted distribution in the total area considered, whereas a plus sign in each of five or six columns could be interpreted as indicating a more widely distributed species. If we consider only the broader aspects of this survey, disregarding at the present time the possibilities implicit in the many different combinations of symbols seen in the checklist, the results of the survey can perhaps best be summarized briefly in another table, as follows:

	Mitridae (6 columns)	Terebridae (5 columns)
Number of species noted in:		
any one column	.....48	.....15
any 2 columns	.....41	.....21
any 3 columns	.....15	.....6
any 4 columns	.....17	.....8
any 5 columns	.....6	.....1
all 6 columns	.....2	

It is hoped that further similar tabulations may be made for these and other adjacent localities, so that at some future date the relative population density and the distributional pattern may be more clearly evident for these as well as other species.

ACKNOWLEDGMENT

We are extremely grateful to Dr. Alan Solem for his ready cooperation and prompt response to our inquiries. For their generosity and helpfulness, we also wish to express our deep appreciation to the various collectors of the material cited in this paper. It is understood that both Mr. Eyerdam and Mr. Jennings expect to publish more complete faunal lists for their particular localities, and we have no desire to intrude upon their plans in this regard. There are unquestionably many species not mentioned in the present list, from each of the regions cited; our contribution has a different purpose, namely that of comparing species from more or less adjacent areas. Future work may extend the study in other directions.

Our sincere thanks go also to Emily Reid for her excellent adaptation of the maps of the area considered in this paper.

EXPLANATION OF TABLES 1 AND 2

Specimens of the species listed are contained in various collections, as designated by the following code:

B	R. D. Burch (Houston)
C	J. M. Cate (Los Angeles)
E	W. J. Eyerdam (Seattle)
J	A. Jennings (Nadi, Fiji)
P	I. Pert (Madang, New Guinea)
T	D. Thaanum (Honolulu)
CNHM	Chicago Natural History Museum

The columns have been arranged to indicate an east-to-west direction, following the same general pattern as the prevailing winds and ocean currents in the areas covered.

Data for columns 1 to 6, Table 1 (Mitridae)

Column 1: Thaanum, 1940 - Viti Levu, Fiji (and nearby islets)

Column 2: Jennings, 1962 - Viti Levu, Fiji (and nearby islets)

Column 3: Eyerdam, 1930 - Suu, Malaita Island, British Solomons

Column 4: Solem, 1953 - Malaita and Guadalcanal Islands

Column 5: Solem, 1958 - Florida and Bougainville Islands

Column 6: Pert, 1962 - Bileau Island, Madang Harbor, New Guinea

Table 2 (Terebridae)

The arrangement of columns is exactly the same as in Table 1 except that Column 1 (Thaanum, Fiji) has been omitted.

Table 1

	Fiji		Solomon Islands		New Guin.	
	Thaanum, 1940	Jennings, 1962	Eyerdam, 1930	Solem, 1953	Solem, 1958	Pert, 1962
<i>Pusia</i> SWAINSON, 1840						
<i>adamsoni</i> (REEVE, 1844) (J)	—	+	—	—	—	—
<i>affinis</i> (REEVE, 1844) (E)	—	—	+	—	—	—
<i>alveolus</i> (REEVE, 1845) (E)	—	—	+	—	—	—
<i>amabilis</i> (REEVE, 1845) (J, E)	—	+	+	—	—	—
<i>aureolata</i> (REEVE, 1844) (J, E, C, CNHM 44863)	—	+	+	+	+	—
<i>consanguinea</i> (REEVE, 1845) (T, E, C)	+	—	+	—	—	+
<i>crocata</i> (LAMARCK, 1811) (C)	—	—	—	—	—	+
<i>discoloria</i> (REEVE, 1845) (J, E, P, C)	—	+	+	+	—	+
<i>ficulina</i> (LAMARCK, 1811) (E)	—	—	+	+	—	—
<i>leucodesma</i> (REEVE, 1845) (J, E)	—	+	+	—	—	—
<i>luculenta</i> (REEVE, 1845) (T, C)	+	—	—	+	—	—
<i>microzonias</i> (LAMARCK, 1811) (E, C)	—	—	+	—	—	+
<i>muriculata</i> (LAMARCK, 1811) (E)	—	—	+	—	—	—
<i>pardalis</i> (KÜSTER, 1841) (E)	—	—	+	—	+	—
<i>patriarchalis</i> (LAMARCK, 1811) (E, C)	—	—	+	—	—	+
<i>porphyretica</i> (REEVE, 1844) (E, C)	—	—	+	—	—	+
<i>rosea</i> (SWAINSON, 1835) (E)	—	—	+	—	—	—
<i>tuberosa</i> (REEVE, 1845) (J, C)	—	+	—	—	—	+
Totals (18 species)	2	6	14	4	2	7
<i>Vexillum</i> RÖDING, 1798						
<i>acupicta</i> (REEVE, 1844) (T, J, C)	+	+	—	—	—	—
<i>amanda</i> (REEVE, 1845) (J, E)	—	+	+	—	—	—
<i>arracanensis</i> (SOWERBY, 1874) (E, C)	—	—	+	—	—	+
<i>cadaverosum</i> (REEVE, 1844) (J, E, C)	—	+	+	—	—	+
<i>caffrum</i> (LINNAEUS, 1758) (J)	—	+	—	—	—	—
<i>comptum</i> (A. ADAMS, 1853) (J, C)	—	+	—	—	—	+
<i>coronatum</i> (HELBLING, 1779) (J, C)	—	+	—	—	—	—
<i>costellaris</i> (LAMARCK, 1811) (E)	—	—	+	—	—	—
<i>crebriliratum</i> (REEVE, 1844) (J, E, C)	—	+	+	—	—	+
<i>cruentatum</i> (REEVE, 1844) (T, J, E, C)	+	+	+	+	+	—
<i>cumingii</i> (REEVE, 1844)	—	—	—	+	—	—
<i>deshayesii</i> (REEVE, 1844)	—	—	—	+	—	—
<i>exasperatum</i> (GMELIN, 1791) (<i>arenosum</i> LAMARCK, 1811) (J, E, C)	—	+	+	—	—	+
<i>exquisitum</i> (GARRETT, 1873) (C)	—	—	—	—	—	+
<i>flistriatum</i> (SOWERBY, 1874) (J, C)	—	+	—	—	—	+
<i>formosense</i> (SOWERBY, 1890) (J, C)	—	+	+	—	—	—
<i>granosum</i> (GMELIN, 1791) (C)	—	—	—	—	—	+
<i>gruneri</i> (REEVE, 1844) (E)	—	—	+	—	+	—
<i>intertaeniatum</i> (SOWERBY, 1874) (T, J, C)	+	+	—	—	—	+
<i>ligatum</i> (A. ADAMS, 1853) (C)	—	—	—	+	—	+

<i>longispirum</i> (SOWERBY, 1874) (T, J, C)	+	+	-	-	-	-
<i>lubens</i> (REEVE, 1845) (E)	-	-	+	+	-	-
<i>lyratum</i> (LAMARCK, 1822) (J, E)	-	+	+	-	-	-
<i>mica</i> (REEVE, 1845) (J)	-	+	-	-	-	-
<i>michau</i> (CROSSE & FISCHER, 1864) (J)	-	+	-	-	-	-
<i>nodiliratum</i> (A. ADAMS, 1853) (T, J, E, P, C)	+	+	+	-	-	+
<i>noduliferum</i> (A. ADAMS, 1853)	-	-	-	+	-	-
<i>obeliscum</i> (REEVE, 1844) (J, E, C)	-	+	+	+	+	+
<i>obtusispinosum</i> (SOWERBY, 1874) (T, J, C)	+	+	-	-	-	-
<i>pacificum</i> (REEVE, 1845) (J)	-	+	-	-	-	-
<i>plicarium</i> (LINNAEUS, 1758) (E, C, CNHM 44868)	-	-	+	+	+	+
<i>radius</i> (REEVE, 1845) (J)	-	+	-	-	-	-
<i>rectilateralis</i> (SOWERBY, 1874) (T, E, C)	+	-	+	-	-	+
<i>rigidum</i> (SWAINSON, 1821) (T, J, E, P, C)	+	+	+	-	-	+
<i>rubellum</i> (ADAMS & REEVE, 1848) (E)	-	-	+	-	-	-
<i>rufoflosum</i> (E. A. SMITH, 1876) (J)	-	+	-	+	-	-
<i>rugosum</i> (GMELIN, 1791) (<i>corrugatum</i> LAMARCK, 1811) (T, J, E, C; [CNHM 44867 <i>vulpeculum</i>])	+	+	+	+	+	+
<i>salmonia</i> (SOWERBY, 1874) (J)	-	+	-	-	-	-
<i>sanguisugum</i> (LINNAEUS, 1758) (<i>stigmatarium</i> LAMARCK) (T, J, E, C)	+	+	+	-	+	-
<i>sanguisugum caeruleum</i> (DAUTZENBERG & BOUGE, 1923) (J, P)	-	+	-	-	-	+
<i>sculptilis</i> (REEVE, 1845) (E, C)	-	-	+	-	-	+
<i>semifasciatum</i> (LAMARCK, 1811) (T, J, E, C)	+	+	+	+	-	+
<i>subtruncatum</i> (SOWERBY, 1874) (T, J, E, P, C; [CNHM 44862 <i>militaris</i>])	+	+	+	+	-	+
<i>vittatum</i> (SWAINSON, 1821) (J)	-	+	-	-	-	-
<i>vulpeculum</i> (LAMARCK, 1811) (T, J)	+	+	-	-	-	-
Totals (45 species)	13	31	22	12	6	20

Mitra LAMARCK, 1799

<i>aethiops</i> REEVE, 1845 (E, C)	-	-	+	+	-	+
<i>aurantia</i> (GMELIN, 1791) (E)	-	-	+	-	-	-
<i>avenacea</i> REEVE, 1845 (J, C)	-	+	-	-	-	+
<i>boissaci</i> MONTROUZIER, 1860 (T, J, E, C)	+	+	+	-	-	+
<i>caerulea</i> REEVE, 1844	-	-	-	+	-	-
<i>cardinalis</i> (GMELIN, 1791) (J, E, C, CNHM 44878)	-	+	+	+	-	+
<i>casta</i> (GMELIN, 1791) (P)	-	-	-	-	-	+
<i>chrysalis</i> REEVE, 1844 (T, J, E, C)	+	+	+	-	-	+
<i>chrysostoma</i> (SWAINSON, 1835) (J, E)	-	+	+	-	-	-
<i>circula</i> KIENER, 1839 (J, C)	-	+	-	-	-	-
<i>clathrus</i> (GMELIN, 1791) (<i>crenifera</i> LAMARCK) (J, C)	-	+	-	-	-	-
<i>crassa</i> SWAINSON, 1821 (T, J, C)	+	+	-	-	-	-
<i>cucumerina</i> LAMARCK, 1811 (J, E)	-	+	+	-	-	-
<i>eremitarum</i> RÖDING, 1798 (<i>adusta</i> LAMARCK) (T, J, E, C, CNHM 44865)	+	+	+	+	+	+
<i>ferruginea</i> LAMARCK, 1811 (C, CNHM 44864)	-	-	-	+	+	+
<i>flaris</i> (LINNAEUS, 1758) (<i>nexilis</i> MARTYN) (T, J, E, C, CNHM 44861)	+	+	+	+	+	-
<i>fraga</i> QUOY & GAIMARD, 1833 (<i>peregra</i> REEVE) (E, C)	-	-	+	-	+	+

	Fiji		Solomon Islands		New Guin.	
	Thaanum, 1940	Jennings, 1962	Eyerdam, 1930	Solem, 1953	Solem, 1958	Pert, 1962
<i>funerea</i> REEVE, 1844 (E)	—	—	+	—	—	—
<i>granatina</i> LAMARCK, 1811 (J, C)	—	+	—	—	—	+
<i>imperialis</i> RÖDING, 1798 (<i>digitalis</i> CHEMNITZ) (T, E)	+	—	+	—	—	—
<i>interlirata</i> REEVE, 1844 (J)	—	+	—	—	—	—
<i>lugubris</i> SWAINSON, 1821 (T, J, C)	+	+	—	—	—	—
<i>mitra</i> (LINNAEUS, 1758) (<i>episcopalis</i> LINNAEUS) (T, J, E, C)	+	+	+	+	—	+
<i>novaeollandiae</i> SOWERBY, 1874 (J)	—	+	—	—	—	—
<i>ocellata</i> SWAINSON, 1832 (C)	—	—	—	—	—	+
<i>olivaeformis</i> SWAINSON, 1821 (J, C)	—	+	—	—	—	+
<i>papalis</i> (LINNAEUS, 1758) (J)	—	+	—	—	—	—
<i>papilio</i> (LINK, 1808) (<i>sphaerulata</i> MARTYN) (T, E, C)	+	—	+	—	—	+
<i>peasei</i> DOHRN, 1860 (J)	—	+	—	—	—	—
<i>peculiaris</i> REEVE, 1845 (C)	—	—	—	—	—	+
<i>philippinarum</i> A. ADAMS, 1853 (T, J, E, C, CNHM 44870)	+	+	+	+	—	+
<i>polita</i> REEVE, 1844 (T, E)	+	—	+	—	—	—
<i>pretiosa</i> REEVE, 1844 (J, C)	—	+	—	—	—	—
<i>rotundilirata</i> REEVE, 1844 (T, J, E, C)	+	+	+	—	—	+
<i>rubiginosa</i> REEVE, 1844 (J)	—	+	—	—	—	—
<i>rubritincta</i> REEVE, 1844 (E, C)	—	—	+	—	—	+
<i>rufomaculata</i> SOUVERBIE, 1860 (J)	—	+	—	—	—	—
<i>semisculpta</i> ADAMS & REEVE, 1848 (J, C)	—	+	—	—	—	—
<i>sophiae</i> CROSSE, 1860 (J)	—	+	—	—	—	—
<i>stictica</i> (LINK, 1808) (<i>pontificalis</i> LAMARCK, 1811) (T, J, CNHM 44877)	+	+	—	+	+	—
<i>tabanula</i> LAMARCK, 1811 (C)	—	—	—	—	—	+
<i>telum</i> SOWERBY, 1874 (E, C [<i>aurantia</i> GMELIN CNHM 44866, 1 of two specimens])	—	—	+	+	—	+
<i>tiarella</i> A. ADAMS, 1853 (T, J, E, C [<i>aurantia</i> GMELIN, CNHM 44866, 1 of 2 specimens])	+	+	+	+	—	+
<i>ticaonica</i> REEVE, 1844 (T, J, E, C)	+	+	+	—	—	+
<i>turgida</i> REEVE, 1845 (C)	—	—	—	—	—	+
<i>variegata</i> REEVE, 1844 (T)	+	—	—	—	—	—
<i>verrucosa</i> REEVE, 1845 (T, J, C)	+	+	—	—	—	—
<i>vexillum</i> REEVE, 1844 (CNHM 44873)	—	—	—	+	+	—
<i>woldemarii</i> KIENER, 1839 (E)	—	—	+	—	—	—
Totals (49 species)	17	30	22	12	6	23

<i>Strigatella</i> SWAINSON, 1840						
<i>auriculoides</i> (REEVE, 1845) (T, E, C)	+	—	+	—	—	+
<i>decurtata</i> (REEVE, 1845) (E)	—	—	+	—	—	—
<i>litterata</i> (LAMARCK, 1811) (T, J, E, C)	+	+	+	—	—	+
<i>lutea</i> (QUOY & GAIMARD, 1833) (<i>acuminata</i> SWAINSON) (T, E, C)	+	—	+	—	—	+
<i>paupercula</i> (LINNAEUS, 1758) (J, E, C, CNHM 44860)	—	+	+	+	—	+
<i>pellisserpentis</i> (REEVE, 1844) (J, E, C)	—	+	+	—	—	+
<i>retusa</i> (LAMARCK, 1811) (T, J, E, C)	+	+	+	—	—	+
<i>scutulata</i> (GMELIN, 1791) (T, J, E)	+	+	+	—	—	—
<i>tigrina</i> (A. ADAMS, 1853) (C)	—	—	—	—	—	+
<i>virgata</i> (REEVE, 1844) (E, CNHM 44879)	—	—	+	+	—	—
Totals (10 species)	5	5	9	2	0	7
<i>Imbricaria</i> SCHUMACHER, 1817						
<i>conica</i> SCHUMACHER, 1817 (T, J, C, CNHM 44876)	+	+	—	+	+	—
<i>punctata</i> (SWAINSON, 1821) (C)	—	—	—	—	—	+
<i>vanikorensis</i> (QUOY & GAIMARD, 1833) (E)	—	—	+	—	—	—
Totals (3 species)	1	1	1	1	1	1
<i>Cylindromitra</i> P. FISCHER, 1884						
<i>crenulata</i> (GMELIN, 1791) (T, J) [<i>Conus mitratus</i> BRUGUIÈRE; CNHM 44875]	+	+	—	—	—	—
<i>dactylus</i> (LINNAEUS, 1758) (T, J, C) [<i>fenestrata</i> LAMARCK; CNHM 44874]	+	+	—	+	—	—
<i>fenestrata</i> (LAMARCK, 1811) (J, E, C)	—	+	+	—	—	—
<i>nucea</i> (GMELIN, 1791) (T, J, E)	+	+	+	—	—	—
Totals (4 species)	3	4	2	1	0	0
Totals, all species:						
<i>Pusia</i> 18 species	2	6	44	4	2	7
<i>Vexillum</i> 45 species	13	31	22	12	6	20
<i>Mitra</i> 49 species	17	30	22	12	6	23
<i>Strigatella</i> 10 species	5	5	9	2	0	7
<i>Imbricaria</i> 3 species	1	1	1	1	1	1
<i>Cylindromitra</i> 4 species	3	4	2	1	0	0
128 species, all localities	41	77	70	32	15	58

Table 2

	Fiji	Solomon Islands	New Guin.
	Jennings, 1962	Eyerdam, 1930	Pert, 1962
		Solem, 1953	Solem, 1958
<i>Duplicaria</i> DALL, 1908 (<i>Diplomeriza</i> DALL, 1919)			
<i>australis</i> (E. A. SMITH, 1873) [<i>dussumieri</i> KIENER] (J, B, CNHM 11273; excluded from SOLEM, 1953, as collected at New Ireland)	+	—	—
<i>raphanula</i> (LAMARCK, 1822) (P, B)	—	—	+
Totals (2 species)	1	0	1

	Fiji	Solomon Islands		New Guin.	
	Jennings, 1962	Eyerdam, 1930	Solem, 1953	Solem, 1958	Pert, 1962
<i>Hastula</i> H. & A. ADAMS, 1853					
<i>casta</i> (HINDS, 1844) (E, J, B)	+	+	—	—	+
<i>concinna</i> (DILLWYN, 1817) (<i>verreauxi</i> DESHAYES) (E, J, P, B)	+	+	—	—	+
<i>caerulescens</i> (LAMARCK, 1822) (<i>hectica</i> LINNAEUS) (E, J, B, CNHM 45094)	+	+	+	—	+
<i>lanceata</i> (LINNAEUS, 1767) (J, P, B)	+	—	—	—	+
<i>penicillata</i> (HINDS, 1844) (J, B)	+	—	—	—	+
<i>solida</i> (DESHAYES, 1857) (<i>clarkei</i> M. SMITH) (J, P, B)	+	—	—	—	+
Totals (6 species)	6	3	1	0	6
<i>Terebra</i> BRUGUIÈRE, 1789					
<i>affinis</i> GRAY, 1834 (E, J, P, B, CNHM 44649) [<i>cerithina</i> LAMARCK]	+	+	+	—	+
<i>albicostata</i> ADAMS & REEVE, 1850 (J, B)	+	—	—	—	—
<i>amanda</i> HINDS, 1844 (J, B)	+	+	—	—	—
<i>anilis</i> (RÖDING, 1798) (<i>straminea</i> GRAY) (E, J, P, B)	+	+	—	—	+
<i>archimedes</i> DESHAYES, 1859 (J, B)	+	—	—	—	—
<i>areolata</i> (LINK, 1806) (<i>muscaria</i> LAMARCK) (E, J, P, B, CNHM 44982 [<i>tigrina</i> LAMARCK])	+	+	+	+	+
<i>argus</i> HINDS, 1844 (J, P, B)	+	—	—	—	+
<i>babylonia</i> LAMARCK, 1822 (J, P, B)	+	—	—	—	+
<i>cancellata</i> QUOY & GAIMARD, 1832 (E, J, B, [? <i>columellaris</i> HINDS])	+	+	—	—	+
<i>cerithina</i> LAMARCK, 1822 (<i>pulchra</i> HINDS) (J, B)	+	—	—	—	+
<i>chlorata</i> LAMARCK, 1822 (E, J, B)	+	+	—	—	—
<i>cingulifera</i> LAMARCK, 1822 (E, J, B)	+	+	—	+	+
<i>columellaris</i> HINDS, 1844 (E, J, P, B, CNHM 83689)	+	+	+	—	+
<i>conspersa</i> HINDS, 1844 (J, B)	+	—	—	—	—
<i>crenulata</i> (LINNAEUS, 1758) (E, J, P, B, CNHM 45078)	+	+	+	—	+
<i>cumingi</i> DESHAYES, 1857 (J, B)	+	—	—	—	—
<i>dimidiata</i> (LINNAEUS, 1758) (E, J, P, B, CNHM 44985)	+	+	+	—	+
<i>eburnea</i> HINDS, 1844 (B)	—	—	—	—	+
<i>exigua</i> DESHAYES, 1859 (J, B)	+	—	—	—	+
<i>felina</i> (DILLWYN, 1817) (<i>tigrina</i> GMELIN) (E, J, P, B)	+	+	—	—	+
<i>flavescens</i> DESHAYES, 1859 (E, J, B)	+	+	—	—	—
<i>funiculata</i> HINDS, 1844 (J, B)	+	—	—	—	+
<i>guttata</i> (RÖDING, 1798) (<i>oculata</i> DILLWYN) (J, P, B)	+	—	—	—	+
<i>laevigata</i> GRAY, 1834 (E, J, P, B)	+	+	—	—	+

<i>langfordi</i> PILSBRY, 1921 (J, B)	+	-	-	-	-
<i>lauta</i> PEASE, 1869 (J, B)	+	-	-	-	+
<i>maculata</i> (LINNAEUS, 1758) (E, J, B, CNHM 45094)	+	+	+	-	+
<i>marmorata</i> DESHAYES, 1859 (P, B)	-	-	-	-	+
<i>multistriata</i> SCHEPMAN, 1913 (J)	+	-	-	-	-
<i>nebulosa</i> SOWERBY, 1825 (J, B)	+	-	-	-	+
<i>nitida</i> HINDS, 1844 (E, B)	-	+	-	-	+
<i>paucistriata</i> (E. A. SMITH, 1873) (J, B)	+	-	-	-	+
<i>pertusa</i> (BORN, 1780) (J, P, B)	+	-	-	-	+
<i>plumbea</i> QUOY & GAIMARD, 1832 (E, B)	-	+	-	-	+
<i>polygyrata</i> DESHAYES, 1859 (E, J, B)	+	+	-	-	-
<i>roseata</i> ADAMS & REEVE, 1850 (B)	-	-	-	-	+
<i>scabrella</i> LAMARCK, 1822 (E, B)	-	+	-	-	-
<i>subulata</i> (LINNAEUS, 1767) (E, J, P, B, CNHM 44981)	+	+	+	-	+
<i>textilis</i> HINDS, 1844 (E, J, B)	+	+	-	-	-
<i>tiurensis</i> SCHEPMAN, 1913 (J)	+	-	-	-	-
<i>turrita</i> (E. A. SMITH, 1873) (J, B)	+	-	-	-	-
<i>undulata</i> GRAY, 1834 (J, P, B)	+	-	-	-	+
<i>violascens</i> HINDS, 1844 (J)	+	-	-	-	-
Totals (43 species)	37	20	7	2	28

Totals, all species:

<i>Duplicaria</i>	2 species	1	0	0	0	1
<i>Hastula</i>	6 species	6	3	1	0	6
<i>Terebra</i>	43 species	37	20	7	2	28
	51 species, all localities	44	23	8	2	35

LITERATURE CITED

ABBOTT, R. TUCKER

1958. Marine mollusca of Rennell Island, Solomon Islands. The natural history of Rennell Island, British Solomon Islands. Copenhagen. Vol. 2: 203 - 206; pl. 20 (15 December, 1958)

BURCH, R. D.

1963. The Terebridae of Bileau Island, Madang Harbour, New Guinea. The Veliger 5 (4): 157 - 159 (1 April 1963)

DALL, WILLIAM HEALEY

1910. Description of two new pulmonate mollusks with a list of other species from the Solomon Islands, collected by Dr. George A. Dorsey. Field Mus. Nat. Hist. Zool. Ser., 7: 215 to 221; pl. 4

DAUTZENBERG, PHILIPPE

1910. Liste des coquilles recueillies par le R. P. Aubin dans l'île de Rua-Sura (Archipel Salomon) en 1909. Journ. de Conch. 58: 24 - 33

EYERDAM, WALTER

1951. Some Cypraeidae collected in the Solomon Islands and Papua. Min. Conch. Club South. Calif. 107: 6 - 8

GARRETT, ANDREW

1880. Catalogue of the Polynesian Mitridae, with remarks on

their geographical range, station, and descriptions of supposed new species. Journ. Conch. 3: 1 - 73

GUPPY, H. B.

1887. The Solomon Islands and their natives. pp. 336 to 351. London: Sonnenschein, Lowrey and Company [a summary of SMITH (1885) with a few new records]

KURODA, TOKUBEI & TADASHIGE HABA

1952. Check list and bibliography of the Recent marine mollusca of Japan. pp. 1 - 210; 2 maps. Tokyo, Japan (4 April 1952)

SMITH, EDGAR ALBERT

1876. A list of marine shells, chiefly from the Solomon Islands, with descriptions of several new species. Journ. Linn. Soc. London, Zool. 12: 535 - 562; pl. 30

1885. On a collection of shells (chiefly land and fresh-water) from the Solomon Islands. Proc. Zool. Soc. London, 1885, pt. 3: 588 - 609; pls. 36 - 37

SOLEM, ALAN

1953. Marine and fresh-water mollusks of the Solomon Islands. Fieldiana: Zool. 34 (22): 213 - 227 (23 Oct. 1953)

1958. Marine mollusks from Bougainville and Florida, Solomon Islands. Fieldiana: Zoology 39 (20): 213 - 226 (17 October 1958)

A New Opisthobranch Mollusk from La Jolla, California

BY

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AND

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(Plate 18; 2 Text figures)

THE FOUR SPECIES of the genus *Ancula* LOVÉN, 1846 are found in widely separated parts of the world. As far as we can determine from the literature, none occur sympatrically. Recently we have become aware of a new member of this genus occurring within the range of *Ancula pacifica* MACFARLAND, 1905 and in the same habitat.

We would like to express our appreciation to Miss Carol Bumgardner and Gillian Shane who called our attention to this new nudibranch and collected several of the specimens, and to Mrs. Rosemarie Fiebig for literature translations.

Ancula lentiginosa FARMER, spec. nov.

Type: — The type specimen was collected by the authors (WMF 294 a) at Scripps Institution of Oceanography, La Jolla, California (32° 52' N, 117° 15' W) in June 1963. The holotype is deposited at the California Academy of Sciences, San Francisco, California Academy of Sciences Invertebrate Type Series IZ No. 13. It consists of a whole specimen. Paratypes are also deposited there, consisting of five preserved specimens, one with dissected radula. These will bear the California Academy of Sciences Invertebrate Type Series Nos. 14 to 18, inclusive. All specimens will be associated with the Frank Mace MacFarland Memorial Collection of Opisthobranchs in the Academy's Invertebrate Zoology Collection.

Description: — The body is slightly compressed, smooth and limaciform. It is highest just anterior to the branchiae, tapering behind to the tip of the long pointed tail, in front sloping less rapidly to the high blunt, rounded head. There are three nonretractile, tripinnate branchiae. A single pair of extra-branchial processes is present; each process is located lateral and posterior to the branchiae, and is long, slender, blunt, and flaccid. The rhinophores

are large, perfoliate, with seven leaves, without sheaths and nonretractile. At the base of each rhinophore is a pair of slender processes, half as long as the rhinophore, which extend obliquely forward and outward. The oral tentacles are slender, short, and blunt.

The ground color is translucent tan to off white. There are irregular specks of dark reddish-brown pigment on the head, tail and sides of the body. In one paratype (WMF 294 b) (Plate 18, figure 1) this coloration forms a solid freckled pattern, and in another (Plate 18, Figure 2), and also in the holotype (Text figure 1) it is separated by wide clear areas. Rhinophores and associated processes, branchiae, and extra-branchial processes with varying amounts of dark reddish-brown pigment, are all tipped with white. Oral tentacles are off white.

The radular formula is 1 · 1 · 0 · 1 · 1 x 36 with the ribbon increasing in size from front to back. The posterior teeth are twice the size of the anterior ones; no rachis present. The inner margin of the first tooth is at a slight angle to the median line, thickened and bearing 13 sharp recurved denticles (Text figure 2 a) terminating above in a strong hook. The outer pleural teeth (Text figure 2 b) are triangular, thin below and thicker above, terminating in a strong apical hook. The lip plate is provided with many small hooks on its surface.

We were unable to determine the number of rows of small hooks on the glans penis.

The largest individual, measured while crawling actively, was 21 mm long, 6.5 mm high, and 4 mm broad. Other live individuals were 19 x 6 x 4, 17 x 7 x 5, and 17 x 7 x 4 mm respectively.

A nudibranch collected in May deposited an egg mass on an aquarium wall. The ribbon was white, 1 mm high and about 25 mm long in a single irregularly shaped counter-clockwise whorl 10 mm in diameter.



Figure 1: Solid freckled pattern of paratype.
Ancula lentiginosa FARMER, spec. nov.



Figure 2: Faint freckled pattern of paratype.
Ancula lentiginosa FARMER, spec. nov.

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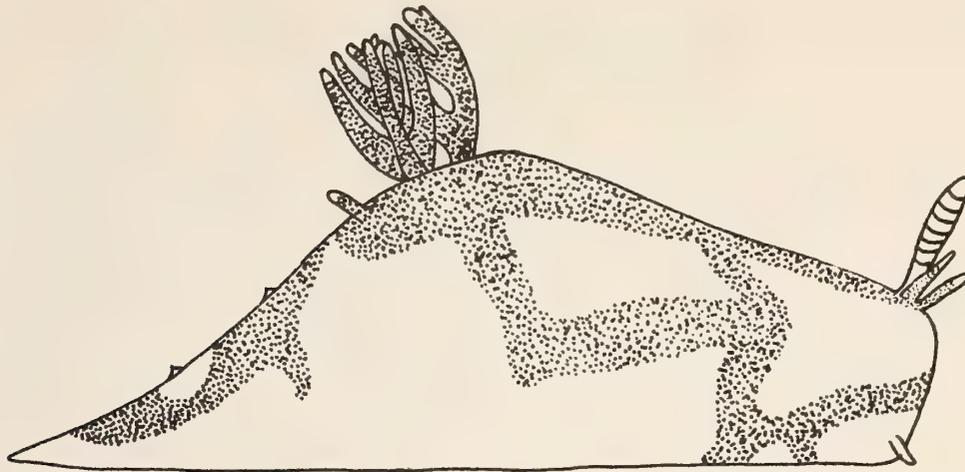


Figure 1: *Ancula lentiginosa* FARMER, spec. nov. Holotype showing a typical color pattern

The name *lentiginosa* was chosen to call attention to the distinct freckled appearance of this animal. *Lentiginosa* is derived from the Latin word *lentiginis*, a freckle.

Range: — This animal has been collected only from the salt water system (pipes) of Scripps Institution of Oceanography in La Jolla, California. Twelve have been found (six of which have come through the spigots) during the months of May and June. A variety of other animals have been taken from these pipes. These include: silicious sponges, amphipods, annelid worms, mussels (shell fragments), the gastropods *Acanthina* and *Ocenebra* (shells only) and *Ancula pacifica*.

The nature of the salt water system is as follows: Water is pumped from the end of the pier into a two-compartment tank with a sand-gravel filter on the bottom. Water enters the first compartment, circulates, and must rise over a center baffle into the second compartment. Larger solid material is deposited on the bottom of the first compartment. Water is pumped from the bottom of the second compartment (through the sand and gravel) into a storage tank. From the storage tank, lines are fed to the experimental and public aquaria. The majority of the lines are P. V. C. (Poly Vinyl Chloride), although older parts of the lines are stainless steel, transite

Comments: — A comparison of the species of *Ancula*.

	radular formula	no. pairs of extra-bran- chial pro- cesses	no. leaves in rhino- phore	dent- icles	Range	Ref.
<i>A. fuegiensis</i>	1 · 1 · 0 · 1 · 1 x 35	1	77	20	Tierra del Fuego	(1)
<i>A. evelinae</i>	1 · 1 · 0 · 1 · 1 x 40	1	7-8	14-18	No. Carolina to Brazil	(2)
<i>A. cristata</i>	1 · 1 · 0 · 1 · 1 x 23-27	5-6	7-8	10-13	Arctic seas to Mass., N. Europe	(3)
<i>A. pacifica</i>	1 · 1 · 1 · 1 · 1 x 35	3-4	8-9	11-17	Monterey Bay to San Diego, Calif.	(4)
<i>A. lentiginosa</i>	1 · 1 · 0 · 1 · 1 x 36	1	7	13	La Jolla, Calif.	

References for above:

- (1) ODHNER, 1926, pp. 45-46
 (2) MARCUS, 1961, p. 144

- (3) MEYER & MÖBIUS, 1865, pp. 59-60
 (4) MACFARLAND, 1905, p. 53

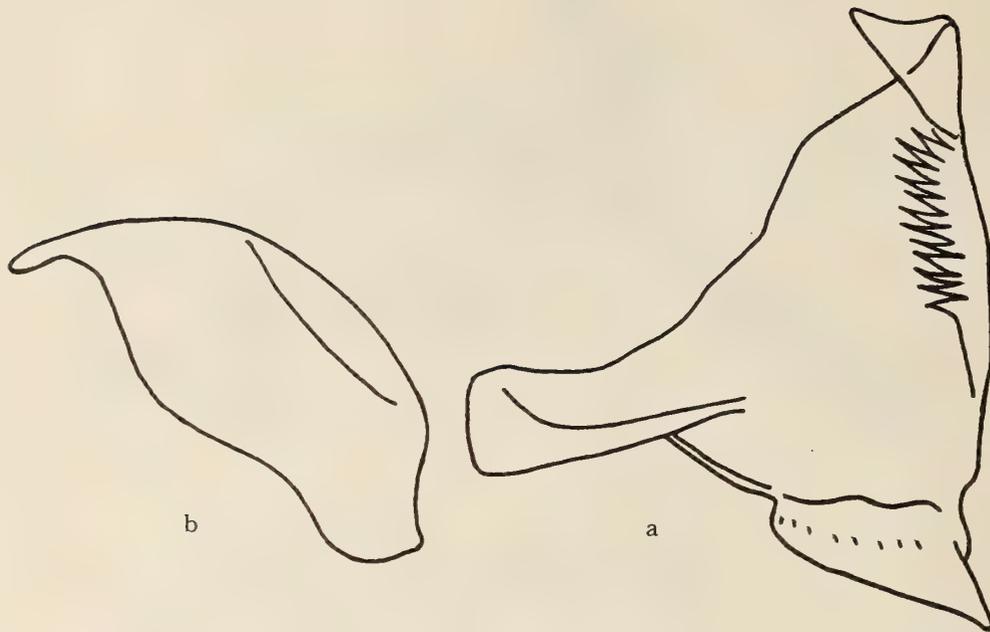


Figure 2: *Ancula lentiginosa* FARMER, spec. nov.
First (a) and second (b) lateral radular teeth

or cast iron. All pipes in the experimental aquarium are plastic.

Mr. Carr Tuthill, Senior Museum Scientist and Curator of the Aquarium at Scripps Institution of Oceanography, states that the sand-gravel filtertrap has been in operation for three years. Planktonic organisms come through the filter continuously.

Animals in the pipe lines are either developing in the lines or in the storage tank, but few are found living at the ends of the lines in the experimental aquarium. We believe that the animals are probably developing in the storage tanks, later to get into the lines.

Ancula lentiginosa has a pair of rhinophoral processes to each rhinophore but they arise separately from the body and not from a common trunk as in *Eucrairia* BURN (1961 a & b). As pointed out by MARCUS (1961), *A. fuegiensis* ODHNER, 1926 is distinguished from *A. evelinae* MARCUS, 1961 by the shape of the inner tooth. Color, inner tooth, and presence of several extra-branchial processes separate *A. lentiginosa* from *A. cristata* ALDER, 1841 and *A. pacifica* (MACFARLAND, 1905). *Ancula pacifica* has rachidian teeth behind the first 8 to 10 rows. *Ancula lentiginosa* is distinguished from *A. evelinae* and *A. fuegiensis* by the shape of the inner and outer teeth. The

branchiae are bipinnate in *A. evelinae* and *A. fuegiensis*, and tripinnate in *A. lentiginosa*.

LITERATURE CITED

BURN, ROBERT

1961 a. *Drepaniella mapae* gen. et spec. nov., a new goniodoridid nudibranch from Southeastern Australia. *The Veliger* 3 (4): 102 - 104 (1 April 1961)

1961 b. *Eucrairia* nom. nov. for *Drepaniella* BURN. *The Veliger* 4 (1): 51. (1 July 1961)

MACFARLAND, FRANK MACE

1905. A preliminary account of the Dorididae of Monterey Bay, California. *Proc. Biol. Soc. Washington*, 18: 35 - 54

MARCUS, ERNST

1961. Opisthobranchia from North Carolina. *Journ. Elisha Mitchell Sci. Soc.* 77 (2): 141 - 151

MEYER, HEINRICH & KARL AUGUST MÖBIUS

1865. *Fauna der Kieler Bucht. I. Die Hinterkiemer oder Opisthobranchia.* viii + xxx + 88 pp.; 26 pls. Leipzig, Wilhelm Engelmann, Verlag.

ODHNER, NILS HJALMAR

1926. Die Opisthobranchien. In: Further zoological results Swedish Antarctic Exped. 1901 - 1903; 2 (1): 1 - 100; pls. 1 to 3

On the Identity of *Murex macropterus* DESHAYES, 1839 (Mollusca : Gastropoda)

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(Plates 19 and 20)

DISCUSSION

Murex macropterus was described by DESHAYES (1839) on the basis of a single specimen from an unknown locality. Despite the fact that DESHAYES (1841) later illustrated the specimen, the identity of this taxon has remained an enigma to the present time. The description and figure indicate a muricid specimen of 43 mm in height, having a blade-like outer lip that is sculptured with numerous crenulate imbrications (see Plate 19, figure 1). The original illustration was later copied by SOWERBY (1880) and TRYON (1880), and a second specimen, also lacking locality data, was referred to this species and figured by REEVE (1845).

Speculation over the identity of *Murex macropterus* resulted in the name being applied to species occurring in several faunal provinces. TRYON (1880) compared it to the west African species, *Murex lingua* DILLWYN, 1817. DALL (1889) and others cited it from the western Atlantic, but CLENCH & FARFANTE (1945) rejected this identification and named the east American species *Murex (Pteropurpura) bequaerti*. Several students, including SOWERBY (1880), have suggested that the name was applicable to one of the trivariolate species from Japanese waters. EMERSON (1960) proposed that the type specimen most closely resembles some of the forms of the *Murex trialatus - rhyssus* complex of ABBOTT (1954) from the eastern Pacific. Obviously, none of these suggestions can be verified without reference to the type specimen, the depository of which was not indicated. Inasmuch as *Murex macropterus* DESHAYES is the type species, by monotypy, of *Pteropurpura* JOUSSEAUME (1880), the identity of this taxon is of taxonomic importance as well as of nomenclatural interest.

I undertook, therefore, to inquire of colleagues in European museums if the type specimen is still extant.

Mr. Peter Dance informed me (*in litteris*) that a specimen labeled *Murex macropterus* DESHAYES, lacking locality data, was present in the Hugh Cuming collection of the British Museum (Natural History). This probably is the specimen mentioned by SOWERBY (1880) as being in the British Museum, but the label accompanying the specimen does not indicate the person responsible for the identification or the name of the collector. An examination of the specimen (see Plate 19, figure 3) shows it to be referable to the eastern Pacific species commonly referred to *Pteronotus carpenteri* DALL (1899). While not the holotype of *M. macropterus* DESHAYES (*cf.* Plate 19, figures 1 and 3), the specimen in the British Museum appears to be referable to Deshayes' taxon.

My search eventually proved to be fruitful after several other unsuccessful inquiries. Dr. P. H. Fischer, Curator of Paleontology of the École des Mines in Paris, informed me (*in litteris*) that the type specimen was in the collection of his institution. He kindly provided me with photographs of the holotype, Plate 19, figure 2. The type appears to be a badly worn specimen of *Pteronotus carpenteri* DALL (1899), a species commonly dredged in shallow water off the coast of California (*cf.* Plate 19, figures 2 and 4). It apparently was picked up from a beach by a member of the party of the ship "Venus", which visited California, including Monterey, during 1837 or 1838.

More than passing mention must be made of the status of *Pteronotus carpenteri* DALL (1899) and *Murex petri* DALL (1900) before attempting to propose a synonymy for *Murex macropterus*. The dubious nature of Dall's taxa has been recently discussed by several students, including KEEN (1945), SMITH (1945), SMITH & GORDON (1948), BURCH (1952), and ABBOTT (1952). The confusion results from Dall's failure to designate holotypes.

Briefly, DALL (1899) described *Pteronotus carpenteri* without providing an illustration. The description and measurements indicate a large shell with prominently digitate varices, the form later named *Murex carpenteri alba* by BERRY (1908) and *M. carpenteri tremperi* by DALL (1910). This is the "southern" form that is commonly dredged off southern California in shallow water. However, DALL (1899) also mentioned that "Young specimens are more pointed, and with narrower, less digitate varices than the adults", the so-called northern form that is common in shallow water off Monterey (see Plate 19, figure 4). Thus, Dall included both the presently recognized "northern" and "southern" forms in the original description and neglected to designate a holotype or to state the type locality. DALL (1899) listed specimens from three localities: Monterey, California, F. L. Button; Farallone Islands, California, J. S. Arnheim; and off Point Conception, California, in 31 fathoms (U. S. Fish Commission). Only the last locality is represented by a specimen in the U. S. National Museum collection (U. S. N. M. cat. no. 160023). This is a small specimen, measuring 28.3 mm in altitude and 13.4 mm in width, of the "northern" form.

In 1902, DALL figured a specimen from off San Diego, California, in 36 fathoms (U. S. N. M. cat. no. 122596), as *Murex (Pteropurpura) carpenteri*, and this specimen, which is in the U. S. National Museum, is accompanied by a label carrying the designation "Co-type" in Dall's handwriting (see Plate 20, figure 2). This specimen is not mentioned by DALL (1899) in the original description, but was catalogued in July of 1891 and must have been part of the original lot. It is one of the specimens that Dall apparently thought to be a "young specimen", but actually represents the slender form commonly dredged off Monterey, not the larger form with more digitate varices that is common off southern California. ABBOTT (1952) suggested that the F. L. Button collection might contain

the specimen (co-type) for which measurements were cited by DALL (1899). Through the kind offices of Dr. Alan Solem of the Chicago Natural History Museum, I was able to borrow three specimens that retain the original Button label reading "Pteronotus carpenteri, Monterey, California." The largest of these specimens, all the "southern" form (Plate 19, figure 5), has dimensions that are somewhat smaller than those cited by Dall in the original description. As there is no evidence to indicate that the specimens in the Button collection formed part of Dall's original lot, and as only one specimen from Monterey was mentioned by DALL (1899) as remaining in the Button Collection, these specimens would seemingly not qualify as syntypes. Thus, Dall's measured specimen, the other co-type, would appear to be lost.

Under the circumstances, the most logical procedure would be to consider Dall's existing co-type (1902, pl. 34, fig. 9) the lectotype of *Pteronotus carpenteri*, and thus retain the presently generally accepted concept of this taxon (see Plate 20, figure 2).

The status of *Murex petri* DALL (1900) is also confused owing to the lack of an illustration or the designation of a type specimen. The type locality was given as "San Pedro, California", in rather deep water and the specimen was from the Oldroyd Collection. There is, however, a specimen in the U. S. National Museum (cat. no. 183056) having the dimensions cited by Dall in the original description. This specimen was not catalogued until April 1, 1905, and, apparently owing to the delay in cataloguing, only "California, Mrs. Oldroyd" is entered in the catalogue book. A smaller specimen, measuring 52.4 mm in height and 27.9 mm in width, is labeled San Pedro, California, Oldroyd (U. S. N. M. cat. no. 160499) and was catalogued on July 3, 1900. These specimens should be considered the lectotype and a paratype, respectively. Unfortunately, DALL (1902, pl. 34, fig. 7) later figured a specimen of *Murex rhyssus* DALL

Explanation of Plate 19

(All figures x 1½)

Pteropurpura macropterus (DESHAYES, 1839)

Figure 1: Original figure of *Murex macropterus* DESHAYES, 1839 (after DESHAYES, 1841, plate 38).

Figure 2: Holotype of *Murex macropterus* DESHAYES, 1839, in École des Mines, Paris, courtesy of Dr. P. H. Fischer

Figure 3: Specimen labeled *Murex macropterus* DESHAYES, 1839, in the British Museum (Natural History), courtesy of S. P. Dance.

Figure 4: A typical specimen of the "northern" form of *Pteronotus carpenteri* DALL, 1899, from off Del Monte, California, in 10 to 12 fathoms (A. M. N. H. cat. no. 100490; *ex* - M. Gordon coll., *ex* - CAS coll. no. 36241).

Pteropurpura alba (BERRY, 1908)

Figure 5: A typical specimen of the "southern" form of *Pteronotus carpenteri* DALL, 1899, from "Monterey, California" (C. N. H. M. cat. no. 108441, *ex* Button coll.).

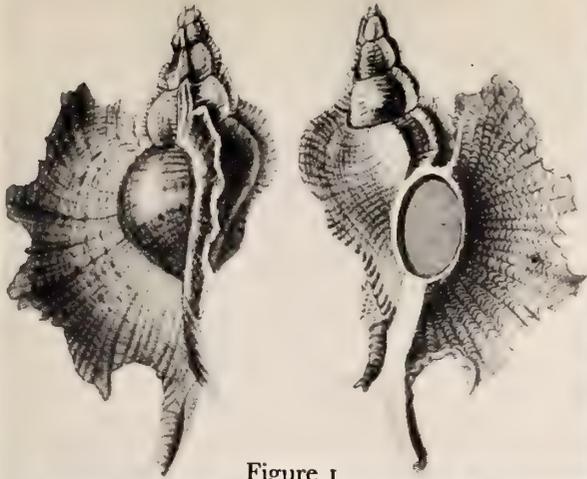


Figure 1

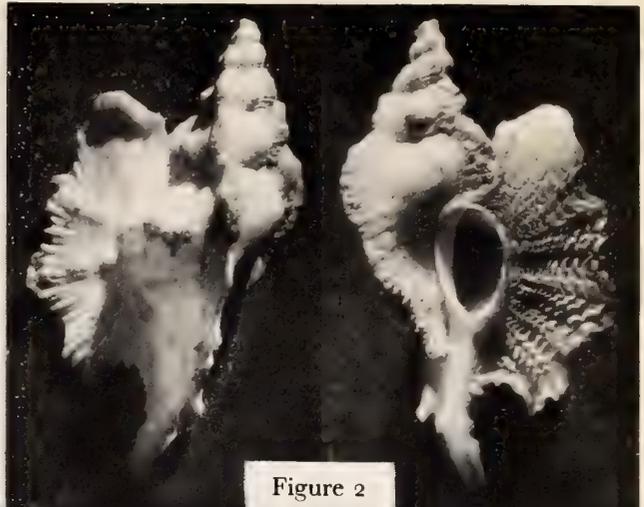


Figure 2

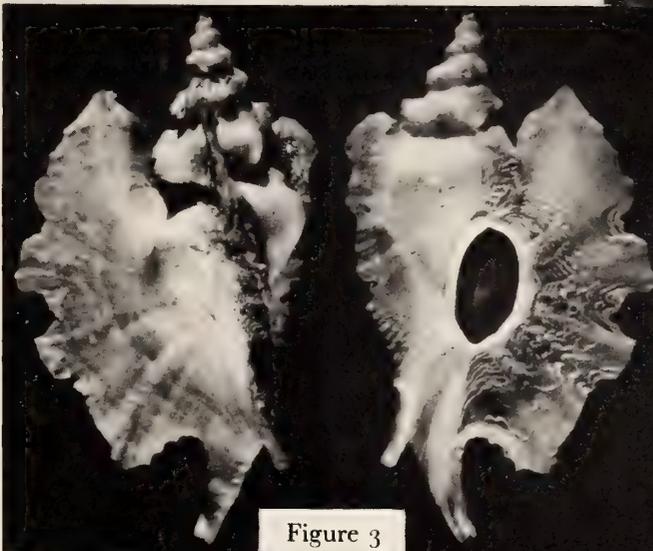


Figure 3

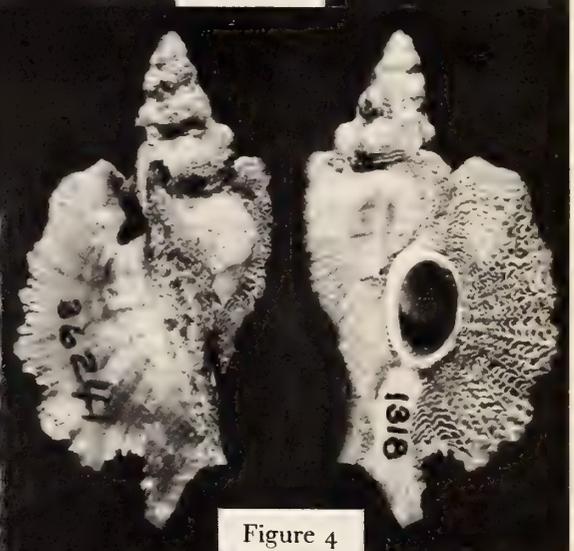


Figure 4



Figure 5

(1919) under the name of *Murex (Pteropurpura) petri* DALL, causing additional confusion.

As ABBOTT (1952) pointed out, *Murex (Alipurpura) rhyssus* DALL (1919) is curatorially pure. DALL (1919) selected the holotype by citing the catalogue number (U. S. N. M. 160500) and designated the type locality: off San Pedro, California. OLDROYD (1927, pl. 30, fig. 1) later figured the holotype. This may be a form of *Murex erinaceoides* VALENCIENNES, 1832.

Annotated synonymies of these taxa are given below. While additional work is needed to determine the biological validity of these closely related species, the nomenclatural validity of the type specimens representing these taxa now appears to be established.

Although the group of *Pteropurpura* recently has been referred to the genus *Pterynotus* SWAINSON (1833) of the subfamily Muricinae, this placement appears to be invalid. Mrs. Emily H. Vokes of Tulane University has called my attention (*in litteris*) to the fact that the operculum of the *Pteropurpura*-group is purpuroid, necessitating placement of *Pteropurpura* in the subfamily Ocenebrinae [Purpurinae auct.], near *Ocenebrellus* JOUSSEAUME (1880).

SYNONYMIES

Pteropurpura (Pteropurpura) macropterus (DESHAYES, 1839)

Plate 19, figures 1 to 4; Plate 20, figures 2, 3

Murex macropterus DESHAYES, 1839, p. 360; DESHAYES, 1841, pl. 38, type locality: here designated, Monterey Bay, California; type depository, holotype in École Nationale Supérieure des Mines, Paris; here figured, Plate 19, figures 1, 2.

Pteronotus carpenteri DALL, 1899, pp. 138, 139; type locality: off San Diego, California (U. S. F. C. Sta. 2934), in 36 fathoms; type depository: lectotype, here designated, in the U. S. National Museum, Washington, D. C., cat. no. 122596 ["Co-type" in Dall's handwriting], here figured, Plate 20, figure 2; Paratype, U. S. National Museum, cat. no. 160023.

Murex petri DALL, 1900, pp. 37, 38; type locality: off San Pedro, California; type depository: lectotype, here designated, in the U. S. National Museum, Washington, D. C., cat. no. 183056, here figured, Plate 20, figure 3; Paratype, U. S. National Museum, cat. no. 160499.

Murex (Pteropurpura) carpenteri DALL, DALL, 1902, p. 532, pl. 34, fig. 9 [figure of lectotype].

Murex carpenteri DALL, OLDROYD, 1927, pl. 28, fig. 9 [copy of DALL (1902) pl. 34, fig. 9].

Pteropurpura (Pteropurpura) alba (BERRY, 1908)

Plate 19, figure 5

Murex carpenteri form *alba* BERRY, 1908, pp. 105, 106; type locality: off Newport, California; type depository: private collection, S. S. Berry.

Murex carpenteri var. *tremperi* DALL, 1910, p. 96; type locality: off Newport, California, in 35 fathoms; type depository: California Academy of Natural Sciences, San Francisco, California, *fdc* SMITH (1945).

Murex carpenteri tremperi "HEMPHILL" DALL, HEMPHILL, 1911, pp. 99, 100, pl. 1.

Murex (Pteropurpura) carpenteri DALL, DALL, 1921, pl. 13, fig. 5. Not *Pteronotus carpenteri* DALL, 1899.

Murex (Pterynotus) trialatus SBY., form *carpenteri* DALL, ABBOTT, 1954, fig. 45c [copy of DALL (1921), pl. 13, fig. 5]. Not *Pteronotus carpenteri* DALL, 1899.

Pteropurpura (? Pteropurpura) rhyssa (DALL, 1919)

Plate 20, figure 1

Murex (Pteropurpura) petri DALL, DALL, 1902, pl. 34, fig. 7 [U. S. N. M. cat. no. 122553]. Not *Murex petri* DALL, 1900.

Murex (Alipurpura) rhyssus DALL, 1919, vol. 56, p. 332; type locality: off San Pedro, California; type depository: holotype, in the U. S. National Museum, Washington, D. C., cat. no. 160500, here illustrated, Plate 20, figure 1.

Murex (Alipurpura) rhyssa DALL, OLDROYD, 1927, p. 9, pl. 30, fig. 1 [figure of holotype].

Murex petri DALL, OLDROYD, 1927, pl. 28, fig. 7 [copy of DALL (1902), pl. 34, fig. 7]. Not *Murex petri* DALL, 1900.

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LITERATURE CITED

- ABBOTT, R. TUCKER
1952. [Letter to J. Q. Burch.] Conch. Club South. Calif. Minutes No. 122: 9 - 10
1954. American seashells. Princeton, New Jersey. D. van Nostrand Co., Inc.; xiv + 541 pp.; 100 figs.; 40 pls.
- BERRY, SAMUEL STILLMAN
1908. *Murex carpenteri*, form *alba*. The Nautilus 21: 105 to 106
- BURCH, JOHN QUINCY
1952. [Letter to H. A. Rehder.] Conch. Club South. Calif. Minutes No. 122: 8 - 9
- CLENCH, WILLIAM J. & I. PÉREZ FARFANTE
1945. The genus *Murex* in the western Atlantic. Johnsonia, Cambridge, Mass. 1 (17): 1 - 58; 29 pls.
- DALL, WILLIAM HEALEY
1889. Reports on the results of dredging, . . . in the Gulf of Mexico (1877-78) and in the Caribbean Sea (1879-80), by the U. S. Coast Survey Steamer "Blake", . . . Report on the Mollusca, pt. 2, Gastropoda and Scaphopoda. Bull. Mus. Comp. Zool. 14: 1 - 492; pls. 1 - 40
1899. A new *Pteronotus* from California. The Nautilus 12: 138 - 139
1900. A new *Murex* from California. The Nautilus 14: 37 - 38
1902. Illustrations and descriptions of new, or imperfectly known shells, chiefly American, in the U. S. National Museum. Proc. U. S. Nat. Mus. 24: 499 - 566; pls. 37 - 40
1910. Notes on California shells. The Nautilus, 24: 95 - 96
1919. Descriptions of new species of Mollusca from the North Pacific Ocean in the collection of the United States National Museum. Proc. U. S. Nat. Mus. 56: 293 - 371
1921. Summary of the marine shellbearing mollusks of the northwest coast of America, from San Diego, California, to the Polar Sea. . . . Bull. U. S. Nat. Mus. 112: 1 - 217; pls. 1 - 22
- DESHAYES, GERARD PAUL
1839. Nouvelles espèces de mollusques, provenant des côtes de la Californie, du Mexique, du Kamtschatka et de la Nouvelle-Zélande, décrites par M. Deshayes. Rev. Zool. Soc. Cuvierienne: 356 - 361
1841. Mollusques. Mag. Zool. d'Anat. Comp. et Palaeont.: plt. 38 and text
- EMERSON, WILLIAM K.
1960. Remarks on some eastern Pacific muricid gastropods. Amer. Mus. Novitates no. 2009: 15 pp.; 7 figs.
- HEMPHILL, HENRY
1911. Descriptions of some varieties of shells, with short notes on the geographical range and means of distribution of land shells. Trans. San Diego Soc. Nat. Hist. 1: 99 - 108
- JOUSSEAUME, F. P.
1880. Division des purpuridés. Le Naturaliste 1 (42): 335 to 336
- KEEN, A. MYRA
1945. [Notes on muricidae.] Conch. Club South. Calif. Minutes No. 51: 32 - 33
- OLDROYD, IDA SHEPARD
1927. The marine shells of the west coast of North America. Stanford Univ. Publ. Univ. Ser., Geol. Sci., 2 (1): 1 - 297; pls. 1 - 29; 2 (2): 1 - 304; pls. 30 - 72
- REEVE, LOVELL AUGUSTUS
1845. Conchologia Iconica. London, 3, *Murex*: pls. 1 - 36; 1 suppl. plt.
- SMITH, ALLYN GOODWIN
1945. [Notes on *Pterynotus petri* (DALL), 1900]. Minutes Conch. Club South. Calif. no. 51: 33 - 34
- SMITH, ALLYN G., & MACKENZIE GORDON, JR.
1948. The marine mollusks and brachiopods of Monterey Bay, California, and vicinity. Proc. Calif. Acad. Sci., 4th. Ser., 26 (8): 147 - 245; pls. 5 - 4; textfigs. 1 - 4.
- SOWERBY, GEORGE BETTINGHAM (second of name)
1880. Thesaurus conchyliorum, or monographs of genera of shells. London, 4 (pts. 33, 34), *Murex*: 1 - 55; pls. 380 - 403
- SWAINSON, WILLIAM
1833. Zoological illustrations. London, ser. 2, vol 3
- TRYON, GEORGE WASHINGTON, JR.
1880. Manual of conchology. Philadelphia, ser. 1, 2, Muricinae, Purpurinae: 1 - 289; pls. 1 - 70

Explanation of Plate 20

(All figures x 1½)

Figure 1: Holotype of *Murex (Pteropurpura) rhyssus* DALL, 1902, from off San Pedro, California (U. S. N. M. cat. no. 160500).

Figure 2: Lectotype of *Pteronotus carpenteri* DALL, 1899 [= *Pteropurpura macropterus* (DESHAYES, 1839)] from off San Diego, California (U. S. N. M. cat. no. 122596).

Figure 3: Lectotype of *Murex petri* DALL, 1900 [= *Pteropurpura macropterus* (DESHAYES, 1839)] from off San Pedro, California (U. S. N. M. cat. no. 183056).

Photographs through the courtesy of Dr. H. A. Rehder, United States National Museum.

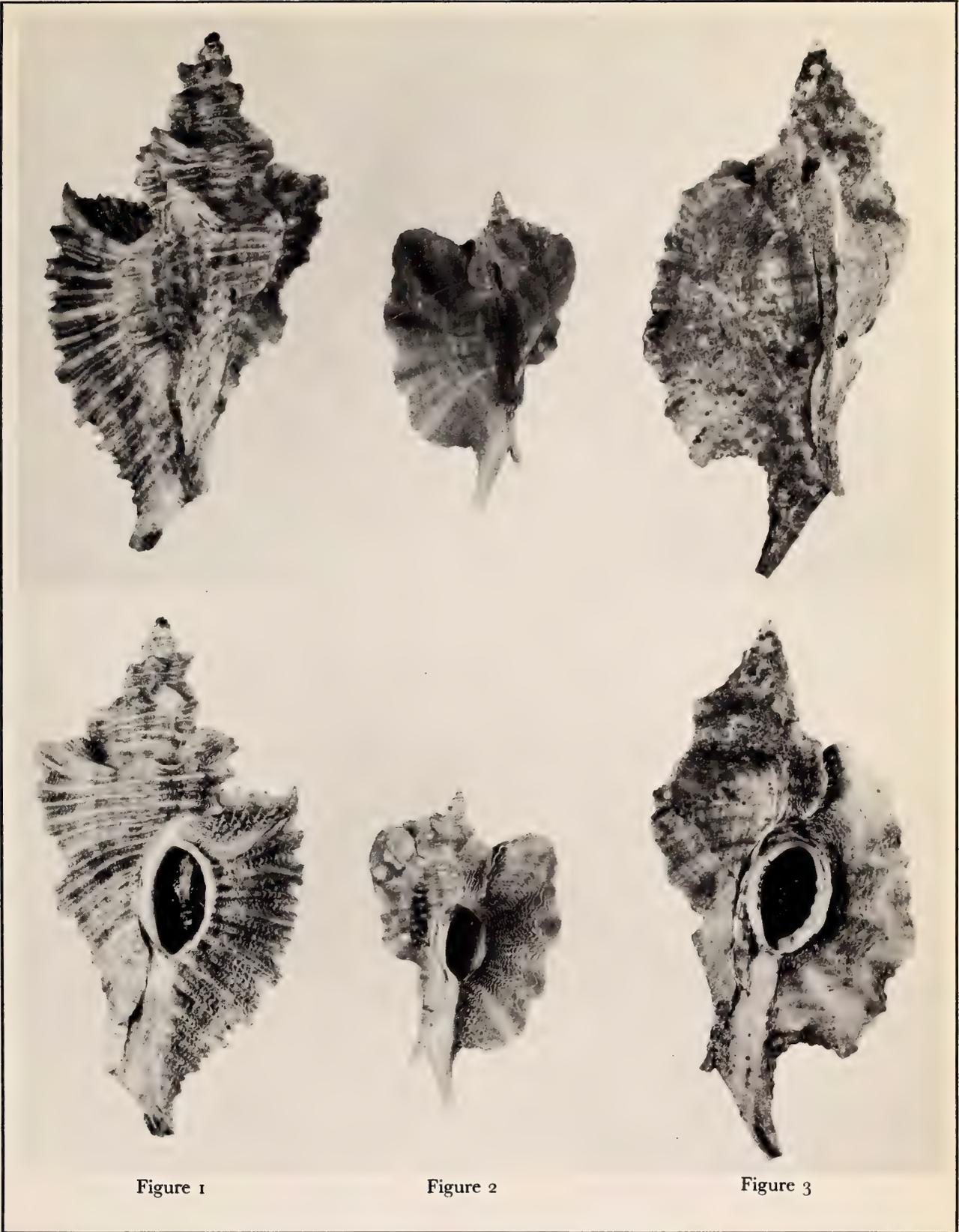


Figure 1

Figure 2

Figure 3



The Cowrie Fauna of Penrith Island

(Mollusca : Gastropoda)

BY

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(1 Text figure)

(G. Houston collected the cowries and described their habitat; the Schilders examined the shells and animals.)

PENRITH ISLAND is situated about 70 kilometers off Mackay, Queensland, at a distance of about 37 kilometers from the inner border of the Great Barrier Reef so that the island is almost half way to its outer fringe.

The island extends about three kilometers from West to East. Along its sheltered South coast there is a typical coral reef (see map) the profile of which is shown in the diagram; the letters A to H indicate the following zones:

A = land formation

B = sand overgrown with scrub

C = beach

D = sand and broken patches of dead coral; pools from 15 centimeters to one meter deep

E = dead coral

F = live coral, mostly soft

G = live hard coral edge at zero low tide (outer fringe)

H = deep water

The limit between D and E is about 1.5 m, that between E and F about 60 cm above zero.

The mean temperature of the sea surface is about 20° C in August and almost 27° C in February, according to SCHOTT (1935).

COLLECTED SPECIES

The following list contains the species of the superfamily Cypraeacea collected in 24 collecting tides spread over the past three years. The first column indicates the total number of specimens of rather rare species collected in the entire period (the + sign indicates frequent species

represented by not counted specimens); the second column gives the number of specimens collected on a three weeks trip to Penrith Island in August and September 1962, which were packed in cotton wet by alcohol and put in plastic bags so that the animals were still soft after being in transit for three months and suitable for anatomical dissection.

CYPRAEIDAE

Cypraeinae

3	—	<i>Luria isabella</i> (LINNAEUS, 1758)
+	56	<i>Mauritia eglantina</i> (DUCLOS, 1833)
+	46	<i>Lyncina lynx</i> (LINNAEUS, 1758)
+	20	<i>Lyncina vitellus</i> (LINNAEUS, 1758)
4	1	<i>Lyncina carneola</i> (LINNAEUS, 1758)

Nariinae

+	44	<i>Monetaria annulus</i> (LINNAEUS, 1758)
+	35	<i>Monetaria moneta</i> (LINNAEUS, 1758)
1	—	<i>Erosaria labrolineata</i> (GASKOIN, 1848)
+	22	<i>Erosaria caputserpentis</i> (LINNAEUS, 1758)
+	49	<i>Erosaria erosa</i> (LINNAEUS, 1758)
13	—	<i>Staphylaea limacina</i> (LAMARCK, 1810)

Cypraeovulinae

+	122	<i>Erronea erroneus</i> (LINNAEUS, 1758)
2	2	<i>Erronea cylindrica</i> (BORN, 1778)
+	19	<i>Erronea caurica</i> (LINNAEUS, 1758)
9	—	<i>Erronea listeri</i> (GRAY, 1825)
1	—	<i>Palmadusta punctata</i> (LINNAEUS, 1771)
30	—	<i>Palmadusta asellus</i> (LINNAEUS, 1758)

+	22	<i>Palmadusta clandestina</i> (LINNAEUS, 1767)
+	30	<i>Palmadusta gracilis</i> (GASKOIN, 1848)
15	—	<i>Palmadusta minoridens</i> (MELVILL, 1901)
18	—	<i>Bistolida pallidula</i> (GASKOIN, 1848)
5	—	<i>Bistolida hirundo</i> (LINNAEUS, 1758)

AMPHIPERATIDAE

Amphiperatinae

+	20	<i>Calpurnus verrucosus</i> (LINNAEUS, 1758)
1	—	<i>Amphiperas ovum</i> (LINNAEUS, 1758)

The frequently encountered species evidently prefer certain zones of the reef:

1. The callous *Monetaria annulus*, *M. moneta*, and *Erosaria caputserpentis* live mostly exposed in crevices from the beach to 1.5 m above zero (zones C and D); *M. annulus* could have been collected well in the thousands. *M. moneta* is slightly less abundant.

2. The large *Mauritia eglantina*, *Lyncina lynx*, and *L. vitellus* live under stones and corals, almost from the beach to 60 cm (zones D, E, and F).

3. The mostly less heavy *Erosaria erosa*, *Erronea erronea*, *Erronea caurica* and *Palmadusta gracilis* as well as the minute *Trivirostra oryza* (LAMARCK) which belongs to the Lamellariacea, live from 1.5 m to the outer fringe (zones F and G).

4. *Palmadusta clandestina* has been found only in one hollow under dead coral (zone E, marked by a small circle on the map), and *Calpurnus verrucosus* has been found in one area only on soft coral resembling a flat cabbage (zone F, marked with * on the map).

Among true cowries (Cypraeidae) the 22 collected species represent scarcely more than one third (39%) of the 56 species occurring along the coast of Queensland and on the neighboring islands. The most surprising fact is that *Cypraea tigris* LINNAEUS, 1758 which is common in most parts of the Great Barrier Reef, never was found on Penrith Island, and there is no evidence of it ever having been there. The absence of *Erronea xanthodon* (SOWERBY, 1832) is also remarkable as it is rather frequently encountered along the coast of Queensland and New South Wales.

THE TABLES

Table 1 contains the following nine quantitative characters:

Shell: L = length of the shell in millimeters

BL = maximum breadth in per cent of length

LT = closeness of labial teeth expressed by letters (with decimals expressing the exact value between two letters), according to SCHILDER, 1958.

CT = closeness of columellar teeth (the anterior terminal ridges excluded) treated in the same way

Radula: r/12 = number of rows in dozens (and decimals of dozens)

m/L = relative breadth of the median

dr/L = relative length of the radula; all figures concerning radulae have been calculated according to SCHILDER, 1963

Animal: ♀ % = sex ratio (females in percent of the sum of both sexes)

P/L = Length of the penis in per cent of the length of the shell

Each character comprises two columns: the left column indicates the average character of the specimens collected at Penrith Island (P. I.) in 1962, the number of which has been given in the species list above; the right column indicates the average character in comparable populations from other localities (oth.) named in the right margin of Table 1; most figures refer to the sum of various localities in Vitilevu, Fiji Islands, from where we have received large numbers of specimens containing the well preserved animal from Mr. Walter O. Cernohorsky, Vatukoula, Fiji (the 141 *Erosaria caputserpentis* came from a single locality, i.e. St. Annes-on-Sea on the South coast of Vitilevu); species not occurring in Fiji in satisfactorily large numbers have been compared with populations from East Australia (*Palmadusta gracilis*), New Britain (*Calpurnus verrucosus*), the entire Pacific (*Palmadusta clandestina*), or Kenya (*Erronea caurica*).

These two columns for each character are connected with the symbols >, <, or =, indicating that the mean of the Penrith specimens is distinctly larger, or distinctly smaller than, or very similar to identical with the mean of specimens from the other locality.

Table 2 enumerates several variable qualitative characters of shells in most species; based on former studies (SCHILDER, 1952, p. 55) they have been classified in six classes as indicated in the columns 1 to 6.

Table 3 indicates the average development of these qualitative characters of shells, expressed in classes with one decimal; the central pair of columns compares the mean of the shells from Penrith Island (P. I.) with that from other localities (oth.) mentioned in Table 1, whereas the two right pairs of columns show the sexual differences at Penrith Island and those in the other populations, respectively.

Table 4 shows the sexual differences in four quantitative characters of the shells and in three characters of the radulae; in each species, the first line refers to the specimens from Penrith Island, the second line to the comparable population. Whenever the mean of the two sexes greatly differs from the mean indicated in Table 1, this fact may be explained by the impossibility to state the sex in many extreme specimens.

The symbols $>$, $<$, and $=$ are used in Tables 3 and 4 in the same manner as in Table 1.

COMPARISON OF POPULATIONS

It is surprising that the average length of the shells obtained from Penrith Island distinctly exceeds that of other populations (Table 1): at P. I. all species grow larger than elsewhere, *Mauritia eglantina* excepted, which is smaller (*Lyncina vitellus* seems to be as large as in Fiji).

The relative breadth does not deviate in such a distinct direction: though many species are less broad in P. I., according to their greater length, the two *Lyncina* and some Cypraeovulinae are broader in P. I. than in other localities.

The relative closeness of teeth also does not show any general trend at P. I., though there are significant differences in several species; there is also no parallelism in local relative closeness between the labial and columellar teeth.

The ecotypes (called morphae by J. Huxley) distinguished in *Monetaria* have not been tabulated in this paper. If we express the relative tendency to $H:A:Q$ in *M. annulus* and $S:C:R:E:M$ in *M. moneta* (see SCHILDER, 1952, pp. 99, 104) in tenths (1 = 10%, 0 = less than 5%, o = less than 1%, — = absent), the formulae of Penrith Island are 0:9:1 and 2:o:7:0:0, those of Fiji populations 2:5:3 and 0:2:5:2:o respectively; in both areas *A* and *R* predominate, but in the small area of P. I. they predominate more distinctly; besides in *M. moneta* of P. I. the ecotype *R* tends to the large flattened *S*, in Fiji to the small callous ecotypes *C* and *E*.

There is no general tendency in qualitative characters of the shells (Table 3), neither in callosity (*Monetaria moneta* and *Erosaria erosa* are less callous, but *Erronea erronea* is much more callous in P. I. than in Fiji) nor in the various characters in color and markings in which class 1 always designates the palest and least marked shells, class 6 the darkest and most marked specimens.

However, in the radula (Table 1) the Penrith fauna consistently differs from the comparable populations as follows: the number of rows (r/L) is always larger or at least equal (3 species), but never smaller; the size of the median (m/L) is also greater in most species, rarely equal (2 species), and only in *Palmadusta clandestina* smaller; therefore the whole radular ribbon (dr/L) is relatively longer in all species collected at Penrith Island than in the populations from elsewhere, without any exception! This parallelism in the development of the radula in the eleven species of Cypraeidae is most interesting; as the tendency to become longer and mostly

broader is apparent in all cowrie species collected at Penrith Island it must be caused by environmental peculiarities.

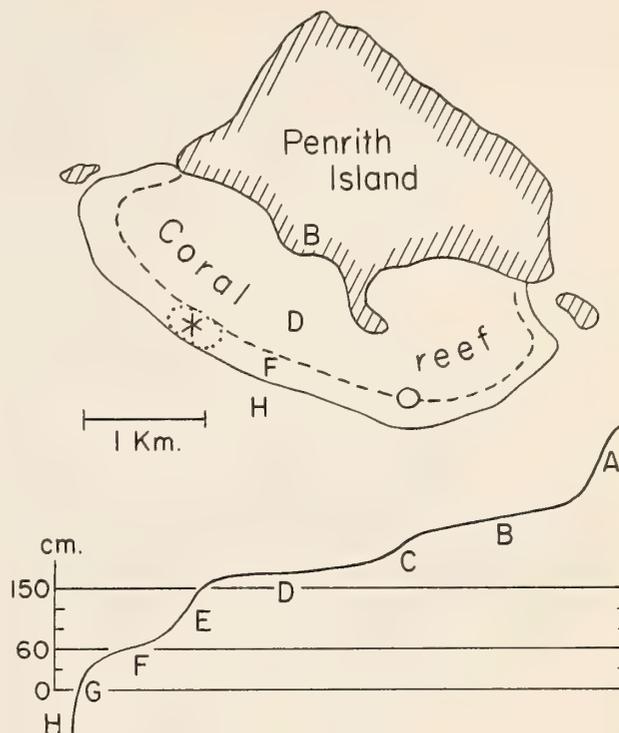


Figure 1: Outline map of Penrith Island and profile of shore line.

The differences in the sex ratio (Table 1) should be regarded as random only, as the mean of all percentages of females in P. I. (54%) is practically identical with that in foreign populations (52%).

The relative length of the penis (P/L in Table 1) is very interesting; in the seven first listed species, which belong to the subfamilies Cypraeinae and Nariinae, the penis is distinctly shorter in the males from P. I. than in those from Fiji; this difference cannot be explained as caused by different preservation of the animals, as in the four remaining species, belonging to the subfamily Cypraeovulinae, the penis, in contrast, is longer in P. I. males (except in *Palmadusta clandestina*, in which the greater length of the penis in specimens from the entire Pacific may be random only, as we could examine only six males); we presume that there may be a different reaction of species to local influences, according to their belonging to different subfamilies! Besides, the figures of both columns confirm the fact that the penis of Cypraeovulinae is relatively shorter than that of the two other subfamilies (SCHILDER, 1961, p. 209).

Table 1

Species	L		BL		LT		CT	
	P. I.	oth.	P. I.	oth.	P. I.	oth.	P. I.	oth.
<i>Mauritia eglantina</i>	49.4	<51.2	55.6	<58.7	t.9	< u.4	u.1	> t.5
<i>Lyncina lynx</i>	41.1	>38.2	58.3	=58.2	o.6	= o.5	o.2	= o.4
<i>Lyncina vitellus</i>	47.7	=47.7	64.4	>63.2	n.7	< o.3	o.6	< p.2
<i>Monetaria annulus</i>	23.9	>19.8	68.2	<71.0	g.4	= g.3	f.8	= f.5
<i>Monetaria moneta</i>	25.4	>20.8	71.4	<72.5	g.5	= g.4	h.0	= h.3
<i>Erosaria caputserpentis</i>	31.0	>25.7	70.8	<74.8	k.3	> i.8	h.7	= h.8
<i>Erosaria erosa</i>	33.0	>31.7	59.0	<60.9	l.7	> l.3	i.5	= i.7
<i>Erronea erronea</i>	23.4	>19.5	57.2	>55.4	h.6	< i.4	k.6	< l.6
<i>Erronea caurica</i>	35.8	>32.7	52.4	<56.8	k.9	> k.2	l.2	< n.5
<i>Palmadusta clandestina</i>	15.9	>14.6	62.0	>58.8	p.5	< q.6	p.4	< p.8
<i>Calpurnus verrucosus</i>	18.3	>17.6	59.9	=60.2	n.8	> n.3	o.1	= n.8
<i>Palmadusta gracilis</i>	22.2	>20.3	62.6	<63.9	o.4	< p.2	—	—

COMPARISON OF SEXES

The well preserved animals of the cowries collected at Penrith Island allow confirmation of previous statements on sexual differences (SCHILDER, 1961, 1962, 1963). The figures concerning "other areas" have been added

to control the tendency of differences in P. I., indicated in the columns and lines of Tables 3 and 4, respectively; these figures are based on much more numerous specimens and anticipate the results to be published in a future paper on the Fiji cowries.

Table 2

species	character	1	2
<i>Mauritia eglantina</i>	dorsal markings	pale yellow	yellow
	lacunae interrupting the longitudinal striae	obsolete	scarce
	dark brown spire blotch	absent	obsolete
<i>Lyncina lynx</i>	dorsal bluish grey layer	absent	at margins
<i>Lyncina vitellus</i>	dorsal color	pale fulvous	fulvous brown
<i>Monetaria annulus</i>	dorsal orange ring	absent	short traces
<i>Monetaria moneta</i>	LT (labial) : CT (columellar teeth) *	both short	produced: short
	dorsal orange ring	absent	short traces
<i>Erosaria erosa</i>	dorsal golden suffusion	absent	obsolete
	right margin and rim	rounded; pitted	narrow; pitted
	large blotch on outer lip	absent	obsolete
	id. on columellar margin	absent	obsolete
	fawn basal striae	absent	obsolete
<i>Erronea erronea</i>	base and aperture	flat; very wide	flat; wide
	dorsal zones	absent	obsolete
	dorsal central blotch	absent	obsolete
	right anterior spot	absent	obsolete
	left anterior spot	absent	obsolete
	color of base and margins	white	hardly yellowish
<i>Erronea caurica</i>	dorsal central blotch	absent	obsolete
<i>Palmadusta gracilis</i>	dorsal central blotch	absent	obsolete

* see SCHILDER, 1962, p. 100

Table 1

r/12		m/L		dr/L		♀ %		P/L		oth.=
P. I.	oth.									
14.9>	12.0	8.0=	8.0	13.2>	11.1	53 >	49	39.3<	52.7	Fiji
21.1>	17.1	10.0>	9.1	12.8>	8.9	39 <	45	42.1<	48.2	Fiji
21.3>	18.8	9.7>	8.8	12.7>	10.3	45 >	38	43.0<	43.8	Fiji
10.9>	10.3	10.2>	9.8	10.8>	8.7	59 <	64	43.8<	53.5	Fiji
8.0=	8.1	11.7>	9.8	9.9>	8.0	62 =	60	41.0<	43.3	Fiji
9.4=	9.5	10.8>	9.6	9.3>	8.3	41 <	51	58.4<	67.4	St. Annes
10.3>	9.9	9.3>	7.8	10.4>	8.3	41 =	44	42.4<	50.3	Fiji
8.0=	8.1	11.7>	9.8	9.9>	8.0	62 =	60	31.5>	28.7	Fiji
9.2>	8.6	11.1>	9.4	9.9>	7.8	68 >	57	29.2>	28.6	Kenya
10.4>	9.0	9.2<	9.8	5.4>	4.6	74	?	24.0<	30.8	Pacific
7.6=	7.7	10.9=	11.1	7.7>	7.4	70 >	50	35.6>	28.9	E. Australia
—	—	—	—	—	—	—	—	—	—	New Britain

The shells of females (Table 4) are distinctly longer than those of males, both in P. I. and in other areas, excepting the two species of the genus *Erronea*, in which they are of equal size or even smaller.

The female shells are also generally broader than those

of the males, though one might expect them to be more slender, since larger cowries generally are less broad than smaller shells. The greater breadth of females can be noted in all species, both from P. I. and from other areas, except in *Palmadusta gracilis* and in the most callous

Table 2

3	4	5	6
fulvous brown	red-brown	dark brown	blackish brown
rather scarce	equal to striate areas	numerous	predominant
small	rather large	large	very large
half the dorsum fawn	thin, transparent dark fawn	thick brown	very thick blackish brown
pale yellow	yellow	orange	rich reddish
produced: one terminal wart	subnodose : 1-2 terminal warts	both nodose	both acutely nodose
pale yellow	yellow	orange	rich reddish
indistinct	distinct	thick, orange	very thick, orange
swollen, pitted	swollen, pits covered	very callous	extremely callous
small	rather large	large	very large
small	rather large	large	very large
scarce	distinct, pale	distinct, saturate	very rich
subconvex; wide	convex, less wide	convex; narrow	callous; narrow
indistinct	pale	well marked	saturate
small	rather large	large	very large
small	rather large	large	very large
small	rather large	large	very large
yellowish white	pale yellow	rich yellow	yellowish orange
small	rather large	large	very large
small	rather large	large	very large

species, *Monetaria moneta* and *Erosaria caputserpentis*.

There is evidently no sexual difference in closeness of teeth, as evident differences observed at P. I. seem to be random, annulled by equal numbers in other areas; the only possible difference is in the labial teeth of *Palmadusta gracilis* and in the columellar teeth of *P. clandestina*, in both of which the female teeth seem to be closer together.

The ecotypes in *Monetaria* (see above) seem to indicate that in male *M. annulus* the ecotype *Q* is more frequent than in females (P. I. - ♀ 1:9:—, ♂ 0:9:1; Fiji-

♀ 1:6:3, ♂ 1:4:5); in *M. moneta* from P. I. no sexual difference becomes apparent, while in Fiji the *C* of females is often replaced by *E* in males (♀ 1:4:3:2:0; ♂ 1:0:4:5:0).

In the same way, sexual differences in the basal ribs of *Monetaria moneta* are absent in P. I. though distinct in Fiji (Table 3; see also SCHILDER, 1962, p. 101). Sexual differences in color and markings are irregularly scattered, but in *Lyncina* the females seem paler, while the *nebrites*-like basal striae of *Erosaria erosa* prevail in this sex.

Table 3

species	character	mean	P. I.		other	
		P. I. oth.	♀	♂	♀	♂
<i>Mauritia eglantina</i>	dorsal markings	3.6>3.3	3.7>3.4		3.3=3.3	
	dorsal lacunae	3.4=3.4	3.4=3.3		3.3=3.4	
	spire blotch	3.4<4.2	3.5=3.3		4.3=4.2	
<i>Lyncina lynx</i>	grey layer	3.0<3.6	2.4<3.4		3.5<3.7	
<i>Lyncina vitellus</i>	dorsal color	3.9=3.8	3.8<4.0		3.6<3.8	
<i>Monetaria annulus</i>	orange ring	4.6<4.9	4.5<4.9		4.9=5.0	
<i>Monetaria moneta</i>	basal ribs	2.4<3.0	2.1=2.0		2.6<3.9	
	orange ring	2.3<2.7	1.9<2.2		2.5<3.2	
	golden suffusion	3.0>1.0	2.2<2.6		1.0=1.0	
<i>Erosaria erosa</i>	right margin	2.8<3.1	3.0=2.8		3.0=3.1	
	labial blotch	3.8=3.9	3.8=3.8		3.9=4.1	
	columellar blotch	4.6=4.6	4.6=4.7		4.7=4.6	
	basal striae	2.8>2.6	3.1>2.6		2.9>2.4	
<i>Erronea erronea</i>	base, aperture	3.1>2.2	3.2>2.9		2.2=2.3	
	dorsal zones	4.6>3.6	4.6=4.7		3.5<3.8	
	dorsal blotch	4.3>2.8	4.3=4.5		3.2>2.8	
	right spot	1.1<3.0	1.1=1.2		3.1=3.0	
	left spot	1.0<1.5	1.0=1.0		1.6=1.6	
	basal color	3.0<3.6	3.0=3.0		3.6=3.5	
	dorsal blotch	2.1<2.5	2.0<2.3		2.4=2.4	
<i>Erronea caurica</i>	dorsal blotch	2.1<2.5	2.0<2.3		2.4=2.4	
<i>Palmadusta gracilis</i>	dorsal blotch	3.0=3.0	2.9=3.1		3.0=2.9	

The radula (Table 4) of females contains almost invariably more numerous rows than that of the males, while the median tooth is less broad in females, the two species of *Lyncina* excepted; but these contrary characters do not cancel each other out, as the radular ribbon of females is shorter in all species than the ribbon of males, again the two species of *Lyncina* excepted.

ADDITIONAL REMARKS

The racial characters of the cowries from Penrith Island generally agree with those attributed by SCHILDER & SCHILDER 1952 to the Melanesian subspecies which spread to Queensland. Special East Australian subspecies should

be rejected taxonomically; the only exceptions seem to be *Palmadusta gracilis macula* (ANGAS, 1867) and *Erosaria caputserpentis caputanguis* (PHILIPPI, 1849); the former is restricted to Queensland and New South Wales, while the latter is a typical "cline" as its characters are developed best at its southern border in the Sydney area, while such specimens become more and more rare among farther Northern populations; at Penrith Island few shells exhibit some characters reminiscent of *E. c. caputanguis*.

The single examined *Lyncina carneola* is a female of 44.5 mm with dark margins adorned with six paler low pustules on the right side. The only *Erosaria labrolineata*

Table 4

		L		BL		LT		CT		r/12		m/L		dr/L	
		♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
<i>Mauritia eglantina</i>	P. I.	50.1	>49.1	56.1	>54.8	t.9	= u.0	u.0	= u.1	14.3	>13.2	7.6	< 8.4	12.9	<13.7
	Fiji	51.6	>50.4	59.5	>58.0	u.4	= u.4	t.5	= t.5	12.7	>11.4	7.4	< 8.5	10.7	<11.5
<i>Lyncina lynx</i>	P. I.	43.9	>39.4	58.6	>58.1	o.5	= o.7	o.1	= o.4	22.6	>20.7	9.9	=10.0	13.5	>12.5
	Fiji	41.0	>37.0	58.8	>57.5	o.5	= o.5	o.5	= o.3	17.4	>17.0	9.2	= 9.1	8.9	= 8.9
<i>Lyncina vitellus</i>	P. I.	48.4	>47.1	65.9	>63.1	n.8	= n.6	o.9	> o.3	21.9	>20.8	10.2	> 9.3	13.5	>12.0
	Fiji	49.0	>47.2	64.1	>62.3	o.4	= o.2	p.1	= p.2	18.1	<19.4	9.1	> 8.6	10.2	=10.2
<i>Monetaria annulus</i>	P. I.	24.0	=24.0	68.8	>68.4	g.5	= g.4	g.0	= f.7	11.2	>10.4	10.1	<10.4	10.3	<11.0
	Fiji	20.1	>18.9	71.0	>70.4	g.5	= g.2	f.6	= f.4	10.9	> 9.0	9.2	<11.0	8.6	< 9.2
<i>Monetaria moneta</i>	P. I.	26.3	>25.6	70.7	=70.8	h.0	> g.2	h.0	= h.2	10.2	> 9.6	10.4	<10.6	9.2	<10.0
	Fiji	20.7	>19.6	75.1	>73.0	g.5	= g.5	h.0	= h.2	9.2	> 8.9	8.7	< 9.8	8.1	< 8.8
<i>Erosaria caputserpentis</i>	P. I.	31.9	>30.4	70.3	<71.1	k.6	> k.1	h.9	= h.6	9.9	> 9.1	9.7	<11.7	8.6	< 9.8
	St. Ann.	26.0	>25.2	75.0	=74.7	i.8	= i.9	h.8	= h.7	9.9	> 9.3	9.0	<10.1	7.8	< 8.7
<i>Erosaria erosa</i>	P. I.	33.4	>32.7	59.6	>58.6	l.4	< 1.9	i.3	= i.6	10.9	>10.0	8.6	< 9.8	9.9	<10.7
	Fiji	32.8	>31.9	60.8	>60.1	l.5	= 1.2	i.6	= i.8	10.8	> 9.4	7.2	< 8.5	8.0	< 8.5
<i>Erronea erronea</i>	P. I.	23.5	=23.3	57.6	>56.6	h.6	= h.7	k.5	< k.9	8.2	> 7.7	10.8	<13.2	9.3	<10.9
	Fiji	19.6	=19.9	55.6	>54.6	i.4	= i.4	l.6	= 1.6	8.2	= 8.2	9.3	<10.5	7.5	< 8.8
<i>Erronea caurica</i>	P. I.	35.2	<37.2	52.9	>51.5	k.6	< 1.7	l.1	= 1.5	9.3	> 8.7	10.3	<12.8	9.6	<10.7
	Kenya	33.0	<33.3	57.2	>56.6	k.2	= k.3	n.5	= n.7	8.9	> 8.3	8.0	<11.1	6.8	< 8.8
<i>Palmadusta clandestina</i>	P. I.	16.3	>15.4	62.0	>61.6	p.1	< p.8	p.6	> p.2	10.6	> 9.5	9.2	= 9.2	5.4	= 5.5
	Pacific	(16.5)	14.7	(59.0)	59.0	q.0	= p.9	r.0	> q.1	(8.5)	9.2	(10.5)	8.8	(5.0)	4.6
<i>Palmadusta gracilis</i>	P. I.	18.4	>18.0	59.7	<60.3	o.0	> n.2	o.2	= n.8	8.3	> 6.2	10.4	<12.1	7.1	< 9.2
	Austral.	17.4	>16.9	61.0	=61.0	m.8	>m.2	n.5	= n.7	7.7	= 7.8	10.7	<11.5	6.6	< 8.2

recalls the shell named *maccullochi* by IREDALE in 1939. Among the 13 *Staphylaea limacina* seven shells are smooth (*facifer* IREDALE, 1935) and six are pustulose (*monstrans* IREDALE, 1935). The *Erronea erronea* connect the typical *E. coerulea* (SCHRÖTER, 1804) with *E. mageronnes* (IREDALE, 1939), a callous ecotype occurring at various localities in Queensland. The *E. caurica* mostly recall the shell figured 1939 by IREDALE as *thema*. Two *Palmadusta gracilis* exhibit ferruginous striae outside the posterior labial teeth, as it often occurs in specimens from Queensland. *Bistolida pallidula* belongs to the New Caledonian race *rhinoceros* (SOVERBIE, 1865) and not to the more Eastern *summersi* SCHILDER, 1960, as the closeness of teeth is pn; the radula of the Penrith specimen shows five denticles on the anterior margin of the median (which is destitute of basal teeth) and four denticles each on the admedian and the laterals, as it is in *B. coxeni* (Cox) in contrast to *B. quadrimaculata* (GRAY, 1824).

SUMMARY

An exact analysis of the characters of shells and animals observed in the two sexes of eleven cowrie species collected at Penrith Island off Mackay, Queensland, shows interesting differences between this restricted population

and cowries mostly coming from the zoogeographically adjacent, but more tropical Fiji Islands. There is a distinct parallelism in several characters of shells and radulae in all species or in taxonomical groups of species, which may be caused by influence of the habitat.

LITERATURE CITED

- SCHILDER, FRANZ ALFRED
1958. Bezeichnung der Zahndichte der Cypraeaacea. Arch. Molluskenk. 87 (1-3): 77-80; 3 tables.
- SCHILDER, FRANZ ALFRED, & MARIA SCHILDER
1952. Ph. Dautzenberg's collection of Cypraeidae. Mém. Inst. Roy. Sci. Nat. Belgique, (2) 45: 1-243; 4 pls.
1961. Sexual differences in cowries. Proc. Malacol. Soc. London 33 (4): 207-209.
1962. Zur Kenntnis der Cypraeidae: 4. Geschlechtsunterschiede bei *Monetaria moneta*. Arch. Molluskenk. 91 (1-3): 99-103.
1963. Statistical studies on cowrie radulae. The Veliger 5 (3): 106-111; 2 text figs.; 3 tables. (1 Jan. 1963)
- SCHOTT, GERHARD
1935. Geographie des Indischen und Stillen Ozeans. Hamburg.

Effects of Antennectomy, Dehydration and Superhydration on the Movements of *Helix aspersa* (Mollusca : Gastropoda)

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ALTHOUGH MOISTURE RECEPTORS are known for some animals (GUNN, 1937; BENTLEY, 1944; and others) we have been unable to find any evidence concerning their location in terrestrial snails. However, it is well known that *Helix aspersa* does respond to moisture, and some experimental work has been done on this (HERZBERG & HERZBERG, 1962). The effects of an animal's previous hydration upon its preference for dry or moist areas have also been studied (KENNEDY, 1937; and others).

The upper two tentacles of *Helix aspersa* are eye stalks and the lower two are thought to be olfactory organs (PROSSER, 1950). This study was designed to determine 1) whether the two lower tentacles of *Helix aspersa* contain humidity receptors as do the antennae of some other animals, and 2) whether previous dehydration or environmental saturation with water influences the preference of this animal for a moist environment.

MATERIAL AND METHODS

This study was carried out between July 31, 1961 and August 18, 1961 with specimens of *Helix aspersa* gathered from a garden in Woodland Hills, California. There were four groups of 35 snails each. The snails in Group 1 were kept in glass jars of one quart capacity, 5 snails per jar, with a layer of dry soil, 5 cm thick, in the bottom of each. The tops of the jars were covered with aluminum screening. No water was supplied at any time. The snails in Group 2 were kept in similar jars for the same period of time but the soil in these jars was kept wet, with a water level readily apparent. Both groups were provided with equal and more than adequate amounts of fresh lettuce. The snails in Group 3 were gathered after Groups 1 and 2

had been kept for 13 days. The lower two tentacles of each of the snails in Group 3 were amputated with sharp scissors. The animals were not disturbed by the procedure and continued to move about as before, nor was there any fluid loss apparent following antennectomy. The snails in Group 4 were gathered on the same day as those in Group 3 to serve as controls. All snails were identified by markings in red nail polish on the shells. All four groups were then placed into a wooden box, 45 cm by 45 cm, with a height of 4 cm, exclusive of 4 cm of soil in the bottom of the box. A wooden divider extending from the bottom of the box to the aluminum screen covering the top of the box, was placed in its exact center in a manner which would divide the box into two equal parts. A gap of 7½ cm was left at one end of the divider, giving the snails access from one side of the box to the other through this opening. The soil on the side of the box into which the snails were placed was left entirely dry and the other side was kept constantly moist, with the soil almost muddy in consistency. Adequate amounts of fresh lettuce were supplied equally to both halves of the box. The snails in the previously dry group (Group 1) had, without exception, sealed themselves off within their shells. The epiphragms with which they were sealed often broke when the animals were removed from the jars. Therefore all of the epiphragms left intact were broken by the experimenters in order to give each of the snails an equal opportunity to react to the presence of moisture.

The snails were placed into the wooden box at 1:30 p. m. on August 13 and were observed at various times until 3:00 p. m. on August 18. The number of snails

from each group present on the wet side was counted at each observation.

RESULTS

The number of snails from each group found on the wet side of the box at various times is shown in Table 1. Snails from Group 1 (dehydrated for 13 days) did not begin to move to the wet side until several hours after snails from the other groups had begun to do so. Fewer snails from this group than from any other were found on the wet side until 1½ days after the snails had been placed into the box. For a similar period more snails from the antennectomized group (Group 3) than from any other group were found on the wet side. After the 1½ day period the only consistent difference between the groups was the slight increase in the number of antennectomized snails on the wet side. A few of the dehydrated animals failed to emerge from their shells during the experimental period.

DISCUSSION

As one observes the activities of individuals of *Helix aspersa* in glass jars it appears that the lower tentacles are used by the animal to help feel its way over the soil or glass. However, the animals appear in no way incapacitated in their ability to move without these organs present. We have observed the use of the lower tentacles during courtship, when the snails seem to locate each other with the help of these organs. We did not test the antennectomized animals to ascertain whether the courtship process was affected. From the evidence acquired in this study it appears clear that the lower antennae are not required by this species when it expresses its need for moisture. This would indicate either that there are no moisture receptors in the lower antennae or, if present, that they are not important in seeking moisture.

SUMMARY

The preference of *Helix aspersa* for moist areas is not influenced by 13 days exposure to a wet or a dry environment. Snails kept dry for this length of time have a latent period of several hours before they begin to move. Antennectomized snails congregated in the moist areas in essentially the same numbers as did controls, dehydrated and superhydrated snails. It appears likely that

moisture receptors are not limited to the lower antennae of this species, and may even be entirely absent from these organs.

Table 1

Chart showing the number of animals found on the wet side of the box at various time intervals.

Date	Time of day	Dehydrated	Superhydrated	Control	Antennectomized
8 / 13	13:30	0	0	0	0
	18:00	0	1	3	3
	22:00	0	2	4	6
	24:00	8	16	11	14
8 / 14	9:00	27	27	28	31
	20:00	25	26	31	32
	23:00	25	24	26	29
8 / 15	0:30	23	21	29	28
	10:00	30	24	20	30
	18:00	31	25	25	28
8 / 16	11:00	28	28	30	20
	18:00	29	29	29	20
8 / 17	9:00	23	28	32	24
8 / 18	15:00	27	29	32	30

LITERATURE CITED

- BENTLEY, E. W.
1944. The biology and behavior of *Ptinus tectus* BOIE (Coleoptera. Ptinidae), a pest of stored products. V. Humidity reactions. *Journ. Exp. Biol.* 20: 152 - 158
- GUNN, D. L.
1937. The humidity reactions of the wood-louse, *Porcellio scaber* (LATREILLE). *Journ. Exp. Biol.* 14: 178 - 186
- HERZBERG, FRED & ANDREA HERZBERG
1962. Preliminary report on time elements involved in hydrotropism in *Helix aspersa* (Gastropoda, Pulmonata) following dehydration. *The Veliger*, 5 (2): 87 - 90 (1 Oct. 1962)
- KENNEDY, JOHN S.
1937. The humidity reactions of the African migratory locust, *Locusta migratoria migratorioides* R. and F., gregarious phase. *Journ. Exp. Biol.* 14: 187 - 197
- PROSSER, CLIFFORD LADD
1950. Comparative animal physiology. W. B. Saunders C., Philadelphia. ix + 888 pp.; 312 text figs.



A Proposed Revision of the Rissoacean Families

Rissoidae, Rissoinidae, and Cingulopsidae

(Mollusca : Gastropoda)

BY

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(1 Text figure)

DURING THE PREPARATION of the portion of the *Treatise of Invertebrate Paleontology* dealing with the three families Rissoidae, Rissoinidae, and Cingulopsidae of the superfamily Rissoacea, it quickly became apparent that important changes would have to be made in the position and rank of many of the named genera, a few type species would have to be designated, and several new subfamilies would have to be proposed. For these reasons, and because these changes could not be accompanied by necessary explanation in the *Treatise*, this article seems to be needed as an advance treatment.

A file, in preparation for the *Treatise*, was begun by the late Dr. Julia Gardner; it was turned over to Dr. Myra Keen of Stanford University upon Dr. Gardner's death. Lee A. Smith, then a graduate student in Dr. Keen's department, added much information to the growing file. Priscilla Militante worked up the forms that she believed to be members of the family Rissoinidae and prepared her unpublished doctoral dissertation on that group. Dr. Keen has, since that time, added some solutions for nomenclatural problems.

MONTAGU and other early workers included these small forms in the genus *Turbo*. Slowly, more and more genera were named. The first important review of the group was that of VON MOHRENSTERN (1861 - 1864). BUCQUOY, DAUTZENBERG & DOLLFUS (1884), and TRYON (1887) included treatments, as did COSSMANN (1921). There has not been since THIELE (1929 - 1935) and WENZ (1939 - 1944) a comprehensive review of these families. Many genera have been named in recent years, especially in the literature of Australia and New Zealand, where generic names have proliferated nearly as fast as have specific names. LASERON (1956) is a useful reference to a major portion of the Australian fauna.

FRETTER & GRAHAM (1962) believe the three Rissoacean families Hydrobiidae, Rissoidae, and Assimineidae

to be very closely related to one another, Tornidae to be somewhat less related; *Barleeia*, the only British representative of the Rissoinidae, to be quite distinct, and the Skeneopsidae, Omalogyridae, Rissoellidae, and Cingulopsidae to be so distinct as to be doubtfully even Rissoacean. The family Cingulopsidae was recently created by FRETTER & PATIL (1959). MOORE (1962) considers the families Caecidae and Ctiloceratidae to be members of the Rissoacea, close to the Tornidae.

The family Rissoinidae has been here built around forms known to have an apophysis on the inner side of the horny operculum (see Figure 1) and those fossil and living genera that can convincingly be assigned on the basis of external morphology. If most members of this group are similar to *Barleeia*, in which the operculum is of similar form, then we may also characterize the family on the basis of the anatomical work of FRETTER & GRAHAM on *Barleeia* as (1) having a complex reproductive system, (2) lacking a metapodial tentacle, (3) not having a free veliger larva, and (4) having the secretive tissue of the posterior pedal mucous gland confined to the foot. The tentacles of *Barleeia* are moderate in length, simple, and obtuse at their bases. The foot is a little emarginate behind and truncate in front. Some of these characters, such as the lack of a free swimming larva, may not be characteristic of the entire family, but only of the British *Barleeia*.

The Rissoidae, on the other hand, have (1) a less complex reproductive system, (2) a metapodial tentacle developed from the opercular lobe of the foot (some *Cingulas* do not have one), (3) a free swimming veliger larva, with two British exceptions, and (4) the secretive tissue of the posterior pedal mucous gland extending into the haemocoel of the head. The tentacles of the Rissoids, in contrast to those of *Barleeia*, appear to be long and ciliated. The foot is attenuated behind.

The family Cingulopsidae is characterized by having a small unicuspid rachidian tooth, two esophageal pouches, no jaws, no crystalline style, no penis, and a diaulic female duct. Again, these features indicate a considerable departure from the Rissoidae.

It has long been known that the difference in operculum between the Rissoidae and the Rissoinidae is one way to tell the two closely related families apart, for, as it turns out, there are smooth, cancellate, axially, and concentrically sculptured members in both families. Figure 1 is of the operculum of *Barleeia rubra* (J. ADAMS, 1797). Also observed or previously illustrated as possessing a rissoinid operculum were *Diala marmorata* CARPENTER, 1864;



Figure 1: Operculum of *Barleeia rubra* (J. ADAMS, 1797), showing the apophysis on the inner side of the horny structure.

Dardanula olivacea HUTTON, 1882 (type of *Dardanula*); *Eatoniella kerguelensis* (SMITH, 1875) (type of *Eatoniella*); *Skenella georgiana* MARTENS & PFEFFER, 1886 (type of *Skenella*); and *Barleeia (Nodulus) contorta* (JEFFREYS, 1856) (type of *Nodulus*). Radulae of some of the European species have been illustrated by SARS in 1878.

The following classification is tentative, and there is much room for change. As a basis for the arrangement, we have the anatomical work of the British and the opercula that have been studied or previously illustrated. The rest becomes guess work.

Rissoidae: The trend of European workers seems to be the synonymizing of some of the many generic names and the use of others as subgenera. I have done more subjective synonymizing of the names in this family than in the Rissoinidae, following this trend. I found it sufficiently difficult to believe West American forms to be congeneric with the comparatively large and globular type of the genus *Alvania*, *A. cimex* (LINNAEUS, 1758), that I have elevated *Alvinia* to full generic rank and consider our species to be members of that genus, *Willettia* being a subgenus of *Alvinia*. It is a difficult decision as to which European forms come under *Alvania* or *Alvinia*, but the *Alvanias* are larger and more globular.

The genera grouped around *Haurakia* appear to be members of the Rissoidae, being more closely related to *Rissoa* than to *Alvania*. The many genera grouped as only questionably Rissoidae, are, for the most part, from Australia and New Zealand. It remains for more detailed work to show whether they are indeed Rissoids.

The new subfamily Anabathroninae, formed around the genus *Anabathron* and other Pacific Ocean genera (plus one from the Atlantic), seems a natural grouping.

The new subfamily Cingulinae is formed around the European *Cingula*. It is to be noted that the West American *Cingula martyni* DALL, 1886 is a member of the subgenus *Falsicingula* HABE, 1958. The remaining genera following *Cingula* in this subfamily are nearly all Australian, at present of uncertain position and rank. I have not been able to study pertinent material.

The subfamily Stenothyridinae has been added here on the advice of Dr. J. P. E. Morrison of the United States National Museum.

Rissoinidae: The family Rissoinidae is in somewhat better shape, since most of its members have in common a clearcut opercular character. The genus *Rissoina* is so well-defined a unit that I consider the many names proposed by the Australian workers to be at best of subgeneric rank. A few forms, however, stand out conspicuously enough to be left as genera.

The Phosinellinae, a new subfamily, is characterized by cancellate sculpture of varying degrees of intensity. A few of the genera are included in this subfamily only provisionally, among them *Emblanda* and *Herewardia* of IREDALE (1955) and the fossil genera *Anteglosia* VOKES, 1948 and *Cossmannia* NEWTON, 1891.

The new subfamily Zebininae is built around smooth genera or genera with confined axial sculpture.

The Barleecinae are assumed to belong to the Rissoinidae on the basis of the operculum in the type species of *Barleeia* and in other related genera. Perhaps this group is sufficiently different to warrant being placed in a separate family. Many genera are being placed here with misgivings.

As can be easily seen, much more work remains to be done, and it is my hope that this compilation, rearrangement, and discussion will stimulate others to consider the problems concerned with these prolific small forms.

CONVENTIONS

The following conventions are adopted herein. They are, for the most part, those of the *Treatise of Invertebrate Paleontology*.

- (1) Brackets [] and an asterisk (*) indicate the type species of the genus.
- (2) Type designations are abbreviated as follows:
 - M = Monotypy
 - SD = Subsequent Designation
 - OD = Original Designation
- (3) Other abbreviations:
 - auctt.* = of authors
 - emend.* = emendation
 - err.* = error
 - ex* = from
 - MS. = manuscript
 - nom.* = name
 - non* = not, not of
 - pro* = for
 - transl.* = translation (from one taxonomic level to another - *nom. transl.*)
 - van.* = invalid emendation (*nomen vanum*)
 - ? (before a generic name) = position questioned
 - ? (before =) = synonymy questioned

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Family RISSOIDAE H. & A. ADAMS, 1854

Subfamily RISSOINAE H. & A. ADAMS, 1854

nom. transl. STOLICZKA, 1868, *ex* RISSOIDAE

Rissoa FRÉMINVILLE, 1813 (genus without species) [**R. ventricosa* DESMAREST, 1814; SD BUCQUOY, DAUTZENBERG & DOLLFUS, 1884]

= *Anatasia* GISTEL, 1848, *nom. van.*

= *Apanthausa* GISTEL, 1848, *nom. van.*

= *Persephona* LEACH, 1852, *non* LEACH, 1817

= *Rissoia*, *emend.*, *auctt.*

R. (*Rissoa*)

R. (*Apicularia*) MONTEROSATO, 1884 [**Rissoa similis* SCACCHI, 1836; SD CROSSE, 1885]

R. (*Goniostoma*) VILLA, 1841, *ex* MOHRENSTERN MS (not preocc. by SWAINSON, 1840, *err. pro Gonyostoma* SWAINSON, 1840). [**Turbo auriscalpium* LIN-

NAEUS, 1758; SD herein]

= *Zippora* LEACH, 1847 [**Z. drummondii* LEACH, 1847 (= *Turbo auriscalpium* LINNAEUS, 1758); M]

R. (*Loxostoma*) BIVONA-BERNARDI, 1838 [**Rissoa monodonta* PHILIPPI, 1836, *ex* BIVONA-BERNARDI MS; M]

= *Loxotoma*, *err.*, *auctt.*

= *Schwartzia* BUCQUOY, DAUTZENBERG & DOLLFUS, 1884 [**Rissoa monodonta* (PHILIPPI, 1836); M]

R. (*Manzonina*) BRUSINA, 1870 [**Turbo costatus* J. ADAMS, 1797, *non* VON SALIS, 1793 (= *T. crassa* KANMACHER in ADAMS, 1798); M]

R. (*Pusillina*) MONTEROSATO, 1884 [**Rissoa pusilla* PHILIPPI, 1836, *non* GRATELOUP, 1828 (= *R. dolium* NYST, 1843); M]

= "*Turboella* GRAY, Nov. 1847, *ex* LEACH MS.," *auctt.*, *non* *Turboella* LEACH, Oct. 1847 [**Turbo parvus* MONTAGU, 1803; OD (= *T. parvus* DACOSTA, 1778)]

= *Turbella*, *err. pro* "*Turboella* GRAY, 1847," *auctt.*

R. (*Rissostomia*) SARS, 1878 [**Turbo membranaceus* J. ADAMS, 1800; M]

Alvania RISSO, 1826 [**A. europea* RISSO, 1826, SD WINCKWORTH, 1932 (= *Turbo cimex* LINNAEUS, .. 1758)]

= *Acinus* MONTEROSATO, 1884 [**Turbo cimex* LINNAEUS, 1758; OD]

= *Turboella* LEACH, Oct. 1847 [**T. calathiscus* .. (MONTAGU, 1803) (= *Turbo cimex* LINNAEUS, 1758); SD herein]

A. (*Alvania*)

A. (*Acinopsis*) MONTEROSATO, 1884 [**Turbo cancellatus* DACOSTA, 1778; SD CROSSE, 1885]

A. (*Acinulus*) SEGUENZA, 1903 [**Rissoa cimicoides* FORBES, 1844; M]

A. (*Galeodina*) MONTEROSATO, 1884 [**Turbo carinatus* DACOSTA, 1778, (?) *non* BORN, 1778 (= *T. striatulus* DACOSTA, 1778, *non* LINNAEUS, 1758); M]

A. (*Galeodinopsis*) SACCO, 1895 [**Rissoa tiberiana* COPPI, 1876; OD]

A. (*Massotia*) BUCQUOY, DAUTZENBERG & DOLLFUS, 1884 [**Rissoa lactea* MICHAUD, 1830; OD]

Alvinia MONTEROSATO, 1884 [**Rissoa weinkauffi* MONTEROSATO, 1877, *ex* MOHRENSTERN, MS; SD CROSSE, 1885]

A. (*Alvinia*)

A. (*Actonia*) MONTEROSATO, 1884 [**Rissoa testae* ARADAS & MAGGIORE, 1843; SD CROSSE, 1885]

A. (*Alcidiella*) COSSMANN, 1921, *ex* MONTEROSATO MS., *nom. nov. pro Alcidia* MONTEROSATO, 1890, *non* WESTWOOD, 1879 [**Alcidia spinosa* MONTE-

ROSATO, 1890, *nom. nov. pro Risssoa angulata* SEGUENZA, 1873 - 79, *non* EICHWALD, 1830; M]

A. (Alvaniella) SACCO, 1895, *ex* MONTEROSATO MS [**Risssoa scabra* PHILIPPI, 1844; OD]

= *Seguenziella* SACCO, 1904, *non* NEVIANI, 1901, *nom. nov. pro Taramellia* SEGUENZA, 1903, *non* CAMPANA, 1903, *nom. nov. pro Flemingia* JEFFREYS, 1884, *non* JOHNSTON, 1832 [**Turbo zetlandica* MONTAGU, 1815; M]

A. (Arsenia) MONTEROSATO, 1891 [**Risssoa striatissima* RAYNEVAL, HECKE & PONZI, 1854; M? (? = *Turbo puncturus* MONTAGU, 1803)]

A. (Thapsiella) FISCHER, 1885, *nom. nov. pro Thapsia* MONTEROSATO, 1884, *non* ALBERS, 1860 [**Risssoa rudis* PHILIPPI, 1844; M]

A. (Turbona) GRAY, 1847, *ex* LEACH MS. [**Turbo reticulatus* J. ADAMS, 1797, *non* SOLANDER, 1766; OD (= *Cingula beanii* HANLEY in THORPE, 1844)]
= *Zacanthusa* GRAY, 1852, *ex* LEACH MS. [**Z. reticulata* (= *Turbo reticulatus* J. ADAMS, 1797); SD herein]

A. (Willettia) GORDON, 1939 [**Alvania montereyensis* BARTSCH, 1911; OD]

Haurakia IREDALE, 1915 [**Risssoa hamiltoni* SUTER, 1898; OD]

H. (Haurakia)

H. (Haurakiopsis) POWELL, 1937 [**H. pellucida* POWELL, 1937; OD]

H. (Subbestea) COTTON, 1944 [**Alvania seminodosa* MAY, 1915; OD]

Subfamily Risssoinae:

groups of uncertain position and rank

Austronoba POWELL, 1927 [**Risssoa candidissima* WEBSTER, 1905; OD]

Awanuia POWELL, 1927 [**Merelina (A.) dilatata* POWELL, 1927; OD]

Discrevinia LASERON, 1956 [**D. balba* LASERON, 1956; OD]

Feldestea IREDALE, 1955 [**Alvania salebrosa* FRAUENFELD, 1867; OD]

Ihungia MARWICK, 1931 [**I. luteophila* MARWICK, 1931; OD]

Larochella POWELL, 1927 [**L. toreuma* POWELL, 1927; OD]

Linemera FINLAY, 1924 [**L. interrupta* FINLAY, 1924, *nom. nov. pro Risssoa gradata* HUTTON, 1885, *non* ORBIGNY in SAGRA, 1842; OD]

Merelina IREDALE, 1915 [**Risssoa cheilostoma* TENISON-WOODS, 1877; OD]

Nodulestea IREDALE, 1955 [**Estea castella* LASERON, 1950; OD]

Notoscrobs POWELL, 1927 [**N. ornatus* POWELL, 1927; OD]

Parashiella LASERON, 1956 [**P. ambulata* LASERON, 1956; OD]

Promerelina POWELL, 1926 [**P. crosseaformis* POWELL, 1926; OD]

Scalarnoba POWELL, 1927 [**S. costata* POWELL, 1927; OD]

S. (Scalarnoba)

S. (Manawatawhia) POWELL, 1937 [**M. analoga* POWELL, 1937; OD]

Veterator LAWS, 1944 [**Brookesena quadricincta* MARWICK, 1931; OD]

Subfamily Anabathroninae COAN, subfam. nov.

Anabathron FRAUENFELD, 1867 [**A. contabulata* FRAUENFELD, 1867; M]

A. (Anabathron)

A. (Lironoba) IREDALE, 1915 [**Risssoa suteri* HEDLEY, 1904; M]

A. (Chrystella) LASERON, 1956 [**C. islandica* LASERON, 1956; OD]

= *Crystella*, *err.*, *auctt.*

Cylonidea LASERON, 1956 [**C. carina* LASERON, 1956; OD]

Nannoteretispira HABE, 1961 [**N. japonica* HABE, 1961; OD]

Nobolira FINLAY, 1926 [**Lironoba polyvineta* FINLAY, 1924; OD]

N. (Nobolira)

N. (Adolphinoba) POWELL, 1930 [**A. finlayi* POWELL, 1930; OD]

Tropidorissoia TOMLIN & SHACKLEFORD, 1915 [**T. taphrodes* TOMLIN & SHACKLEFORD, 1915; OD]

Subfamily Cingulinae COAN, subfam. nov.

Cingula FLEMING, 1828 [**Turbo cingillus* MONTAGU, 1803; SD GRAY, 1847 (? = *T. trifasciatus* J. ADAMS, 1800)]

= *Cingilla* MONTEROSATO, 1884 [**Turbo trifasciatus* J. ADAMS, 1800; SD CROSSE, 1885]

= *Crisilla* COSSMANN, 1921, *ex* MONTEROSATO MS [**Turbo semistriatus* MONTAGU, 1808; OD]

= "*Cingula* MONTEROSATO," *auctt.*, *non* FLEMING, 1828

C. (Cingula)

C. (Botelloides) STRAND, 1928, *nom. nov. pro Botellus* IREDALE, 1924, *non* MONIEZ, 1887 [**Onoba bassiana* HEDLEY, 1911; OD]

C. (Chevallieria) COSSMANN, 1888, [**C. labrosa* COSSMANN, 1888; OD]

- = *Pseudonoba* BOETTGER, 1902 [**P. peculiaris* BOETTGER, 1902; OD]
- C. (Dipsotoma)* LASERON, 1956 [**Rissoa mercurialis* WATSON, 1886; OD]
- C. (Falsicingula)* HABE, 1958 [**Cingula kurilensis* PILSBRY, 1905; OD]
- C. (Hyalia)* H. & A. ADAMS, 1852 [**H. vitrea* (= *Turbo vitreus* MONTAGU, 1803); M]
- = *Ceratia* H. & A. ADAMS, 1852 [**Rissoa proxima* FORBES & HANLEY, 1850, ex ALDER MS; M]
- C. (Onoba)* H. & A. ADAMS, 1852, nom. nov. pro *Turbonilla* LEACH, 1847, non RISSO, 1826 [**O. striata* (= *Turbo striatus* J. ADAMS, 1797, non DACOSTA, 1778 = *Turbo semicostatus* MONTAGU, 1803); M]
- C. (Peringiella)* MONTEROSATO, 1878 [**Rissoa laevis* MONTEROSATO, 1877; M]
- C. (Pisinna)* MONTEROSATO, 1878 [**Rissoa punctulum* PHILIPPI, 1836 = *Helix glabrata* MÜHLFELD, 1824; SD COSSMANN, 1921]
- C. (Setia)* H. & A. ADAMS, 1852 (not preocc. by OKEN, 1815 - ICZN Op. 417) [**Rissoa pulcherrima* JEFFREYS, 1848; SD KOBELT, 1878]
- = *Parvisetia* MONTEROSATO, 1884 [**Rissoa scillae* ARADAS & BENOIT, 1870, ex SEGUENZA MS; M]
- = *Obtusella* COSSMANN, 1921 nom. nov. pro *Cingulina* MONTEROSATO, 1884, non A. ADAMS, 1860 [**Rissoa obtusa* CANTRAINE, 1842, (non BROWN, 1841) ? = *R. soluta* PHILIPPI, 1844; M]
- Cingulinae: groups of uncertain position and rank
- Amphithalamus* CARPENTER, 1865 [**A. inclusus* CARPENTER, 1865; M]
- Badepigrus* IREDALE, 1955 [**Rissoa badia* PETTERD, 1884; OD]
- ? *Elachisina* DALL, 1918 [**E. grippi* DALL, 1918; M]
- Epigrus* HEDLEY, 1903 [**Rissoina cylindracea* TENISON-WOODS, 1878; OD (as *Rissoa ischna* TATE, 1899 nom. nov.) (not preocc. by *Rissoa cylindracea* KRYNICKI, 1837)]
- Estea* IREDALE, 1915 [**Rissoa zosterophila* WEBSTER, 1905; OD]
- Eusetia* COTTON, 1944 [**Rissoopsis expansa* POWELL, 1930; OD]
- Fairbankia* BLANFORD, 1868 [**E. bombayana* BLANFORD, 1868; M]
- Floridiscrobs* PILSBRY & MCGINTY, 1949 [**Amphithalamus dysbatus* PILSBRY & MCGINTY, 1949; OD]
- Heterocyclus* CROSSE, 1872 [**H. perroquini* CROSSE, 1872; M]
- Lucidestea* LASERON, 1956 [**L. vitrea* LASERON, 1956; OD]
- L. (Lucidestea)*
- L. (Mesodestea)* LASERON, 1956 [**M. resima* LASERON, 1956; OD]
- Nanadoma* LASERON, 1956 [**N. imitoris* LASERON, 1956; OD]
- Paronoba* LASERON, 1950 [**P. subquadrata* LASERON, 1950; OD]
- Pelycidion* FISCHER in DE FOLIN & PÉRIER [**P. venustum* FISCHER in DE FOLIN & PÉRIER, 1872; M]
- = *Pelecydium*, err., auctt.
- Rissopsis* GARRETT, 1873 [**R. typica* GARRETT, 1873; M]
- Ruapukea* DELL, 1952 [**R. carolus* DELL, 1952; OD]
- Scrobs* WATSON, 1886 [**Rissoa (S.) scrobiculator* WATSON, 1886; SD COSSMANN, 1921]
- S. (Scrobs)*
- S. (Anxietas)* IREDALE, 1917 [**A. perplexa* IREDALE, 1917; OD]
- S. (Laseronula)* WHITLEY, 1959, nom. nov. pro *Saltatricula* LASERON, 1956, non BURMEISTER, 1861, nom. nov. pro *Saltatrix* LASERON, 1950, non KLUG, 1833 [**Epigrus protractus* HEDLEY, 1904; OD]
- = *Saltratricula*, err., auctt.
- S. (Nannoscrobs)* FINLAY, 1927 [**Amphithalamus hedleyi* SUTER, 1908; OD]
- S. (Obescrobs)* IREDALE, 1955 [**Rissoa jacksoni* BRAZIER, 1895; OD]
- S. (Ultiscrobs)* IREDALE, 1955 [**Scrobs pluteus* LASERON, 1950; OD]
- Striatestea* POWELL, 1927 [**S. bountyensis* POWELL, 1927; OD]
- Subonoba* IREDALE, 1915 [**Rissoa fumata* SUTER, 1898; OD]
- Subfamily Stenothyriinae FISCHER, 1887
- Stenothyra* BENSON, 1856, nom. nov. pro *Nematura* BENSON, 1836, non FISCHER VON WALDHEIM, 1812 [**N. deltae* BENSON, 1836; OD]
- = *Nematuna* err., auctt.
- S. (Stenothyra)*
- S. (Gangetia)* ANCEY, 1890 [**Hydrobia miliacea* NEVILL, 1880; M]
- = *Astenothyra* ANNANDALE & PRASHAD, 1921 [**Hydrobia miliacea* NEVILL, 1880; OD]
- Obesitena* IREDALE, 1943 [**Stenothyra australis* HEDLEY, 1901; OD]
- Family Rissoinidae STOLICZKA, 1868
- nom. transl. COSSMANN, 1919, ex Rissoininae
- Subfamily Rissoininae STOLICZKA, 1868
- Rissoina* ORBIGNY, 1840 [**R. inca* ORBIGNY, 1840; M]
- R. (Rissoina)*
- R. (Apataxia)* LASERON, 1956 [**A. erecta* LASERON, 1956; OD]
- R. (Austrosina)* LASERON, 1956 [**Rissoina pulchella*

- 1850; OD]
 BRAZIER, 1877; OD]
R. (Caporista) IREDALE, 1955 [**Rissoina iredalei* LASERON, 1950; OD]
R. (Condylia) LASERON, 1956 [**C. collaxis* LASERON, 1956; OD]
R. (Contraxiala) LASERON, 1956 [**C. obliqua* LASERON, 1956; OD]
R. (Costalynia) LASERON, 1956 [**Rissoina cardinalis* BRAZIER, 1877; OD]
R. (Eurissoina) WOODRING, 1928 [**Rissoina (E.) ditomus* WOODRING, 1928; OD]
R. (Folinia) CROSSE, 1868 [**Rissoa insignis* FOLIN, 1867, non A. ADAMS & REEVE, 1850 (= *R. signae* BARTSCH, 1915); M]
R. (Fractoralla) LASERON, 1956 [**F. praecida* LASERON, 1956; OD]
R. (Laseronia) COTTON, 1959 [**Rissoina cretacea* TENISON-WOODS, 1878; OD]
R. (Mirarissoina) WOODRING, 1928 [**Rissoina (M.) lepida* WOODRING, 1928; OD]
R. (Palisadia) LASERON, 1956 [**P. subulata* LASERON, 1956; OD]
R. (Pandalosia) LASERON, 1956 [**P. excelsis* LASERON, 1956; OD]
R. (Peripetella) LASERON, 1956 [**P. queenslandica* LASERON, 1956; OD]
R. (Pleneconea) LASERON, 1956 [**P. angulata* LASERON, 1956; OD]
R. (Rissoinella) OYAMA, 1954 [**Rissoina zeltenerioides* YOKOYAMA, 1920; OD]
R. (Rissolina) GOULD, 1861 [**Rissoina plicatula* GOULD, 1861; SD NEVILL, 1885]
R. (Schwartziella) NEVILL, 1881 [**Rissoina orientalis* NEVILL, 1881; OD (? = *R. triticea* PEASE, 1862)]
 = (?) *Schwartziella* NEVILL, 1885, non NEVILL, 1881 [**Rissoina bryerea* MONTAGU, 1803; OD]
R. (Zebinella) MÖRCH, 1876 [**Rissoina decussata* (MONTAGU, 1803); SD NEVILL, 1885 (= *Helix decussata* MONTAGU, 1803)]
Dentrissoina LASERON, 1956 [**D. thornleyana* LASERON, 1956; OD]
Lanzia BRUSINA, 1906 [**Turbo elephantotus* MÜHLFELDT, 1824; M]
Microstelma A. ADAMS, 1863 [**M. daedala* A. ADAMS, 1863; M]
Pachyrissoina BOETTGER, 1893 [**Rissoina walkeri* SMITH, 1893; SD WENZ, 1939]
Parazebinella BOETTGER, 1893 [**Rissoina (P.) crenilabris* BOETTGER, 1893; M]
Stiva HEDLEY, 1904 [**S. ferruginea* HEDLEY, 1904; OD]

Subfamily Phosinellinae COAN, subfam. nov.

- Phosinella* MÖRCH, 1876 [**Rissoa pulchra* C. B. ADAMS, 1850; SD NEVILL, 1885]
P. (Phosinella)
P. (Costabieta) LASERON, 1956 [**C. paucina* LASERON, 1956; OD]
P. (Lucidinella) LASERON, 1956 [**L. conicera* LASERON, 1956; OD]
P. (Phintorene) IREDALE, 1955 [**Rissoina allanae* LASERON, 1950; OD]
P. (Plenapexia) LASERON, 1956 [**P. fractura* LASERON, 1956; OD]
Anteglosia VOKES, 1948 [**A. essoensis* VOKES, 1948; OD]
Cossmannia NEWTON, 1891, nom. nov. pro *Diasticus* COSSMANN, 1888, non MULSANT, 1842 [**Rissoina expansa* DESHAYES, 1861; OD]
C. (Cossmannia)
C. (Chilostigma) MELVILL, 1918 [**Rissoina (C.) refugium* MELVILL, 1918; M]
C. (Pezantia) COSSMANN, 1896, [**Rissoa dactylosa* DESHAYES, 1864; OD]
Emblanda IREDALE 1955 [**Rissoa emblematica* HEDLEY, 1906; OD]
Herewardia IREDALE, 1955 [**Rissoina kesteveni* HEDLEY, 1907; OD]
Iravadia BLANFORD, 1867 [**I. ornata* BLANFORD, 1867; M]
Isseliella WEINKAUFF, 1881, ex NEVILL MS [**Rissoina (I.) mirabilis* WEINKAUFF, 1881, ex DUNKER MS; OD]
Lapsigyryrus BERRY, 1958 [**Alvania contrerasi* JORDAN, 1936; OD]
Pellamora IREDALE, 1943 [**Iravadia australis* HEDLEY, 1900; OD]
Pyramidelloides NEVILL, 1885 [**Rissoina miranda* A. ADAMS, 1861; OD]
 = *Isselia auctt.*, nom. nud., non BOURGUIGNAT, 1877
Zymalata LASERON, 1956 [**Z. concinna* LASERON, 1956; OD]

Subfamily Zebininae COAN, subfam. nov.

- Zebina* H. & A. ADAMS, 1854 [**Rissoina coronata* MOHRENSTERN, 1860, ex RECLUZ MS; SD NEVILL, 1885]
Z. (Zebina)
Z. (Iopsis) GABB, 1873 [**I. fusiformis* GABB, 1873 (= *Rissoina browniana* ORBIGNY, 1840); M]
 = *Cibdezebina* WOODRING, 1928 [**Rissoina browniana* ORBIGNY, 1840; OD]
Crepitacella GUPPY, 1867 [**Melanopsis cepula* GUPPY, 1866; M]

- Dolophanes* GABB, 1873 [**D. melanoides* GABB, 1873; M]
Lealla COSSMANN, 1921 [**Pasithea notata* LEA, 1833; OD]
Morchiella NEVILL, 1885 [**Rissoa gigantea* DESHAYES, TAKIRISSOINA OYAMA, 1962 [**Rissoina japonica* WEINKAUFF, 1885; OD]
Tiphycerma BERRY, 1958 [**T. preposterum* BERRY, 1958; OD]

Subfamily Barleeinae THIELE, 1929

- Barleeia* CLARK, 1855 [**Turbo ruber* J. ADAMS, 1797, non VON SALIS, 1793 (= *T. unifasciatus* MONTAGU, 1803); M]
B. (Barleeia)
B. (Nodulus) MONTEROSATO, 1878 [**Rissoa contorta* JEFFREYS, 1856; M]
B. (Pseudosetia) MONTEROSATO 1884 [**Rissoa turgida* JEFFREYS, 1870; SD CROSSE, 1885]
Amphirissoa DAUTZENBERG & FISCHER, 1897 [**A. cyclostomoides* DAUTZENBERG & FISCHER, 1897; M]
A. (Amphirissoa)
A. (Assiminopsis) LOCARD, 1897 [**A. abyssorum* LOCARD, 1897; M]
A. (Microdochus) REHDER, 1943 [**M. floridanus* REHDER, 1943; OD]
Antinodulus COSSMANN in COSSMANN & PEYROT, 1919 [**Bulimus globulus* GRATELOUP, 1828; OD]
Boogina THIELE, 1913 *nom. nov. pro Watsonella* THIELE, 1912, non GRABAU, 1900. [**Rissoa sinapi* WATSON, 1886; M]
B. (Boogina)
B. (Nilsia) FINLAY, 1927 [**Fossarus conicus* ODHNER, 1924; OD]
Dardanula IREDALE, 1915, *nom. nov. pro Dardania* HUTTON, 1882, non STAL, 1860 [**D. olivacea* HUTTON, 1882; M]
D. (Dardanula)
D. (Cerostraca) OLIVER, 1915 [**C. iredalei* OLIVER, 1915; OD]
Diala A. ADAMS, 1861 [**D. varia* A. ADAMS, 1861; SD SUTER, 1913]
D. (Diala)
D. (Dialessa) IREDALE, 1955 [**Diala translucida* HEDLEY, 1906; OD]
D. (Dialopsis) COSSMANN, 1889 [**Turritella semistriata* DESHAYES, 1832; OD]
D. (Mellitesteia) LASERON, 1956 [**M. simplex* LASERON, 1956; OD]
D. (Rissoalaba) OYAMA, 1954 [**Rissoa plebeja* YOKOYAMA, 1922; OD]
Eatoniella DALL, 1876, *nom. nov. pro Eatonia* SMITH, 1875, non HALL, 1857 [**Rissoa kerguelenensis* SMITH, 1875; SD SUTER, 1913]
E. (Eatoniella)
E. (Eatonina) THIELE, 1912 [**E. pusilla* THIELE, 1912; M]
E. (Eatoniopsis) THIELE, 1912 [**Eatoniella paludinooides* SMITH, 1902; M]
E. (Hemistomia) CROSSE, 1872 [**H. caledonica* CROSSE, 1872; M]
E. (Ovirissoa) HEDLEY, 1916 [**Rissoa adarensis* SMITH, 1902; OD]
E. (Tatea) TENISON-WOODS, 1879 [**Bythinia huonensis* TENISON-WOODS, 1875; M]
Laevitesta LASERON, 1950 [**L. scobina* LASERON, 1950; OD]
L. (Laevitesta)
L. (Australaba) LASERON, 1956 [**A. bowenensis* LASERON, 1956; OD]
L. (Paradiala) LASERON, 1956 [**P. supralecta* LASERON, 1956; OD]
Microdryas LASERON, 1950 [**Cingula australiae* FRAUENFELD, 1867; OD]
Microfossa LASERON, 1950 [**Subanaea incidata* FRAUENFELD, 1867; OD (= *Sabanea incidata* FRAUENFELD, 1867)]
Mistostigma BERRY, 1947 [**M. punctulum* BERRY, 1947; OD]
Nevillia H. ADAMS, 1868 [**N. picta* H. ADAMS, 1868; SD NEVILL, 1884]
Notosetia IREDALE, 1915 [**Barleeia neozelanica* SUTER, 1898; OD]
Nozeba IREDALE, 1915 [**Rissoa emarginata* HUTTON, 1885; OD]
Pellax FINLAY, 1927 [**Phasianella huttoni* PILSBRY, 1888; OD]
Plagyostyla FISCHER in DE FOLIN & PÉRIER, 1872, *pro Plagiostyla* FISCHER in DE FOLIN & PÉRIER, 1871, *nom. nud.* [**P. asturiana* FISCHER in DE FOLIN & PÉRIER, 1872; M]
Putilla A. ADAMS, 1867 [**P. lucida* A. ADAMS, 1867; M]
Skenella MARTENS & PFEFFER, 1886 [**S. georgiana* MARTENS & PFEFFER, 1886; M]
Vitricithna LASERON, 1956 [**Cithna marmorata* HEDLEY, 1907; OD]

Rissoinidae: groups of uncertain position and rank

- Pseudotaphrus* COSSMANN, 1888 [**Bulimus buccinalis* LAMARCK, 1804; OD]
P. (Pseudotaphrus)
P. (Microtaphrus) COSSMANN, 1888 [**Pseudotaphrus (M.) proavius* COSSMANN, 1888; OD]
Stosicia BRUSINA, 1870 [**Rissoa buccinalis* GRATELOUP, 1828, non LAMARCK, 1804, = *R. planaxoides* GRATELOUP, 1838]; M]

= *Stossicia*, *Stossichia*, *emend.*, *auctt.*

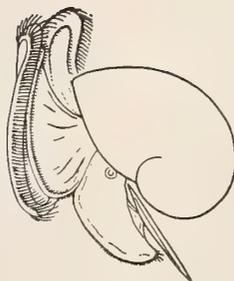
Family Cingulopsidae FRETTER & PATIL, 1958

Cingulopsis FRETTER & PATIL, 1958 [**Cingula fulgida* (J. ADAMS, 1797); OD (= *Helix fulgidus* J. ADAMS, 1797)]

?*Coriandria* TOMLIN, 1917 *nom. nov. pro Microsetia*
MONTEROSATO, 1884, *non* STEPHENS, 1829 [**Rissoa*
coscurae CALCARA, 1841; SD CROSSE, 1885]

LITERATURE CITED

- BUCQUOY, E., PHILIPPE DAUTZENBERG & G. DOLLFUS
1884. Les mollusques marins du Roussillon. 1 (2). Paris.
(Rissoacea: fasc. 7 & 8; pp. 259 - 316; pls.)
- COSSMANN, MAURICE
1921. Essais de paléoconchologie comparée. 12: 3 - 94; pls.
- FRETTER, VERA & A. M. PATIL
1958. A revision of the systematic position of the prosobranch gastropod *Cingulopsis* (= *Cingula*) *fulgida* (J. ADAMS).
Proc. Malacol. Soc. London 33 (3): 114 - 126; illust.
- FRETTER, VERA & ALASTAIR GRAHAM
1962. British prosobranch molluscs: their functional anatomy and ecology. Ray Soc., London.
- LASERON, C. F.
1956. The families Rissoinidae and Rissoidae (Mollusca) from the Solanderian and Dampierian zoogeographic provinces.
Austral. Journ. Marine and Freshwater Res. 7 (3): 384 - 494;
- MOHRENSTERN, GUSTAV SCHWARTZ VON
1861. Über die Familie der Rissoiden, und insbesondere die Gattung *Rissoina*. Denkschr. d. k. Akad. Wiss. Wien, Math.-Nat. Cl. 19 (2): 71 - 188; pls.
1864. . . . *Rissoa*. *ibid.* 23 (2): 1 - 56; pls.
- MOORE, DONALD R.
1962. The systematic position of the family Caecidae (Mollusca: Gastropoda). Bull. Marine Sci. Gulf and Caribbean 12 (4): 695 - 701
December 1962
- SARS, G. O.
1878. Bidrag til kundskaben om norgen arktiske fauna: I. Mollusca regionis arcticae norvegiae. Christiania. (Rissoacea: pp. 169 - 184; plt. 6)
- THIELE, JOHANNES
1929. Handbuch der systematischen Weichtierkunde. (Jena, Gustav Fischer, 1929 - 1935); 1154 pp.; 893 text figs. (Rissoacea: Teil I; pp. 136 - 180; illust.)
- TRYON, GEORGE WASHINGTON, Jr.
1887. Manual of Conchology. Philadelphia. (Rissoacea 9: 314 - 437; 10 December 1887)
- WENZ, WILHELM
1938-1944. Handbuch der Paläozoologie 6 (1). Berlin. (Rissoacea: Lief. 4: 554 - 650; July 1939)



NOTES & NEWS

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Note concerning the Date of Issue of Arnold's Monograph on the Pliocene and Pleistocene of San Pedro

BY

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ONE OF THE WORKS dealing with molluscan systematics referred to by countless students of west American Paleontology and Conchology is the great monograph by Ralph Arnold, "The Paleontology and Stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California." This paper was a thesis presented to the faculty of the department of Geology of Leland Stanford Jr. University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy. It was published as Volume 3 of the Memoirs of the California Academy of Sciences. A certain number of copies were issued with a special title page bearing the caption "Contributions to Biology from the Hopkins Seaside Laboratory of the Leland Stanford Jr. University. XXXI."

It is stated on the title page that the memoir was issued on June 27, 1903. On the bottom of every eighth page a date is given beginning with September 22, 1902, on page 9 and ending with June 23, 1903, on page 417. This led me to question whether or not any of these dated parts were distributed earlier than the date on the title page. An enquiry concerning this matter to the late Ignatius M'Guire, librarian at the California Academy of Sciences, elicited the information that he found no evidence that any of the pages were distributed separately.

To further substantiate this opinion, I wrote Dr. Ralph Arnold, then living in Santa Barbara, California, and a portion of his reply, dated July 23, 1955, concerning the monograph follows:

"I do not believe any of the pages of this book were released prior to its issuance on June 27, 1903. I went east in the fall of 1902 and carried a considerable number of page proofs with me which I showed to Dr. Dall and Dr. C. W. Hayes (Chief Geologist) of the U. S. Geol. Survey in connection with my application for a position

on the Survey. But saw no completed pages prior to June 27th, 1903."

It appears then that the dates at the bottom of every eighth page are the dates of the printing of the various signatures. So far as any evidence is known to me, the entire monograph (including the copies bearing the Hopkins Seaside Laboratory title pages) was issued June 27, 1903.

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Conus gloriamaris

BY

MYRA KEEN

UP TO NOW, all of the definite collecting sites of *Conus gloriamaris* CHEMNITZ, the Glory-of-the-Sea Cone, have been in the area between the Philippines and the Macassar Straits. The range of the species can be extended to eastern New Guinea, for two specimens have come to light there. The first and largest was taken on an offshore island about five years ago, but the collector, who wants to keep his shell, preferred not to publicize it. Recently a second shell was found, washed up on the beach; it is smaller, about 3½ inches long, whereas the first was about 4½ inches. Photographs submitted for identification compare so closely with published figures of the species that one does not hesitate to say that these are authentic specimens of *C. gloriamaris*. A report on the finds is being prepared by interested persons in New Guinea, who are well aware of the importance of the shells.

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A Correction

BY

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ON PAGE 75 of the *Veliger* (current volume) the type number for *Atagema quadrimaculata* COLLIER, *spec. nov.* is given as a series of zeros. This may now be corrected to read as follows:

THE HOLOTYPE is deposited in the California Academy of Sciences Invertebrate Type Series No. 19. It consists of a preserved animal and mounted slides of its radula, its labial cuticle, and seven serial sections of its genital area.

A Note on the Natural History of *Pleurobranchaea spec.* (Gastropoda : Opisthobranchia)

BY

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WHEN MANY FINE SPECIMENS of *Pleurobranchaea* sp.¹ were brought in from Santa Cruz Island in late February of this year by divers of the Biological Sciences Department of the University of California at Santa Barbara, it was decided to begin a series of experiments on them for this research. Preliminary behavioral tests were begun, to be later supplemented by further, more refined work of the same type and by recordings from the nerves of the rhinophores. Unfortunately, on another trip to the island in early July, the divers could not locate additional needed animals. Although it may be some time before the experiments may be begun again, if it is so decided, I believe that these preliminary notes would be of interest at this time.

The *Pleurobranchaea*, which had been taken from between twenty and forty feet on a fine sand bottom, are about as active a mollusk as can be found. In aquaria, they move rapidly, rarely remaining long in any one spot. Their feeding behavior is extraordinary. They seem to be entirely carnivorous, and, when hungry, will attack any animal offered. They will even attack members of their own species, if more than one is left in a single tank. Such attacks are accompanied by violent thrashing. When suitable prey touches or is touched by their sensitive anterior end, they react with a quick upward curving of the anterior end around the prey. The proboscis is rapidly extended, and the prey or pieces of it are taken in.

During the experimentation, certain chemicals, including pure solutions of various amino acids, dissolved in boiled, filtered sea water were placed with a dropper near one rhinophore of a submerged specimen. A feeding response in which the animal raised its anterior end, curved it forward, and extended its proboscis, was elicited by juice from a crushed *Mytilus* and by some amino acids. Other chemicals tested elicited only searching behavior, which consisted of lifting and side to side movement of the anterior end, and bending of the rhinophores. A control, boiled, filtered sea water gave no reaction.

Near the end of June the *Pleurobranchaea* began to lay eggs; however, it is well known that the behavior of lab-

¹ identified by Mr. Allyn G. Smith, California Academy of Sciences, San Francisco, California.

oratory animals in this regard may not be a good indication of the behavior of the species in nature. The eggs are white and were extruded in a lace-like band about a half inch wide and three inches long. This was attached to the side of the aquarium along one margin of the band.

A New Introduced Land Snail

BY

ALLYN G. SMITH

Associate Curator of Invertebrate Zoology
California Academy of Sciences

A New Introduced California Land Snail

FROM THE OFFICE OF THE INSECT TAXONOMY LABORATORY, Bureau of Entomology, California State Department of Agriculture, the California Academy of Sciences has received a sizeable series of the common middle western pupillid—*Pupoides albilabris* (C. B. ADAMS, 1841)—from a *Dichondra* and *Lippia* lawn in Brawley, Imperial County, California. The snails were collected by Messrs. J. Thayer and R. A. Flock, 23 September 1963.

The colony, which is evidently a thriving one consisting of both juvenile and adult individuals, is the first reported introduction in California that has apparently "taken hold." The western end of the range of the species is in the Dakotas, Colorado and western Arizona (Yuma County); it occurs also in the Mexican mainland, Baja California, and on *Islas Angel de la Guarda*, *Tortuga*, *San Lorenzo*, *San Esteban*, and *Montserrat* in the Gulf of California. A related species, *P. catalinensis* Hanna, 1923, occurs on *Isla Santa Catalina* in the Gulf.

A Misunderstanding

BY

CRAWFORD N. CATE

BECAUSE OF A MISUNDERSTANDING, erroneous information was given in my recent paper, *The Cypraea martini* of SCHEPMAN, 1907 (*The Veliger* 6(2): 80-84, pl. 15, 1963) regarding the origin of the shell and its collector. I wish to make the following correction: the shell was not collected during a phase of the Palawan Expedition in April 1962, but was taken, rather, by Romeo Lumawig of Manila. The dates and other pertinent information, however, are as originally chronicled.

A. M. U.

Pacific Division

THE SEVENTEENTH ANNUAL MEETING of the American Malacological Union, Pacific Division, is scheduled for June 18 to 21, 1964, at Asilomar Conference Grounds, Pacific Grove, California. Housing accommodations in three price ranges are being reserved in Guest Inn, Tide Inn, and Surf and Sand. Costs per person, including all meals for the three days, will amount to approximately \$ 30.- to \$ 44.-, depending upon the number of persons per room and the type of room chosen.

Further notices of the meeting and a call for papers will be issued soon. These will be mailed to all members of the A. M. U. P. D. Other interested persons may request their names to be placed on the mailing list by sending 50 cents to the Secretary, Mrs. Lucille Zellers, 714 Elm Street, El Cerrito, California 94530.

MYRA KEEN, Chairman.

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BOOKS, PERIODICALS, PAMPHLETS

On *Uncancylus ticagus*

by EVELINE & ERNST MARCUS

Bol. Fac. Fil., Ciên. Letr. Univ. São Paulo, no. 261. Zoologia no. 24. pp. 217-254, pls. 1 to 4. São Paulo, Brazil, 1962.

THE AUTHORS describe a new species of a fresh water limpet on the basis of a complete study of external characters as well as the internal anatomy and radula. The 19 figures—of which the last consists of 9 sketches showing the manner in which this mollusk rights itself when turned upside down—illustrate all the major aspects discussed in the paper. It may be said that this paper sets high standards for the description of new species, since every possible factor affecting the status of the species is taken into consideration.

RS

A new species of *Latiaxis* from the western Atlantic
(Mollusca, Gastropoda)

by WILLIAM K. EMERSON & ANTHONY D'ATTILIO

American Museum Novitates No. 2149, 9 pp.; 6 figs. July
Latiaxis (Babelomurex) dalli is described as a new taxon. Comparison of the figures accompanying the text shows

clearly the relationship of the new species with several known forms.

RS

On *Leucozonina nassa*

by EVELINE & ERNST MARCUS

Bol. Fac. Fil., Ciên. Letr. Univ. São Paulo, no. 261. Zoologia no. 24. pp. 11-30; pls. 1, 2. São Paulo, Brazil, 1962.

IN THIS RELATIVELY SHORT PAPER the authors manage to convey a wealth of information about this stenoglossan snail: taxonomy, range, external characters and complete anatomy; egg capsules are also described. The nine figures on the two plates illustrate all the main points.

RS

Studies on Columbelloidea

by EVELINE & ERNST MARCUS

Bol. Fac. Fil., Ciên. Letr. Univ. São Paulo, no. 261. Zoologia no. 24. pp. 335-402; pls. 1 to 8. São Paulo, Brazil, 1962.

AS THE AUTHORS point out, the anatomy and especially the histology of the Columbelloidea has remained unknown, except for some small beginnings of a relatively super-

facial nature. On the basis of 8 different species, assigned to 4 genera, this lack is now remedied. In their usual thorough manner, the authors deal with every facet pertaining to the subject of the paper, including a chapter on the parasites encountered. We have only one small criticism to offer: the authors consistently use the trivial names only which in the case where several genera are involved makes the following of arguments unnecessarily difficult for the non-specialist in Brazilian columbellids.

RS

**A new subgenus and species of *Cymatium*
(Mollusca, Gastropoda)**

by WILLIAM K. EMERSON AND WILLIAM E. OLD, JR.

American Museum Novitates No. 2137, 13 pp.; 6 figs.
May 7, 1963.

THE AUTHORS establish the new subgenus *Lotoria* and assign the type species *Cymatium (Lotoria) perryi*, which is described as new. The paper is well illustrated and convincing that this is indeed a heretofore unknown taxon.

RS

Results of the Puritan-American Museum of Natural History Expedition to western Mexico. 19. The Recent mollusks: Gastropoda, Strombacea, Tonnacea, and Cymatiacea.

by WILLIAM K. EMERSON & WILLIAM E. OLD, JR.

American Museum Novitates No. 2153. 38 pp.; 28 figs.
September 24, 1963.

IN THIS PAPER the authors discuss 18 taxa belonging to the groups enumerated in the title of the article. For students of the gastropod fauna of the Gulf of California and Eastern Pacific, this is an indispensable work.

RS

Bulletin of the Institute of Zoology, Academia Sinica

Volume 1, Nos. 1 and 2, June and December 1962.

THE FIRST TWO NUMBERS of this new journal have just reached the editor's desk. The articles range widely, from applied to basic research, the majority dealing with animals other than mollusks. The subscription rate is

\$ 4.- per volume for the United States and other non-Chinese countries. Subscriptions may be entered with the Managing Editor, Institute of Zoology, Academia Sinica, Nankang, Taipei, Taiwan (Formosa), China.

In the first number an article by Shui-Chen Chiu and Ken-Ching Chou, entitled "Observations on Biology of the Carnivorous snail *Euglandina rosea* FERUSAC" deals with this species as a possible means of controlling the giant African snail, which is a pest in Formosa. Observations on the ability of *Euglandina* to go without food for prolonged periods, including newly hatched snails, are well documented. The text is in English, as is the entire journal (Chinese summaries are at the end of each number of the journal).

RS

Cephalopods of the Philippine Islands

by GILBERT L. VOSS

Bull. 234, Smithsonian Inst., United States National Mus. Washington, D. C., 1963. 180 pp.; 4 pls.; 36 text figs.

THIS REPORT is based on the extensive collections made by the U. S. Fisheries steamer 'Albatross' from December 1907 to September 1909. Of 46 species collected during the entire period, 8 were new species and 2 were new subspecies; of these Voss described 6 species and the 2 subspecies in the Proceedings of the Biological Society of Washington, vol. 75, in 1962, while one species, *Abralia lucens*, is described in this volume. This reviewer could find no clue as to the description of the eighth species mentioned in Voss' foreword.

Of the 46 species collected by the 'Albatross' 43 were new to the fauna of the Philippines, bringing the total of reliably known species from that area to 54.

The paper is carefully illustrated, both with halftone plates and with superb line drawings in the text. The latter are stated to be so accurate that comparative measurements may be taken by the reader, if desired.

The paper-bound book, available from the Superintendent of Documents, U. S. Government Printing Office in Washington, D. C. for \$ 1.-, is an important contribution to our knowledge of the molluscan fauna of the Philippine region.

RS

Statement of Ownership, Management, etc.

Statement of Ownership, Management, etc. of the "Veliger", published quarterly, on the first day of the months of July, October, January, and April, at Berkeley, California, as required by the act of August 24, 1912. Publisher: Northern California Malacozoological Club; Editor: Rudolf Stohler. Owner: Northern California Malacozoological Club, a non-profit, educational corporation. Bondholders, mortgagees and security holders: none.

(signed)

R. Stohler, Editor.

THE VELIGER is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable. In the unlikely event that space considerations make limitations necessary, papers dealing with mollusks from the Pacific region will be given priority. However, in this case the term "Pacific region" is to be most liberally interpreted.

It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or lesser taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, will be published in the column "NOTES & NEWS"; in this column will also appear notices of meetings of the American Malacological Union, as well as news items which are deemed of interest to our subscribers in general. Articles on "METHODS & TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

Manuscripts should be typed in final form on a high grade white paper, 8½" by 11", double spaced and accompanied by a carbon copy.

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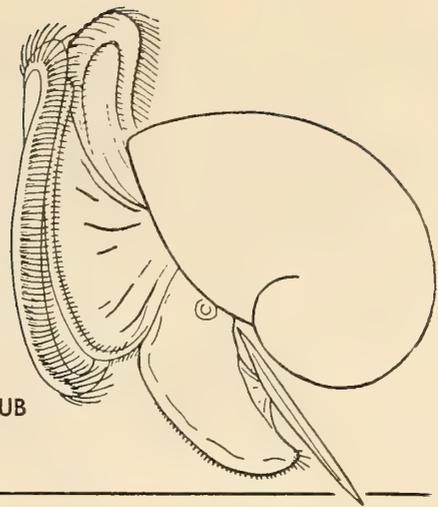
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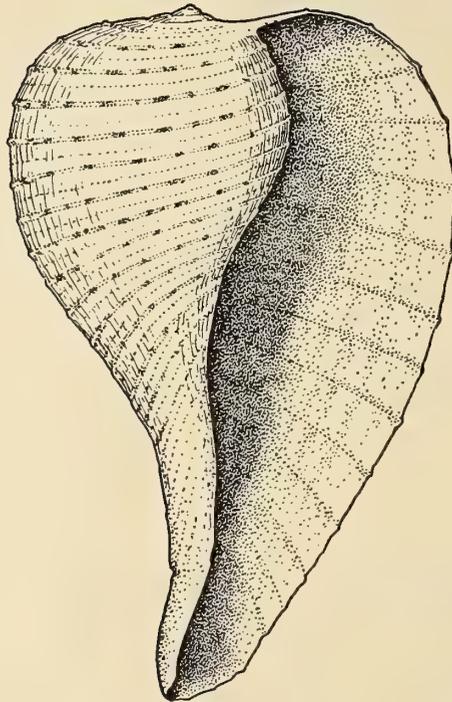
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The Department of Invertebrate Zoology of the California Academy of Sciences
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Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION**, Subdivision, SECTION,

SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).

New Taxa

The Cypraeidae of Fiji

(Mollusca: Gastropoda)

BY

WALTER OLIVER CERNOHORSKY

Vatukoula, Fiji Islands

(Plates 21 to 26; 1 Text figure; 1 Map)

NO MOLLUSCAN FAMILY has received more scientific attention than the Cypraeidae. Although almost 4000 papers have been published dealing with various aspects of this group, few of them give detailed descriptions of shells and animals, as well as illustrations. A thorough study of one molluscan family from a restricted area will give prospective authors some of the basic material for a monograph on that group.

It will be seen from the descriptions given that, while the shells of the animals are fairly well known, the information available on the soft parts of the various species is very scanty. Little is known, too, about the factors which cause the different species to prefer different habitats, or even what the preferred habitats are. Nor is it precisely known during what part of the year the cowries reproduce. Recent observations seem to indicate that the two sexes of some of the species have different mantle colours, but little has so far been done to find to which particular species this applies. These are some of the gaps in our knowledge which can be filled by the active field collector, and by recording what is known, it is hoped that at least some of these gaps can be filled.

GEOGRAPHY

The Fiji Islands are predominantly of volcanic origin; however, there is some intrusion of older rocks (granites, diorites) on the Island of Viti Levu. The Fiji Island chain dates back in geological time to early Miocene (mainly in the centre of Viti Levu), to Pleistocene and Recent towards the coast line. The intrusion of the plutonic series dates back to Eocene.

The Fiji Islands can be regarded as the eastern boundary of the Melanesian region in the Pacific ocean. Fiji's molluscan fauna is predominantly Melanesian, but at the same time receives some of the back wash of Polynesian fauna (*Cypraea ventriculus*, *C. maculifera*, *C. schilderoorum*).

The islands are situated between 16° and 21° South Latitude, and 177° East and 178° West Longitude. They

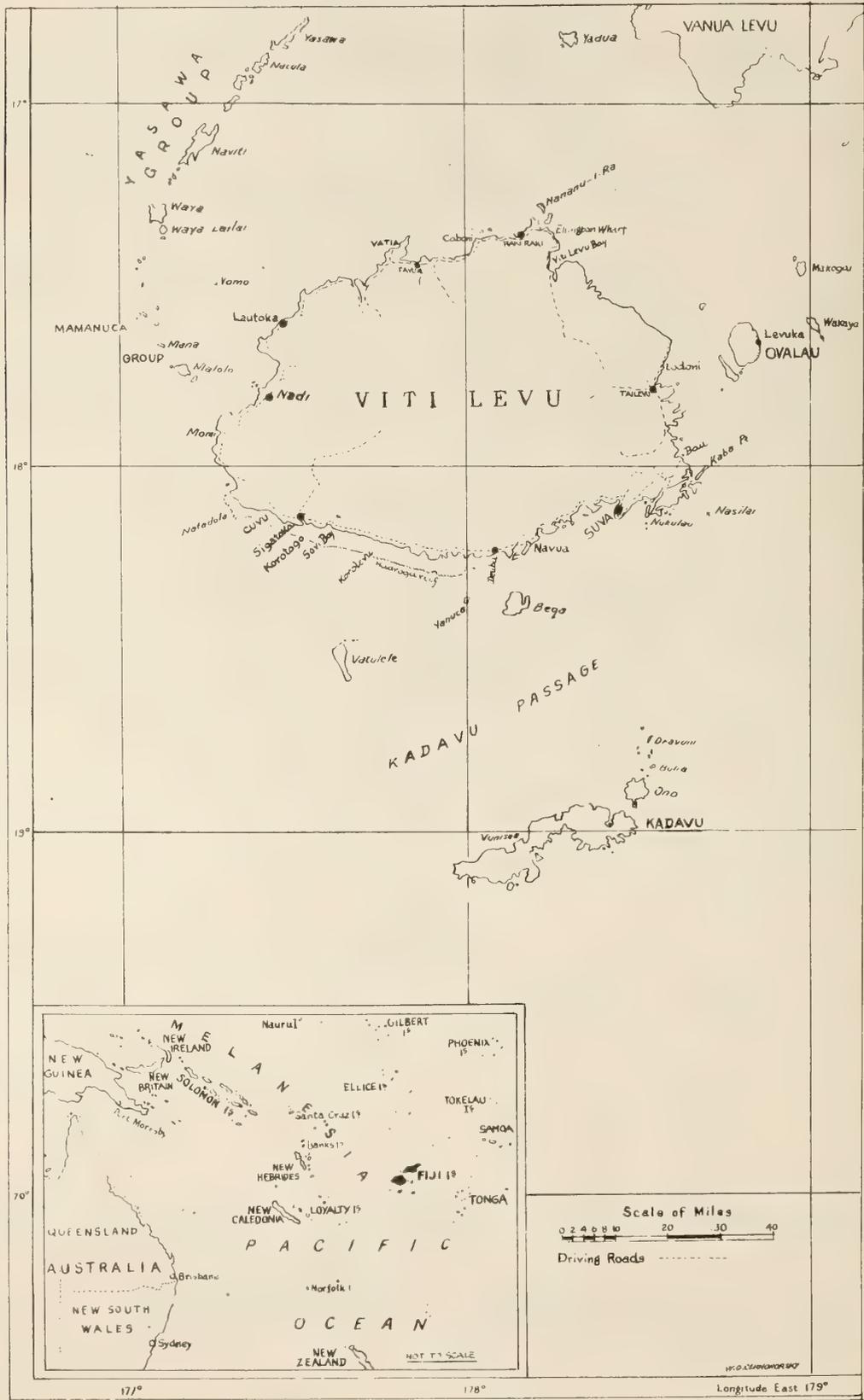
comprise some 300 islands, most of which are uninhabited. The largest island is Viti Levu, followed in size by Vanua Levu, Kadavu, the Yasawa group and the Ono-i-Lau group of islands.

Viti Levu is surrounded by a chain of coral reefs, both fringing and outer reefs. The most accessible localities for collecting are the Suva reef, the Nadroga reef, Vuda Point in the West, Vatia wharf in the North-west, Viti Levu Bay in the North-east and Lodonu in the East of Viti Levu. The Nadroga reef extends for fifty miles from Deuba to Sigatoka. Most of these localities are accessible from the 320 mile-long main road which runs around Viti Levu. Collecting on outer reefs and adjacent islands is more rewarding, but they can only be reached by boat. The shoreline of Viti Levu alternates between sandy beaches, rocky coast and mangroves. Average temperatures from October to February are about 80 to 85 degrees F, with a relative humidity of about 80%. In the cooler months from May to August the average temperature falls to 75 degrees F with a relative humidity of 75%.

HABITAT AND VARIATION

Cowries do not like sunlight, and during the day hide in cracks and crevices of coral boulders. When the loose coral boulders are turned over, the animals will be found clinging underneath. In this dim environment they feed, and in due season, lay and guard their eggs. The importance of returning the boulders to their original position cannot be over-stressed; a boulder left turned the wrong way up leads to the destruction of the algae on which cowries feed, and may lead to the disappearance of the local population. The best times for collecting are the very low tides during which large areas of the reef are exposed, but some species can be found during any low tide. Diving and dredging have (perhaps fortunately) been very little practised in Fijian waters; although some forms can be found only by these means.

It has been noticed in Fiji, as well as in other places, that some species come into shallow water only for limited



periods. A locality may yield a rich harvest one week, and may be found deserted at the next low tide. It may be that the rarer species only occasionally leave deep water to visit the reefs. Habitat seems to vary from locality to locality. In one place *Cypraea mappa* can be found in ankle-deep water, while elsewhere it is only to be found twenty feet deep.

Shells of most species vary in colour as well as in size. In some localities they are larger than average, while in others they are small and stunted. Small size seems to coincide with overcrowding, and is probably the result of keen competition for the inadequate food supply. Differences in shell colour are possibly due to the chemical properties of the sea water; these can affect the food algae, and consequently the mantle cells which produce shell pigment. Normal genetic variation doubtless also is partly responsible.

THE ANIMAL

The thin mantle can be extended over the shell, and serves both to keep it clear of weed and to deposit new layers of enamel. The mantle papillae are probably tactile organs; they may help in respiration. These papillae may be unbranched (simple), or may divide towards the top into two or more branches (digitated). The siphon takes in water, and thus conveys oxygen to the gills. The cephalic tentacles were originally considered to be olfactory organs, but it now seems more likely that they are tactile. On them are located the eyes. The buccal bulb contains the radula, a pliant file-like ribbon of 100 or so rows each containing seven teeth; as the front portion of the radula is worn away by repeated rasping at vegetation, it is replaced by new rows. The foot is used for locomotion.

CLASSIFICATION

Recent taxonomists have proposed many systems of classification, most of which differ in important particulars. The best arrangement of the species is probably that of F. A. and M. Schilder, and the species list given below is based on this. On the other hand the work of Alison Kay in Hawaii has shown that the soft parts of the animal do not differ significantly within the many genera proposed by the Schilders. As there is little agreement on what constitutes a subspecies, this term as well as the generic term used by the Schilders has been added in brackets.

STEADMAN & COTTON (1943) published a paper entitled "The cowries of Fiji." They proposed 33 new sub-specific or even specific names for Fijian cowries - roughly one for every two species found there. Examination of series of shells from different Fijian localities has shown

the described distinctions for these forms to be due to individual or ecological variation, and none of the new names is considered valid. It is unusual in cowries for a subspecies to occupy such a small area as one group of islands. In the Schilders' opinion (1938, 1941 and all papers thereafter) the subspecies extend right across the Pacific. Other investigators consider that many of the species of Cypraeidae do not form separate subspecies. What view is taken on this problem will depend on the definition accepted for the subspecies. However they may differ on this question, few or no authorities support separation of the Fijian forms. These names and other synonyms are listed in the alphabetical index.

METHODS AND OBSERVATIONS

The description of the shell of each species is followed by some indications of size and number of teeth. These consist of:

- (a) mean length of the shell in millimeters
- (b) width of the shell as a percentage of its length
- (c) (d) number of teeth on the labial and columellar sides when converted to the number which would be found on a similar shell 25 mm long.

These four measurements are the means for Pacific shells of the respective subspecies, and are taken from SCHILDER & SCHILDER (1938 and 1952). They are followed by indications of the extremes of shell lengths observed in the Fiji Islands. Examination of series of specimens from Fiji showed that they agree closely (with few exceptions only) with the measurements listed by the Schilders for the same subspecies from different Pacific localities.

The animals of very few species of Fijian cowries have been adequately described. The descriptions given are those of animals collected in the Fiji Islands, and were checked from specimens picked at random from different localities. The colour of the mantle, foot and papillae will vary through shades of one colour, and the colour prevalent in the majority of animals has been recorded. In the case where animal descriptions of a species could not be ascertained from Fiji specimens, other authors' descriptions were adopted. The name of the observer and the locality of the animal follow the description.

The relative frequency of the species of *Cypraea* in Fiji has been calculated on the number of specimens obtained by resident collectors and the author's own active collecting experience. Collections of Fijian material in various museums have not been included, owing to lack of proof of reliable locality data. Species of *Cypraea* classed as common in other geographical regions are uncommon or

rare in Fiji. Some *Cypraea*, however, are more frequent in Fiji than in other areas of the species' distribution. The terms indicating relative frequency of *Cypraea* in Fiji have the following meaning:

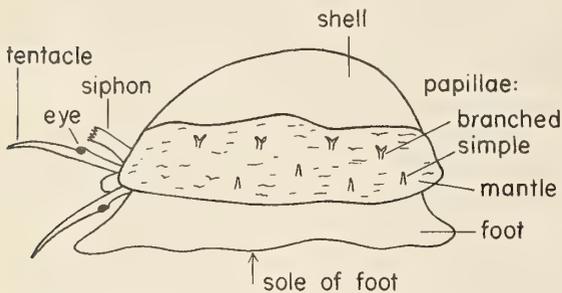
Very common = occurs in unlimited numbers throughout Fiji

Common = fairly frequent in most Fijian localities

Uncommon = Occasionally encountered in certain Fijian localities

Rare = Occasionally encountered during certain times of the year in certain Fijian localities

Very rare = not exceeding 10 specimens in Fiji collections



DISTRIBUTION

In addition to the distribution of each species in Fiji, other geographical distribution data are given, after a dash (—) immediately following the Fijian localities. The geographical regions are designated as follows (adopted from SCHILDER & SCHILDER, 1940):

East Australia: Torres Strait, Queensland, Brisbane, Lord Howe Island, Sydney

South-west Pacific: Geelvink Bay, Humboldt Bay, Astrolabe Bay, South-east New Guinea, Bismarck Archipelago, Solomon Islands, New Hebrides, New Caledonia

Central Pacific: Fiji Islands, Tonga, Samoa, Wallis and Futuna, Tokelau, Phoenix Islands, Howland, Ellice and Gilbert Islands (Kingsmill Islands)

West Pacific: Marshall Islands, Caroline Islands, Palau Islands, Yap, Mariana Islands, Bonin Islands

East Pacific: Cook Islands, Tahiti, Tuamotus, Gambier and Henderson Islands, Marquesas Islands, Flint and Malden Islands, Jarvis and Palmyra Islands

North-east Pacific: Johnston Island, Hawaii, French Frigate Shoals, Laysan, Midway

Synonyms are shown in brackets [].

The symbol / between name and author indicates incorrect use of a name by a subsequent writer (i. e. not in the original sense).

The symbol // before a name indicates that the name is invalid because it is pre-occupied by an older homonym.

ACKNOWLEDGMENTS

I would like to express my appreciation to Dr. F. A. Schilder for the compilation of literature and museum records on Fijian *Cypraea*. To Dr. R. Stohler for his generous assistance and sound advice on the preparation of this paper, and to Lt. Col. John Griffiths, who with his untiring effort assisted in every way possible. My thanks are due to all active field collectors in Fiji, especially Mr. A. Jennings who supplied animal descriptions for checking purposes, and Messrs. R. Pahl, B. Deane, I. Morse and T. Sanders for the loan of their Fijian study material.

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DESCRIPTION OF SPECIES

1. *Cypraea testudinaria* LINNAEUS, 1758[*Chelycypraea testudinaria* (LINNAEUS, 1758)]

(Plate 23, Figure 14)

Cypraea testudinosa PERRY, 1811

Shell: Shell large, elongate-cylindrical, narrow, flattened on top. Dorsum cream to fawn, covered by dark brown and black blotches, often confluent. Shell has a bluish cast over the dorsal pattern, and vivid, conspicuous, small white "dust" spots embedded in the enamel. Base convex, flesh to pale brown, teeth white, short and confined to aperture. The first seven anterior labial teeth are produced; aperture narrow. Fossula very pronounced, wide, deep, and denticulate; extremities calloused.

Size: 102 (50), 28:25; extremes 80, 125 mm.

Animal: Not observed.

Distribution: South and South-west Viti Levu, mainly on the Nadroga reef. Uncommon as live-collected specimens. — Malaysia, Ceylon, Philippine Islands, Formosa, Japan, Torres Strait, Queensland, South-west - Central - West - and East Pacific.

Discussion: The animal usually inhabits holes on the outer edge of coral reefs, mostly in deeper water. During the breeding season the species is encountered in shallow water.

Various authors used *Cypraea testudinosa* PERRY, 1811 to designate the Melanesian race of *C. testudinaria*. The two forms cannot be readily separated.

2. *Cypraea isabella* LINNAEUS, 1758[*Luria isabella lekalekana* (LADD, 1934)]

(Plate 22, Figure 10)

Cypraea isabella lekalekana LADD, 1934*Basilitrona isabella cavia* STEADMAN & COTTON, 1943

Shell: Shell cylindrical, elongate. Dorsum grey, fawn or light brown, crossed by three darker, pale transverse bands and marked with fine, interrupted longitudinal black lines. Extremities blunt, with orange terminal blotches which have black centres; sides rounded. Base white, convex; aperture narrow. Teeth short, very fine and numerous. Fossula steep and denticulate.

Size: 26 (56), 34:26, extremes 20, 42 mm.

Animal: Sole of foot blackish-grey; dorsum of foot black. Mantle blackish brown, spotted with minute, white scattered dots. Papillae appear only as slightly raised fleshy granules. Tentacles blackish-brown; siphon short, blackish-brown, not fringed at the end.

Distribution: West, South and East of Viti Levu. Common. — North-west New Guinea, East Australia, South-west - Central - and West Pacific.

Discussion: Although common in the greater part of Viti Levu, the species has never been recorded from the North of the island.

3. *Cypraea arabica* LINNAEUS, 1758
[*Mauritia arabica* (LINNAEUS, 1758)]

(Plate 21, Figure 3)

Cypraea fragilis LINNAEUS, 1758
C. arabica var. *intermedia* GRAY, 1824
Arabica arabica reticulata / STEADMAN & COTTON, 1943

Shell: Shell subcylindrical, medium in size. The dorsal pattern consists of longitudinal hieroglyphic brown lines interrupted by numerous irregular lacunae; dorsal colour dark grey, lacunae brownish, the pale sulcus clearly visible. Spire conspicuous; margins callous, decorated with fairly large purple-black spots which extend over part of the base. Base flat, rarely convex, cream to grey in colour. Teeth vivid chestnut, labial teeth extend third of the way to the margins, columellar teeth slightly shorter; six or seven central columellar teeth slightly produced. Fossula fairly deep, merging into the columellar sulcus, and denticulate.

Size: 46 (65), 23:19; extremes 39, 70 mm.

Animal: Sole of foot pinkish-grey, edges purplish at the sides, yellow posteriorly; dorsum of foot dark grey. Mantle dark grey; papillae numerous, very short, simple, dark brown. Tentacles dark grey; siphon dark grey, thickly fringed at the end; eyes black and set in white sockets.

Distribution: Throughout Viti Levu. Uncommon — Greater part of Malaysia, Melanesia to Polynesia.

Discussion: STEADMAN & COTTON's *Arabica arabica reticulata* (MARTYN, 1784) (1946, pl. 12, fig. 1) is a typical *Cypraea arabica arabica* LINNAEUS. In their 1946 paper, the authors re-classified the species as *Arabica arabica histrio* (GMELIN, 1791), which does not occur in Fiji.

4. *Cypraea maculifera* (SCHILDER, 1932)
[*Mauritia maculifera* SCHILDER, 1932]

(Plate 21, Figure 4)

Cypraea reticulata MARTYN, 1784 - *nom. nud.*

Shell: Shell solid, slightly pyriform, base convex to flat. Dorsum brown, dorsal sulcus distinct; the prominent white dorsal reticulations are brighter and more numerous than

those of *Cypraea arabica*, and the hieroglyphic lines are lacking. Margins swollen, angular, with large purplish lateral spots tending to form patches, and extending over part of the base. Base grey with a purplish cast and a distinct irregular dark blotch on the columella. Teeth dark brown, labial teeth extend one third way down to the margins, labial teeth slightly shorter. Fossula flattish, white and denticulate.

Size: 55 (68), 22:18; extremes 40, 70 mm.

Animal: Sole of foot light grey; dorsum of foot blue-black and finely mottled with a lighter shade. Mantle brown, translucent at the margins. Papillae short, simple and light grey. Tentacles blue-black with a white streak near the base; siphon blue-black, fringed at the end.

Distribution: South-west of Viti Levu. Very rare. — New Caledonia, Central - West - East - and North-east Pacific.

Discussion: The species has not been recorded as far West as Fiji before. The three specimens so far collected came from a reef near Vatukarasa, in the South-west of Viti Levu.

5. *Cypraea depressa* GRAY, 1824
[*Mauritia depressa depressa* (GRAY, 1824)]

(Plate 22, Figure 9)

Arabica gillei JOUSSEAUME, 1893
Cypraea intermedia / REDFIELD, 1847

Shell: Shell heavy, ovate, broad, base convex. Dorsum depressed, chestnut in colour, ornamented with small white reticulations; dorsal sulcus clear. Sides heavily calloused, and spotted with small indistinct purplish-brown spots which extend over part of the base. Some shells have a broad, transverse dorsal band. Base ivory-white, with chestnut teeth extending one third of the way to the margins; aperture slightly narrow. Fossula fairly deep, white, denticulate and merging with the columellar sulcus.

Size: 35 (72), 22:16; extremes 25, 40 mm.

Animal: Sole of foot orange-brown, dorsum of foot shaded with a darker hue. Mantle brownish-slate; papillae small, simple and pale. Tentacles and siphon slate colour. Other details not observed.

Distribution: South and West of Viti Levu. Very rare. — Philippine Islands, Japan, South-west - Central - West and East Pacific.

Discussion: *Cypraea depressa* is sometimes confused with *C. maculifera*. It is distinguishable by its fewer teeth, smaller size, and the absence of any columellar basal blotch.

6. *Cypraea eglantina* DUGLOS, 1833[*Mauritia eglantina eglantina* (DUGLOS, 1833)]

(Plate 21, Figure 2)

Arabica eglantina momokiti STEADMAN & COTTON, 1943*Arabica intermedia* / STEADMAN & COTTON, 1943

Shell: Shell oblong-ovate to subcylindrical. Dorsum brown to grey, reticulate with irregular clear patches, lined between; dorsal sulcus always distinct. Sides rounded, sometimes slightly margined, with small dark brown spots. Extremities marked with a large pair of dark brown blotches. Base cream coloured, convex; teeth short, chestnut, finer and more numerous than those of *Cypraea arabica*. The other two differences which separate *C. eglantina* and *C. arabica* are the brown blotch near the spire of the former, and the steep vertical edge to its fossula, with the teeth scarcely extending onto the base above it. Size: 50 (59), 26:22; extremes 30, 75 mm.

Animal: Sole of foot cream, edges and dorsum of foot dark grey. The edges of the mantle are dark grey, remaining mantle area wine red. Papillae numerous, short, simple, grey, tipped with white. Tentacles grey with yellowish circles around the eyes; siphon dark grey.

Distribution: Throughout Fiji. Very common. — Astrolabe Bay, New Caledonia, Central Pacific, Cook Islands.

Discussion: Adult specimens from some Fijian localities have four darker transverse dorsal bands.

7. *Cypraea scurra* GMELIN, 1791[*Mauritia scurra retifera* (MENKE, 1829)]

(Plate 23, Figure 16)

Cypraea scurra retifera MENKE, 1829*Arabica scurra vono* STEADMAN & COTTON, 1943

Shell: Shell narrow and cylindrical. Dorsum brown, reticulate, tinged pale orange just above margins; dorsal sulcus straight and distinct. Sides rounded, light brown, with indistinct purple spots; extremities produced with blackish-brown terminal spots. Base convex, bluish-grey; aperture narrow, teeth fine, short, dark brown, interstices pale brown. Fossula deep, white and denticulate.

Size: 36 (50), 35:26; extremes 30, 45 mm.

Animal: Sole of foot pale. Mantle olive-brown; papillae few, simple, rather elongate. Siphon brownish, fringed at the end. Other details not observed.

Distribution: South and West of Viti Levu. Very rare. — Central - West - East - and North-east Pacific.

8. *Cypraea mappa* LINNAEUS, 1758[*Mauritia mappa viridis* (KENYON, 1902)]

(Plate 21, Figures 1, 1 a)

Cypraea mappa viridis KENYON, 1902*Leporicypraea mappa rewa* STEADMAN & COTTON, 1943

Shell: Shell ovate, inflated. Dorsum pale to rich brown, with a pattern consisting of a wide and clear dorsal line from which branch a number of feeler-like extensions; the dorsum is marked with many fine brown lines and a few clear round patches. Sides cream to orange, slightly callous; lateral spots medium brown, extending over part of the convex base. The darker central basal blotch on the columella is absent in most specimens. Teeth bright orange, confined to aperture. Extremities margined, suffused creamy-grey. Fossula flattish, crossed by orange ribs which are interrupted by a prominent longitudinal pale ridge.

Size: 71 (64), 25:22; extremes 49, 75 mm.

Animal: Sole of foot cream, veined with black; dorsum of foot grey. Mantle fawn; papillae at the anterior and posterior extremities are numerous, long and simple, coloured white; on the mantle edges papillae are few, short and bushy. Tentacles fawn; siphon translucent fawn and fringed.

Distribution: Throughout Fiji. Uncommon. — Torres Strait, Queensland, Cook Islands, South-west - Central - West Pacific, Tuamotus, Gambier and Henderson Islands. **Discussion:** The mean average length of 60 Fijian specimens is only 62 mm.

A few specimens with an unusual shell variation have been collected in Fiji. The dorsum is dark brown. The margins are spotted with large dark purple spots, which tend to merge into still larger blotches. Fine white striations extend from the margins onto the purplish base; teeth are vivid red.

9. *Cypraea mauritiana* LINNAEUS, 1758[*Mauritia mauritiana calxequina* (MELVILL & STANDEN, 1899)]

(Plate 23, Figure 12)

Cypraea mauritiana calxequina MELVILL & STANDEN, 1899

Shell: Shell wide, heavy, with sides very prominently angled. Dorsum humped, dark brown, marked with irregular orange reticulations and a pale dorsal line. Spire

conspicuous, sides and base blue-black (immature specimens chestnut-brown). Aperture wide, base flattened; teeth large and coarse, dark brown with yellow-white interstices; central labial teeth shorter. Fossula slightly concave, white and denticulate, columellar sulcus pronounced.

Size: 73 (71), 18:15; extremes 60, 90 mm.

Animal: Sole of foot purplish-grey, dorsum and sides of foot violet. Mantle slightly paler; papillae short and blackish. Tentacles violet-brown; siphon similar in colour, fringed at the end.

Distribution: South and South-west Viti Levu. Uncommon. — Philippine Islands, Japan, East Australia, South-west - Central - West - and East Pacific, Hawaii.

Discussion: Only one unverified specimen had been recorded from the North of Viti Levu.

The habitat of the species in Fiji is confined to dark basalt boulders and wave swept marine benches.

10. *Cypraea aurantium* GMELIN, 1791

[*Callistocypraea aurantium* (GMELIN, 1791)]

(Plate 21, Figure 5)

Cypraea aurora LAMARCK, 1810

Callistocypraea aurantium turanga STEADMAN & COTTON, 1943

Shell: Shell large, ovate, inflated, slightly margined. Dorsum orange, without pattern. Sides and base creamy-white, finely striated. Aperture wide, base convex; teeth short, orange, extending as heavy ribs across the fairly wide and deep fossula. Interstices are a deeper shade of orange.

Size: 95 (67), 23:20; extremes 80, 110 mm.

Animal: Pinkish-grey (Fiji, STEADMAN & COTTON, 1943)

Distribution: Habitat of the species is confined to the Nadroga reef, South-west Viti Levu. It inhabits deeper water on the outside ledge of the reef. — Philippine Islands, South-west - Central - and West Pacific, Cook Islands, Tahiti.

Discussion: Three specimens collected at the Nadroga reef had a reddish-brown dorsum, heavily margined sides of a smoky-grey, with distinct fine striations extending to the smoky-grey base. All three specimens were smaller than average.

11. *Cypraea argus* LINNAEUS, 1758

[*Talparia argus ventricosa* (GRAY, 1824)]

(Plate 22, Figure 6)

Cypraea argus ventricosa GRAY, 1824

Shell: Shell cylindrical, elongate. Basic dorsal colour fawn to bluish-grey, with irregular brown rings of varying size

and thickness and three slightly darker, broad transverse bands. Sides rounded, sometimes slightly callous; base convex, fawn to pale brown, with two large dark brown irregular patches on each side of the aperture; one or two of these are occasionally absent. Aperture wide, constricted anteriorly; labial teeth extend halfway to the margin, columellar teeth are short. Teeth are edged with thin brown lines and extend as ribs onto the wide and deep fossula.

Size: 78 (53), 25:22; extremes 55, 90 mm.

Animal: Dark grey. Other details not observed.

Distribution: Throughout Fiji. Uncommon in the South and East, rare in the West and North of Viti Levu. — Torres Strait, North Queensland, South-west - Central - and West Pacific.

12. *Cypraea talpa* LINNAEUS, 1758

[*Talparia talpa saturata* (DAUTZENBERG, 1903)]

(Plate 22, Figure 8)

Cypraea talpa saturata DAUTZENBERG, 1903

Shell: Shell cylindrical to subcylindrical. Dorsum fawn to yellow-orange, crossed by three or four wide brown bands. Sides, base and extremities blackish-brown (light brown in immature specimens). Base convex, aperture narrow and fairly straight. Teeth fine and short, with pale interstices. Teeth extend as coarse ribs onto the wide and steep fossula and are interrupted by a pale longitudinal ridge.

Size: 68 (55), 32:26; extremes 30, 75 mm.

Animal: Sole of foot grey to deep grey, veined with black; dorsum of foot and mantle show two distinct variations, and are represented in about equal numbers in a population:

1. Dorsum of foot black. Mantle smooth, black, with $\frac{1}{2}$ inch long and $\frac{1}{8}$ inch wide black cusps on the mantle, resembling an inverted test tube. Tentacles black, eyes blue.

2. Dorsum of foot black, with numerous minute white spots. Mantle black, profusely spotted with white and with a few circular black humps over the mantle, about $\frac{1}{8}$ inch in diameter. Tentacles black, eyes blue.

Distribution: Throughout Fiji. Uncommon. — Torres Straits, Queensland, South-west - Central - West - East and North-east Pacific.

Discussion: The frequent occurrence of both types of animals in all localities, points to a possible sexual dimorphism.

ALLAN (1956) listed Samoa as type locality. DAUTZENBERG's specimens of *Cypraea talpa saturata* are from an unknown locality. DAUTZENBERG's racial name had been utilized by the SCHILDERS (1938) for the Pacific race

of *C. talpa*. They selected as lectotype a shell from New Caledonia (1952, pl. 4, fig. 4).

13. *Cypraea tigris* LINNAEUS, 1758

[*Cypraea tigris lyncichroa* MELVILL, 1888]

(Plate 22, Figures 7, 7 a)

Cypraea tigris lyncichroa MELVILL, 1888

Cypraea tigris volai STEADMAN & COTTON, 1943

Cypraea tigris amboolee STEADMAN & COTTON, 1943

Shell: Shell ovate, solid and heavy. Dorsum has large blackish spots over a grey, orange or white base; dorsal line orange or white, absent in many specimens; dorsal spots are often large and confluent, giving the shell a very dark appearance. Margins slightly angular, spotted; base white, convex, with an indistinct darker central patch on columella. Aperture wide, slightly dilated anteriorly; teeth coarse and short, central columellar teeth slightly produced. Fossula fairly deep, crossed by ribs which are somewhat shallow but not interrupted by the longitudinal ridge in the fossula.

Size: 85 (68), 18:16; extremes 60, 110 mm.

Animal: Sole of foot dark grey veined with black, edges cream; dorsum of foot grey, mottled with blackish-brown. Mantle mottled with cream and blackish-brown and veined. Papillae numerous and long, some simple, others branched, grey and tipped with white. Tentacles brown, siphon grey with white-tipped fringes.

Distribution: Throughout Fiji. Very common. — Torres Strait, Queensland, South-west - Central - West - and East Pacific.

14. *Cypraea lynx* LINNAEUS, 1758

[*Lyncina lynx caledonica* (CROSSE, 1869)]

(Plate 24, Figure 20)

Cypraea lynx caledonica CROSSE, 1869

Lyncina lynx pacifica STEADMAN & COTTON, 1943

Shell: Shell ovate to sub-pyriform. Dorsum brown, bluish or orange, with very small brown freckles and larger dark brown to black spots; dorsal line indistinct. Sides rounded or slightly calloused, spotted with brown, finely striated. Base white to light brown, columellar side ridged and flat, labial side rounded. Aperture narrow; teeth large, white, interstices bright orange; teeth on labial side extend one third of the way to the margin, columellar ones are short and extend as ribs onto the wide, pronounced fossula.

Size: 36 (61), 21:17; extremes 22, 55 mm.

Animal: Sole and dorsum of foot cream-yellow, dorsum flecked with dark brown. Mantle olive-brown, veined and flecked with black. Papillae short, thickly branched, white.

Tentacles brown, eyes black and set in yellow sockets; siphon translucent grey, fringed at the end.

Distribution: Throughout Fiji. Very common. — Torres Strait, Queensland, South-west - Central - West - and East Pacific, Hawaii.

15. *Cypraea vitellus* LINNAEUS, 1758

[*Lyncina vitellus polynesiae* (SCHILDER & SCHILDER, 1939)]

(Plate 24, Figure 19)

Cypraea vitellus polynesiae SCHILDER & SCHILDER, 1939

Shell: Shell ovate to pyriform, heavy. Dorsum fawn, brown or dark-brown, marked with many irregular white spots of different sizes, and two or three transverse dorsal bands; bands are either pale or distinct. Sides olive, with white spots and fine white striations which extend halfway up the dorsum on the labial side. Base convex, white, sometimes pale lilac. Aperture wide and sinuous, extremities calloused; teeth white, strong, short and extending as ribs onto the deep fossula.

Size: 57 (64), 21:18; extremes 30, 75 mm.

Animal: Sole of foot fawn, dorsum of foot grey. Mantle grey, flecked and marbled with black. Papillae few, short, yellow, branched straight from the base in a fork-like manner; some papillae are short and simple. Tentacles dark grey; siphon white, with bright yellow fringes at the end.

Distribution: Throughout Fiji. Common. — South-west - Central - West - and East Pacific, Hawaii.

Discussion: STEADMAN & COTTON (1943) and ALLAN (1956) list Fiji as type locality of *Lyncina vitellus polynesiae*. The correct type locality, however, is Papeete, Tahiti.

16. *Cypraea ventriculus* LAMARCK, 1810

[*Lyncina ventriculus* (LAMARCK, 1810)]

(Plate 23, Figure 13)

Cypraea achatina PERRY, 1811

Ponda ventriculus topee STEADMAN & COTTON, 1943

Shell: Shell ovate, depressed and heavy. Dorsum reddish-orange, crossed by four transverse bands, usually indistinct in mature specimens; dorsal line white, often very broad. Sides and extremities callous, smoky-grey to chestnut-brown, with fine distinct striations extending halfway up the dorsum. Base fawn, becoming whiter towards the aperture; teeth short, large and white, crossing the fairly shallow fossula.

Size: 50 (67), 19:17; extremes 35, 61 mm.

Animal: Not observed.

Distribution: Ono-i-Lau Group (East of Viti Levu), Suva main reef, and Kadavu Island (South of Viti Levu). — South-west - Central - West - and East Pacific; Philippines.

17. *Cypraea carneola* LINNAEUS, 1758
[*Lyncina carneola propinqua* (GARRETT, 1879)]

(Plate 24, Figures 21, 22)

Cypraea carneola propinqua GARRETT, 1879
Ponda carneola thepalea IREDALE, 1939

Shell: Shell ovate to pyriform. Dorsum greyish-red to reddish-brown, crossed by four transverse darker bands. Sides rounded or slightly calloused, with a cream callus faintly mottled with brown; most shells have a pale lilac border above the callus. Base cream, aperture wide; very fine striae extend from the margins to the aperture. Teeth short, interstices purple. Fossula deep, strongly denticulate, with a pale longitudinal rib.

Size: 35 (61), 24:19; extremes 25, 65 mm.

Animal: Sole and dorsum of foot cream-yellow. Mantle dirty-white, heavily veined and flecked with dark brown. Papillae few, short, and branched in a fork-like manner, white; papillae at anterior extremity are simple. Tentacles dark grey; siphon pale grey with long fringes at the end.

Distribution: Throughout Fiji. Uncommon. — East Australia, South-west - Central - West - and East Pacific; Hawaii.

18. *Cypraea schilderorum* (IREDALE, 1939)
[*Lyncina schilderorum* (IREDALE, 1939)]

(Plate 24, Figure 23)

Ponda schilderorum IREDALE, 1939
Cypraea // arenosa GRAY, 1824

Shell: Shell ovate, heavy. Dorsum reddish-brown, with central area bluish-white, crossed by four reddish-brown bands. Sides margined, fawn, mottled with paler dots and occasionally vertical striations. Base convex, brownish at the edges, remainder white. Aperture narrow; teeth white, fine, numerous and short. Fossula deep, strongly denticulate.

Size: 33 (68), 26:21; extremes 30, 38 mm.

Animal: Mantle mottled black, brown and white; tentacles black; dorsum of foot light tan; ventral surface of foot cream. Siphon with a simple fringe. Papillae short, feathery projections, cream-white. (Hawaii - KAY & WEAVER, 1963)

Distribution: Nadroga reef, South-west Viti Levu. Very rare. — New Caledonia, Fiji Islands, Samoa, Gilbert & Ellice Islands, East and North-east Pacific.

19. *Cypraea mariae* (SCHILDER, 1927)
[*Annepona mariae* (SCHILDER, 1927)]

(Plate 25, Figure 37)

Pustularia (Pustularia) mariae SCHILDER, 1927
Cypraea // annulata GRAY, 1828

Shell: Shell oval to round, and humped. Dorsum ivory-white, smooth, with yellow spots ocellated with slightly darker rings; the dorsal spots sometimes tend to merge, particularly lower down the dorsum, and extend to the margins. Sides rounded, base white and flattish. Aperture extremely narrow; teeth very fine, numerous, and confined to the aperture. Fossula smooth, forming a broad ledge.

Size: 14 (66), 43:30; extremes 14, 17 mm.

Animal: Not observed.

Distribution: Nadroga reef, South-west Viti Levu. Very rare. — Philippine Islands, South-west and Central Pacific, Palau Islands, Cook Islands, Tuamotus, Gambier-Henderson Islands, Hawaii.

20. *Cypraea globulus* LINNAEUS, 1758
[*Pustularia globulus sphaeridium* SCHILDER & SCHILDER, 1938]

(Plate 26, Figure 54)

Pustularia cicercula jennisoni STEADMAN & COTTON, 1943

Shell: Shell globular, slightly humped, with produced extremities, but shorter than *Cypraea cicercula*. Dorsum smooth, pale to dark rusty-brown, with many small, brown spots which extend to the margins; above the posterior extremity is a wart-like callosity (also present in *C. bistrinotata*, but not in *C. cicercula*, nor in *C. margarita*). Dorsal granulations and sulcus are absent. Base convex, light brown; aperture narrow, with a pair of brown, squarish spots on each side; the basal spots are occasionally absent. Teeth dark brown, fine, and extending three quarter way to the margins; the five to six central columellar teeth are very short. Fossula shallow and denticulate.

Size: 15 (61), 34:23; extremes 12, 17 mm.

Animal: Not observed.

Distribution: Throughout Fiji. Rare. — Torres Strait, South-west Pacific, Fiji Islands, Samoa, Jarvis Island.

Explanation of Plate 21

Dorsal views of Figures 1, 1 a, 2, 3: x 0.8; Figure 4: x 0.7; Figure 5: x 0.4. - Ventral views slightly larger.
Figure 1: *Cypraea mappa viridis* KENYON (typical). Figure 2: *C. mappa viridis* KENYON (ecological variant)

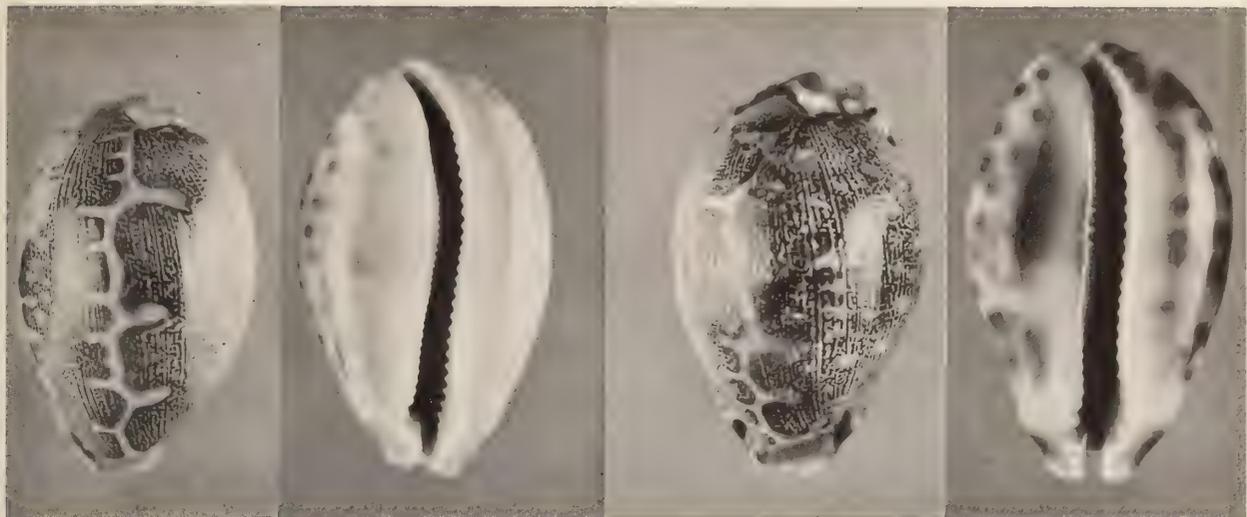


Figure 1

Figure 1 a

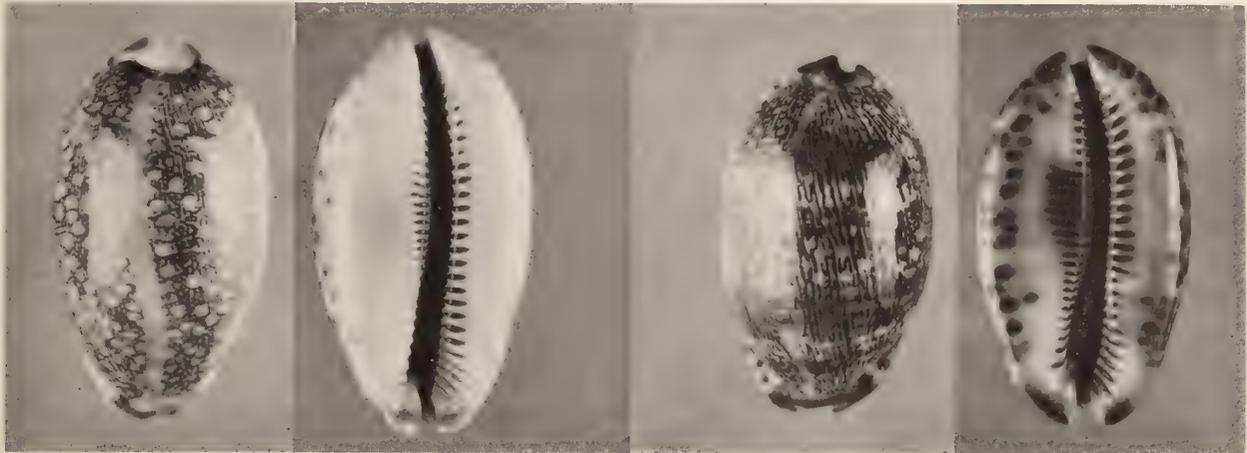


Figure 2

Figure 3



Figure 4

Figure 5

21. *Cypraea bistrinotata* (SCHILDER & SCHILDER, 1937)
[*Pustularia bistrinotata mediocris* SCHILDER & SCHILDER,
1938]

(Plate 26, Figure 55)

Pustularia bistrinotata sublaevis / STEADMAN & COTTON, 1943

Shell: Shell globular, rounded, slightly rostrate. Dorsum ochraceous-yellow to pale brown, with consistent granulations, becoming obsolete towards the prominent sulcus line; this line is always visible near the extremities, and is often continuous; it passes between three pairs of brown spots, which are usually clearly visible, but occasionally obsolete. Dorsum has small brown spots, and a wart-like callosity situated above the posterior extremity. Base pale yellow, convex, curved upwards posteriorly. Aperture narrow, with a pair of dark brown basal blotches each side of it; these spots are either distinct, faint, or even absent. Teeth fine, numerous, tinged brown, and extend to the margins; central labial teeth slightly shorter. Fossula wide, shallow and denticulate.

Size: 16 (64), 31:21; extremes 12, 20 mm.

Animal: Not observed.

Distribution: Throughout Fiji. Rare. — Philippine Islands, Formosa, Japan, Torres Strait, South-west - Central and West Pacific.

Discussion: The preferred habitat of this species is in the folds of live coral.

22. *Cypraea cicercula* LINNAEUS, 1758

[*Pustularia cicercula cicercula* (LINNAEUS, 1758)]

(Plate 26, Figure 53)

Pustularia tricornis vulavula STEADMAN & COTTON, 1943

Shell: Shell humped, slightly rostrate, with produced extremities. Dorsum flesh to pale yellow, faintly or coarsely granulate, with minute brown spots. A distinct dorsal sulcus connects both extremities; above the posterior extremity is a short central groove, brown in colour, resembling a brown streak in a depression. Dorsal and basal blotches are absent. Base convex, curving upward near extremities; aperture narrow. Teeth pale brown, extending fully to the margins; interstices dull. Fossula wide, deep and ribbed.

Animal: Not observed.

Size: 16 (62), 33:23; extremes 12, 21 mm.

Distribution: Throughout Fiji. Rare. — Greater part of Malaysia, Philippine Islands, Japan, South-west Pacific, Fiji Islands, Tonga Islands.

Discussion: The preferred habitat of this species is in the folds of live coral.

23. *Cypraea margarita* DILLWYN, 1817
[*Pustularia margarita* (DILLWYN, 1817)]

(Plate 26, Figure 52)

Cypraea tricornis JOUSSEAUME, 1874

Pustularia globulus sphaeridium / STEADMAN & COTTON, 1943

? *Pustularia margarita tetsuakii* KIRA, 1959 - ex KURODA MS

Shell: Shell very humped, with produced extremities. Dorsum white, rarely very pale yellow, with small brown spots which extend to the margins; above the spire is a brown-coloured groove; the shell is smooth, without a dorsal sulcus or granulations; extremities have a faint orange tinge. Base white and convex; aperture narrow, basal spots absent; outlets tinged pale orange. Teeth extend to the margins, however the central labial and columellar teeth extend only halfway; teeth are finer than in the other three related species. Fossula wide, deep and only faintly denticulate.

Size: 13 (60), 37:26; extremes 10, 13 mm.

Animal: The animal is the colour of the pulp of lemon. The mantle folds are smooth, thin and transparent. Mantle papillae are short and fine, and hardly noticeable. (Hawaii, C. M. BURGESS, 1962)

Distribution: Throughout Fiji. Very rare. — Mauritius, Philippine Islands, Japan, South-west - Central - West - and East Pacific, Hawaii.

Discussion: LADD's record (1945) of *Cypraea margarita* from Fiji is an indeterminable form of one of the *Pustularia* group.

The recent collection of specimens of *Cypraea margarita* from the Philippines and Mauritius confirm the Indo-Pacific distribution of this species. Some writers have suggested that *C. margarita* falls within the range of variability of *C. cicercula*. The smaller size, absence of dorsal sulcus and granulations, the greatest height attained posteriorly, orange tinted extremities, white base, short central teeth and a faintly ribbed fossula of *C. margarita* are of a constant nature. The morphological characteristics are too numerous and constant throughout the whole distributional range of the species, that it appears to be specifically separable.

24. *Cypraea childreni* GRAY, 1825

[*Pustularia childreni novaecaledoniae* SCHILDER & SCHILDER, 1952]

(Plate 24, Figure 29)

Shell: Shell ovate, broad, slightly inflated, with beaked extremities. Dorsum yellow to yellow-brown, with a brown spot, situated centrally and above each extremity. Dorsum crossed by narrow, transverse ribs, with some short finer

ribs in between; the ribs are interrupted by a central longitudinal dorsal sulcus. Left side rounded, right side with a marginal ledge; base flat. Aperture narrow; the very fine teeth extend to the margins, and are actually a continuation of the dorsal ribs. Fossula wide, deep, ribbed, very short.

Size: 21 (67), 38:24; extremes 18, 23 mm.

Animal: Not observed.

Distribution: Islands West off Nadi and Mamanutha group (West off Viti Levu). Very rare. — Solomon Islands, New Britain, New Hebrides, New Caledonia, Fiji Islands.

25. *Cypraea annulus* LINNAEUS, 1758

[*Monetaria annulus noumeensis* (MARIE, 1869)]

(Plate 26, Figure 56)

Cypraea annulus noumeensis MARIE, 1869

Monetaria annulus sosokoana LADD, 1934

Monetaria annulus dranga IREDALE, 1939

Monetaria annulus dranga / STEADMAN & COTTON, 1943

Shell: Shell small, ovoid, heavy. Dorsum pale blue, grey or light brown, top encircled by a bright orange line, with fine hair-lines visible in the center. Sides ivory-white, angled. Base white, slightly flattened; aperture wide; teeth are coarse and short, produced halfway to the margins in some specimens. The fossula is almost absent, being formed only by the tapering away of the coarse white teeth inside the aperture.

Size: 20 (71), 13:11; extremes 11, 30 mm.

Animal: Sole of foot cream-white; dorsum of foot white. Mantle grey, veined and flecked with brown and black. Papillae few, short, branched and yellow. Tentacles grey; siphon grey, sparsely spotted with pale grey, fringed at the end.

Distribution: Throughout Fiji. Very common. — East Australia, South-west - Central - and West Pacific, Jarvis-Palmyra Islands, Rarotonga (Cook Islands).

26. *Cypraea moneta* LINNAEUS, 1758

[*Monetaria moneta barthelemyi* (BERNARDI, 1861)]

(Plate 26, Figure 57)

Cypraea moneta barthelemyi BERNARDI, 1861

Cypraea // tuberculosa QUOY & GAIMARD, 1834

Monetaria monetoides IREDALE, 1939

Monetaria harrisi IREDALE, 1939

Monetaria isomeres IREDALE, 1939

Monetaria moneta endua STEADMAN & COTTON, 1943

Monetaria moneta erua STEADMAN & COTTON, 1943

Monetaria moneta etolu STEADMAN & COTTON, 1943

Shell: Shell pyriform, deltoidal or pentagonal. Dorsum yellow or greyish-white, sometimes with two faint transverse dorsal bands, and a very pale yellow annular ring. The posterior part of some specimens has four tubercles; other specimens are smooth. Sides angled, yellow or white. Base yellow, white or yellow and white, sometimes slightly tuberculate. Aperture narrow, dilated anteriorly; teeth coarse and short, in some specimens extending three-quarter way to the margins. Fossula very shallow, almost absent, but more pronounced than in *Cypraea annulus*.

Size: 22 (72), 13:12; extremes 14, 35 mm.

Animal: Sole of foot cream-white; dorsum of foot white and flecked with black patches. Mantle pale yellow, densely striated with dark brown latitudinal lines. Papillae numerous, very short, mostly simple (a few are branched), white, with a short, brown horizontal dash just below the tips. Tentacles pale orange; siphon translucent white, flecked with brown, and with about 20 fringes at the end.

Distribution: Throughout Fiji. Very common. — East Australia, South-west - Central - and East Pacific, Marshall Islands, Caroline Islands, Hawaii.

Discussion: In sculpture and colour this is one of the most variable species. The different forms ("ecotypes") have been described by the SCHILDERS (1936).

27. *Cypraea dillwyni* SCHILDER, 1922

[*Paulonaria dillwyni* (SCHILDER, 1922)]

(Plate 26, Figure 48)

Cypraea dillwyni SCHILDER, 1922

Cypraea // margarita GRAY, 1828

Pustularia margarita theeva STEADMAN & COTTON, 1943

Shell: Shell small, pyriform, with slightly produced extremities. Dorsum cream to yellow, smooth, with small and medium white spots, and a faint, white dorsal line. Extremities are tinged orange on top of the outlets. Base white and convex; aperture narrow, curved to the left posteriorly. Teeth very fine, the first five to six anterior and posterior teeth on both sides are produced, remaining teeth confined to aperture. Fossula concave and denticulate, the longitudinal sulcus pronounced but shallow. Size: 12 (59), 43:26; extremes unknown.

Animal: Not observed.

Explanation of Plate 22

Dorsal views of Figures 6, 7, 7 a, 8: x 0.7; Figures 9, 10, 11: x 1.0. Ventral views slightly larger.

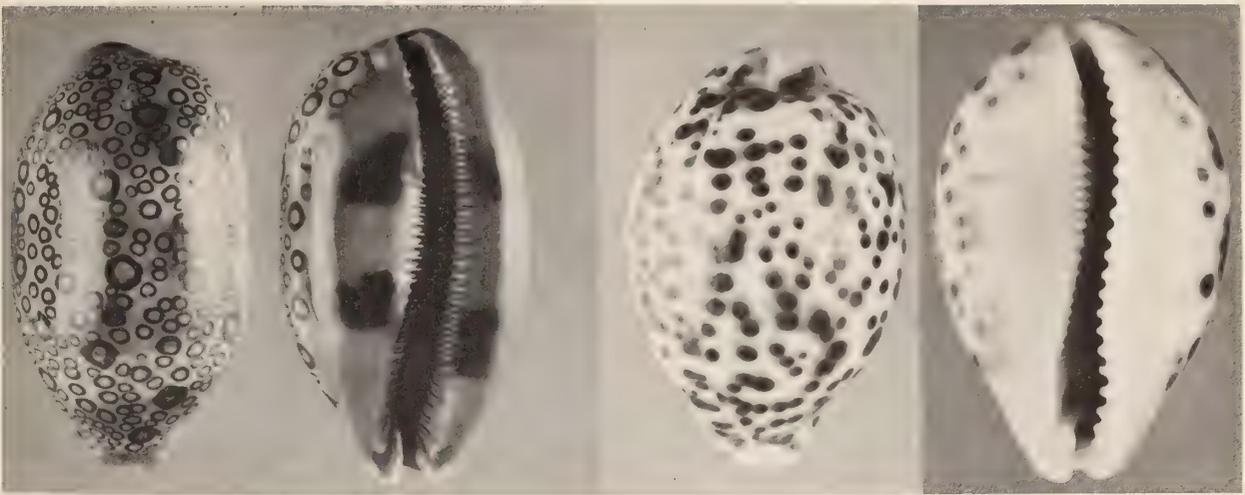


Figure 6

Figure 7

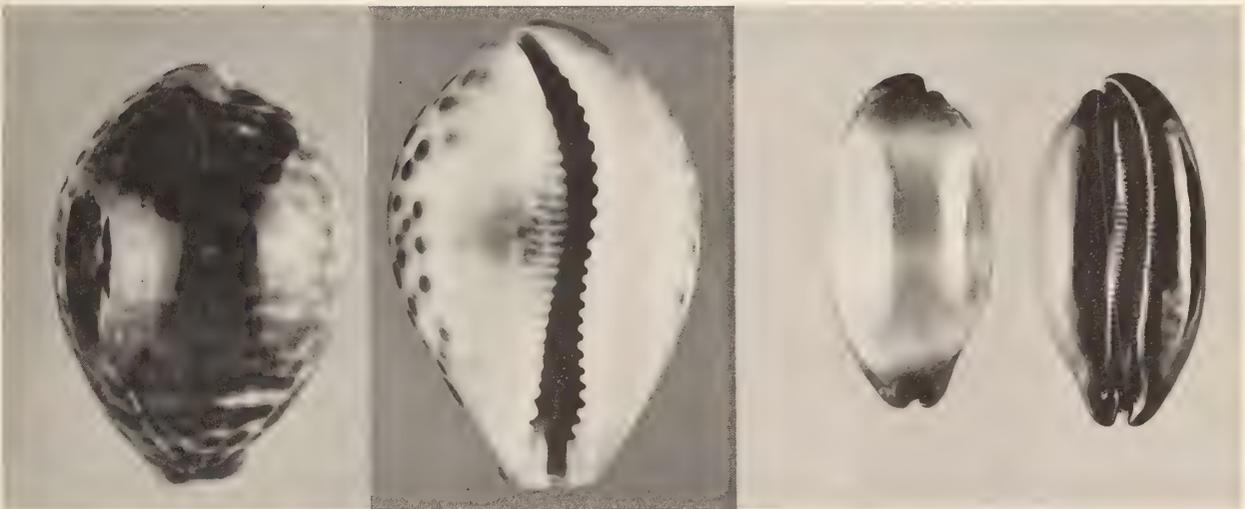


Figure 7 a

Figure 8

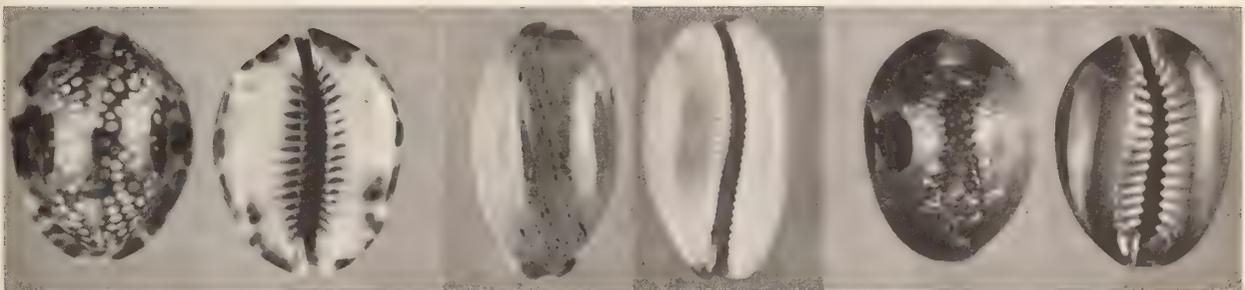


Figure 9

Figure 10

Figure 11

Distribution: South-west Viti Levu, and possibly elsewhere. Very rare. — Central Pacific, Cook Islands, Tuamotus, Gambier & Henderson Islands.

Discussion: The species was believed to range only from the Tuamotus to Samoa. It is known from Viti Levu by one recently collected specimen. STEADMAN & COTTON (1943) recorded the species as *Pustularia margarita theeva* from the Nadroga reef and the islands of Kadavu and Ovalau. *Cypraea dillwyni* was recorded from fairly recent fossil deposits in Vanua Levu by LADD & HOFFMEISTER (1945) under the name of *Pustularia margarita* DILLWYN.

28. *Cypraea labrolineata* GASKOIN, 1849

[*Erosaria labrolineata helenae* (ROBERTS, 1869)]

(Plate 26, Figure 46)

Cypraea labrolineata helenae ROBERTS, 1869

Erosaria maccullochi IREDALE, 1939

Erosaria helenae naseae STEADMAN & COTTON, 1943

Shell: Shell small, elongate-ovate. Dorsum greenish-grey or olive-green, with numerous small, whitish-grey spots and a faint dorsal line. Extremities and margins ridged, labial margin strongly edged, pitted, and with dark brown spots; extremities have dark terminal blotches. Base white, convex, with inner lip flattened. Aperture wide, dilated anteriorly; labial teeth extend three quarters the way to the margin, with the first two to three anterior ones produced to the marginal edge; columellar teeth short, slightly thickened at the ends, first two anterior and posterior teeth produced across base. Fossula shallow, not denticulate.

Size: 15 (59), 18:18; extremes 12, 22 mm.

Animal: Sole of foot cream; dorsum of foot cream, sparsely flecked with dark grey. Mantle yellow to pale orange; papillae numerous, thickly branched and translucent white. Some papillae, especially those near the proboscis, are simple. Siphon brown, with translucent white fringes which are tipped with brown. Tentacles pale orange, tipped with dark orange; eyes black, set in cream sockets.

One animal, observed by A. Jennings (personal communication), from Akuilau Island (West Viti Levu), had a grey mantle, with large, branched white-tipped papillae. **Distribution:** West, South-west and South Viti Levu. Rare. — Torres Strait, Queensland, South-west Pacific, Fiji Islands, Samoa, Tokelau Islands.

Discussion: Fiji specimens have the central columellar teeth uniformly short. Shells from other Melanesian localities show slightly more produced central columellar teeth.

29. *Cypraea helvola* LINNAEUS, 1758

[*Erosaria helvola callista* (SHAW, 1909)]

(Plate 25, Figure 39)

Cypraea helvola callista SHAW, 1909

Cypraea helvola gereti VAYSSIÈRE, 1910

Cypraea erosaria agassizi LADD, 1934

Shell: Shell ovoid, broad, callous. Dorsum lilac, spotted with small white and slightly larger brown spots; extremities bluish-white, dorsal line obsolete. Sides heavily margined, strongly pitted and with chestnut lateral band. Base chestnut-brown; many specimens have a darker brown elongated blotch on the columellar side. Aperture narrow; teeth coarse, labial ones extend three quarters the way to the margin, columellar teeth cross half the base, central teeth being shorter. Fossula shallow with three to four denticles.

Size: 19 (70), 18:15; extremes 14, 24 mm.

Animal: Sole of foot pink, edges grey; dorsum of foot pink, at times cream. Mantle rusty-brown, papillae numerous, thickly branched; the majority of papillae are yellow, few are translucent grey, occasionally tipped with white. Siphon translucent grey, fringed at the end; fringes are flecked with dark grey. Tentacles pink, eyes black.

Distribution: South, East and West Viti Levu. Uncommon. — East Australia, South-west - Central - and East Pacific, Marshall Islands, Caroline Islands.

30. *Cypraea caputserpentis* LINNAEUS, 1758

[*Erosaria caputserpentis argentata* (DAUTZENBERG & BOUGE, 1933)]

(Plate 22, Figure 11)

Cypraea caputserpentis argentata DAUTZENBERG & BOUGE, 1933

Shell: Shell deltoidal, calloused. Dorsum brown, finely reticulated with small white spots, some larger than others; dorsal line either faint or absent; extremities tinged grey. Sides heavily margined, slightly twisted upwards centrally; deep chocolate in colour. Margins of base chocolate-brown, paling towards aperture. Aperture wide, dilated anteriorly; teeth large and white, interstices white or grey to brown; labial teeth extend one quarter way to the margin, columellar ones to halfway across the base, becoming shorter posteriorly. Fossula narrow, with the first two to three anterior teeth forming denticles.

Size: 30 (75), 17:13; extremes 17, 37 mm.

Animal: Sole of foot pale yellow; dorsum of foot fawn, heavily flecked with grey. Mantle dark-grey; papillae numerous, short, thickly branched, translucent white. Tentacles grey; siphon pale brown with a grey shading, fringed at the end.

Distribution: Throughout Fiji. Very common in the South and South-west, very rare in the North of Viti Levu. — Torres Strait, Norfolk Island, Kermadec Islands, South-west - Central - West - and East Pacific.

31. *Cypraea poraria* LINNAEUS, 1758

[*Erosaria poraria scarabaeus* (BORY, 1827)]

(Plate 25, Figure 43)

Cypraea poraria scarabaeus BORY, 1827

Erosaria poraria theoreta IREDALE, 1939

Shell: Shell ovate to deltoidal. Dorsum brown, freckled with small white spots, most of which are ocellated with violet rings; dorsal sulcus line thin and faint. Sides and extremities margined, weakly pitted, pale violet. Base pale violet, becoming lighter towards aperture. Aperture slightly narrow, fairly straight; teeth white, labial ones extending halfway to the margin, columellar teeth slightly shorter centrally. Fossula deep, with five to six denticles. Size: 16 (69), 22:17; extremes 13, 22 mm.

Animal: Sole of foot red; dorsum of foot mottled greenish-grey. Mantle greenish-grey; papillae numerous, small, flecked with white and green. Tentacles pale red; siphon red, fringed at the end.

Distribution: West, South-west and South Viti Levu. Rare. — Parts of Malaysia, Philippine Islands, Japan, East Australia, South-west - Central - West - and East Pacific, Hawaii.

32. *Cypraea erosa* LINNAEUS, 1758

[*Erosaria erosa chlorizans* (MELVILL, 1888)]

(Plate 23, Figure 17)

Cypraea erosa chlorizans MELVILL, 1888

Shell: Shell ovate, elongate. Dorsum fawn, brown or olive green, with numerous small white specks and sometimes larger, less numerous, ocellated brownish spots. Labial side, extremities and part of columellar side heavily flanged, pitted and streaked with brown; sides usually have violet rectangular blotches which extend some way onto the base, with fine vertical white hairline striae across them. Base white to yellowish, sometimes streaked

with brown. Aperture wide; teeth large, labial ones extend almost to the margin, columellar teeth extend halfway to the margin, central ones being shorter. Fossula shallow and denticulate.

Size: 31 (64), 17:14; extremes 21, 45 mm.

Animal: Sole of foot fawn, becoming paler towards the edges; dorsum of foot white, flecked with dark grey. Mantle dark brown, veined with grey. Papillae numerous, extremely branched, thick at the base, pale to dark brown, some tipped with blue, others white. Tentacles orange-brown, eyes black, set in white sockets; siphon grey, spotted with white; the end of the siphon has about 28 whitish fringes streaked with orange centrally. Some specimens examined had a dark brown siphon, spotted with white, but lacking the orange-brown streak on the fringes.

Distribution: Throughout Fiji. Common. — South-west - Central - and West Pacific.

Discussion: A small percentage of every population of *Cypraea erosa* found in Fijian localities lack either one or both marginal blotches.

33. *Cypraea eburnea* BARNES, 1824

[*Erosaria eburnea* (BARNES, 1824)]

(Plate 23, Figure 18)

Erosaria eburnea mara IREDALE, 1939

Shell: Shell pyriform, occasionally elongate. The shell is pure white and unspotted. Extremities and right margin ridged and pitted. Base convex, aperture wide, dilated anteriorly; teeth large, the first two or three anterior labial teeth extending to the margin, the remaining teeth produced to three quarters of the base; columellar teeth short, crossing the fossula and becoming deeply notched centrally. Interior of shell orange to light brown.

Size: 40 (62), 17:13; extremes 23, 50 mm.

Animal: Sole of foot salmon-pink; dorsum of foot blackish-brown. Mantle blackish-brown, mottled with small spots and yellowish striations. Papillae short and branched, numerous, grey with orange tips. Tentacles deep cream, eyes black; siphon grey, dotted latitudinally with pale yellow and fringed at the end (about 32 fringes).

Distribution: Throughout Viti Levu. Uncommon in the North of Viti Levu, rare elsewhere. The preferred habitat of this species is muddy sand. — North-west New Guinea, Queensland, South-west Pacific, Fiji Islands, Tonga Islands.

Discussion: Occasional specimens are found which have a pale orange to pale brown dorsum or are spotted with

Explanation of Plate 23

Dorsal views of Figure 12: x 0.7; Figures 13, 18: x 0.8; Figure 14: x 0.4; Figures 15, 15 a, 16, 17: x 1.0. Ventral views slightly larger.

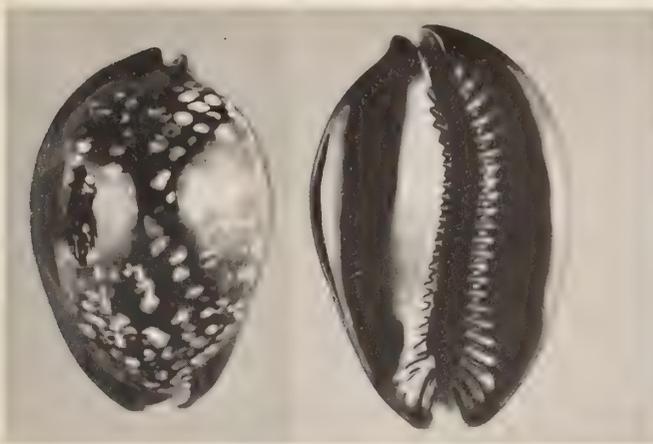


Figure 12

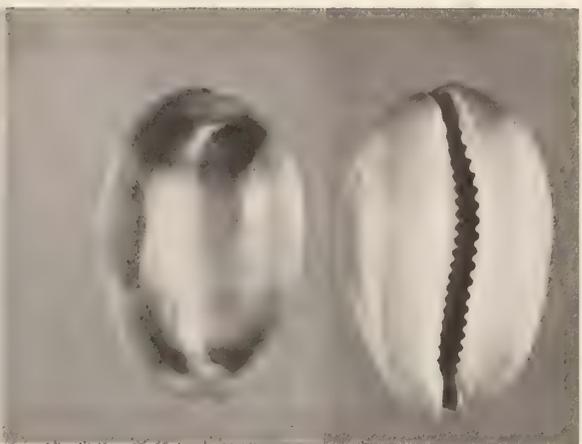


Figure 13



Figure 14

Figure 15

Figure 15 a



Figure 16

Figure 17

Figure 18

milky white. These specimens cannot be interpreted as possible hybrids of *Cypraea eburnea* and *C. miliaris* GMELIN, as the latter species does not occur in Fiji. Reports from Australia indicate that these two allied species interbreed wherever they meet. Until research shows the amount of interbreeding (occasional or frequent) and whether the possible hybrids are fertile, the true status of *C. eburnea* in relation to *C. miliaris* cannot be stated.

34. *Cypraea limacina* LAMARCK, 1810

[*Staphylaea limacina facifer* (IREDALE, 1935)]

(Plate 25, Figure 30)

Cypraea limacina facifer (IREDALE, 1935)

Purperosa facifer monstrans IREDALE, 1935

Staphylaea consobrina / STEADMAN & COTTON, 1943

Staphylaea purperosa ruwaya STEADMAN & COTTON, 1943¹

Shell: Shell pyriformly-elongate, thin. Dorsum grey to purplish-grey, with white spots, more numerous in the centre than on the sides; on some specimens spots are raised; dorsal line weak, hardly visible in most specimens. Labial side and extremities margined and pitted; extremities orange-brown, posteriorly short. The white spots above the margins are raised. Base convex, white with a bluish tinge. Aperture slightly narrow; teeth orange, lined with red, labial teeth almost extending to the margin, columellar teeth never extend more than three quarters of the way to the margin, posterior ones always being the longer. Fossula somewhat concave, weakly denticulate.

Size: 22 (57), 22:18; extremes 15, 33 mm.

Animal: Sole and dorsum of foot vary from pale to dark orange. Mantle pale orange to pale red. Papillae numerous, long, becoming shorter and sparse towards the edges of the mantle; papillae are long, simple, uniformly thick all the way, others stouter at the tips; papillae coloured orange, flecked with white in parts, tipped with white; some papillae have a cluster of white flecks around the base. Tentacles orange, eyes black; siphon pale orange, not fringed at the end.

Among over 100 specimens collected, four animals showed an extreme variation in colouring, which is recorded here:

Sole of foot grey, becoming cream towards the edges; dorsum of foot black. Mantle dusky-black; papillae long, branched, grey tipped with white; few papillae all white, tipped with orange. Tentacles dark grey at the base,

becoming cream at the end; siphon transparent greyish-brown, with ten darker latitudinal lines encircling it, not fringed at the end.

Distribution: Throughout Viti Levu. Uncommon. — East Australia, New Caledonia, Central Pacific.

Discussion: It is doubtful that the extreme difference in animal colour is due to sex-differences, as a black-mantled animal was observed sitting on eggs, and red-mantled animals are frequently seen on eggs. These egg cases are normally a purplish-mauve shade. A recently collected *Cypraea limacina* was found sitting on pale creamy-yellow egg cases (T. Saunders, personal communication).

Immature shells of the species (those which have weakly formed columellar teeth, but not labial teeth) have a fully brown dorsum and lack the white spots. The orange-red lining of the teeth is present only in fully mature specimens, and appears to be the final stage in the growth cycle of the shell.

35. *Cypraea staphylaea* LINNAEUS, 1758

[*Staphylaea staphylaea consobrina* (GARRETT, 1879)]

(Plate 25, Figure 31)

Cypraea staphylaea consobrina GARRETT, 1879

Staphylaea nukulau STEADMAN & COTTON, 1943

Shell: Shell small, ovate, slightly globular. Dorsum pale grey or purplish-green, with numerous raised close-set white granules; dorsal sulcus distinct. Extremities tinged orange to dark brown. Left side rounded, right side slightly margined, the last set of raised pustules connected to the margin by raised lines. Base slightly convex, flesh-coloured. Aperture narrow; teeth pale brown, well-developed, bordered by brown lines, and extending across the base to the margins. Fossula wide, fairly deep, denticulate. Size: 14 (62), 26:19; extremes 10, 20 mm.

Animal: Sole of foot dark grey; dorsum of foot dark grey, flecked with small white spots. Mantle black, minutely spotted with white. Papillae numerous, short, simple, few branched, black and minutely spotted with white; some specimens have translucent pale grey papillae; only a few papillae (3 to 7) are white and branched. Tentacles black; siphon dark brown, fringed at the end.

Distribution: Throughout Fiji. Uncommon. — Southwest - Central - and West Pacific.

Discussion: An interesting observation was made in regard to the animal of *Cypraea staphylaea*. Specimens were collected, which in their natural surroundings displayed a black mantle. After being placed in an air-tight bottle, the animals expired within a short time. When death set in, the animals exuded a bright red pigment which coloured the animal's parts visible in the aperture. The pigment was delible and could be wiped off with the finger.

¹ IREDALE (1935) established *Purperosa* as a genus. STEADMAN & COTTON (1943) used *Purperosa* in a specific sense. When using *staphylaea* in a specific sense the authors spelled it consistently *staphylea* throughout their paper.

36. *Cypraea nucleus* LINNAEUS, 1758[*Nuclearia nucleus granulosa* (SOWERBY, 1870)]

(Plate 24, Figure 27)

Cypraea nucleus granulosa SOWERBY, 1870*Nuclearia nucleus gemmosa* / STEADMAN & COTTON, 1943

Shell: Shell ovate, solid, fairly broad in centre, extremities rostrate. Dorsum slightly depressed, yellowish to yellowish-brown, with a distinct dorsal groove; the small raised dorsal pustules are ocellated with brown and connected by fine reddish-brown lines. Sides margined, extremities tinged orange. Base fawn to very pale brown, aperture narrow. Teeth well-developed, lined with reddish brown, extending fully to the margins; on the columellar side, smaller teeth extend inwards from the margins, but never extend to the aperture. Fossula shallow, with a longitudinal ridge, denticulate.

Size: 19 (63), 27:17; extremes 15, 26 mm.

Animal: Sole of foot white; dorsum of foot fawn, minutely spotted with white. Mantle rusty-red; papillae numerous, translucent fawn, alternating in geometrical progression from short, simple ones which are tipped with black, to long ones which are thick and branched. Tentacles pale yellow; siphon pale grey, with white, short fringes at the end.

Distribution: West, South and South-east Viti Levu. Rare. — Torres Strait, Queensland? (they appear to belong to *Cypraea nucleus s. str.*), Central Pacific.

37. *Cypraea walkeri* SOWERBY, 1832[*Erronea walkeri bregeriana* (CROSSE, 1868)]

(Plate 26, Figure 58)

Cypraea walkeri bregeriana CROSSE, 1868

Shell: Shell ovate to pyriform, light in weight. Dorsum fawn to brown, sprinkled with numerous green spots and crossed by a centrally-placed transverse band; this is sometimes darker at the edges and partly interrupted, forming one or two rectangles. Margins rounded, sometimes slightly callous; base rich brown or ferruginous, spotted with minute, conspicuous white dots, which extend partly up the dorsum. Extremities tinged pale purple; spire blotch dark brown; anterior extremity has two purplish-brown terminal blotches. Aperture wide, dilated

anteriorly; teeth pale brown, interstices very pale purple; columellar teeth extend halfway to the margin, central teeth shorter; labial teeth extend three quarters of the way to the margin. Fossula absent, the ribs crossing it being level and not notched.

Size: 27 (59), 21:20; extremes 15, 23 mm.

Animal: Foot deep orange anteriorly, fading to creamy-white towards the rear, extreme posterior end translucent. Mantle smoky-brown, mottled with minute white spots. Papillae short, branched, white, scattered around the sides of the mantle, absent towards the edges. Tentacles pale orange, eyes black; siphon cream with minute black fringes at the end. Buccal bulb area dark orange.

Distribution: Islands off Nadi Bay and Mamanutha group (West off Viti Levu). — Louisiade Archipelago, New Caledonia, Fiji Islands.

Discussion: All known Fiji specimens were dredged in from 15 to 60 feet; dead specimens dredged from 120 feet. The largest known Fiji specimen is 22.8 mm; others fluctuate between 15 and 21 mm. The brown marginal spots usually present on specimens from New Caledonia are absent in Fiji specimens; the usual lilac rim encircling the dorsum is either very pale or absent.

38. *Cypraea erronea* LINNAEUS, 1758[*Erronea erronea coeruleascens* (SCHRÖTER, 1804)]

(Plate 24, Figures 25, 25 a)

Cypraea erronea coeruleascens SCHRÖTER, 1804*Erronea nimisserans kalavo* STEADMAN & COTTON 1943*Erronea nimisserans vivili* STEADMAN & COTTON, 1943²

Shell: Shell subpyriform to cylindrical. Dorsum pale blue or grey, crossed by three wide brownish bands, and mottled with small olive-green freckles; some specimens have a dark brown central blotch. Anterior extremity sometimes has one or two dark brown patches. Sides and base cream-yellow, occasionally light brown and unspotted; base flat. Aperture wide, dilated anteriorly; labial teeth distant, columellar teeth confined to aperture, becoming weak centrally. Fossula slightly narrow, crossed by coarse ribs which are slightly notched.

Size: 24 (55), 15:15; extremes 14, 35 mm.

² IREDALE (1935) established *nimiserrans* to replace *erronea*; STEADMAN & COTTON consistently quoted this name as *nimisserans*.

Explanation of Plate 24

Dorsal views of Figures 19, 21: x 0.7; Figures 20, 22, 23, 25, 25 a, 28: x 1.0; Figure 24: x 0.8; Figures 26, 27, 29: x 1.2. Ventral views slightly larger.

Figure 15: *Cypraea caurica thema* IREDALE (typical). Figure 15 a: *Cypraea caurica thema* IREDALE (broad ecological variant).



Figure 19

Figure 20

Figure 21

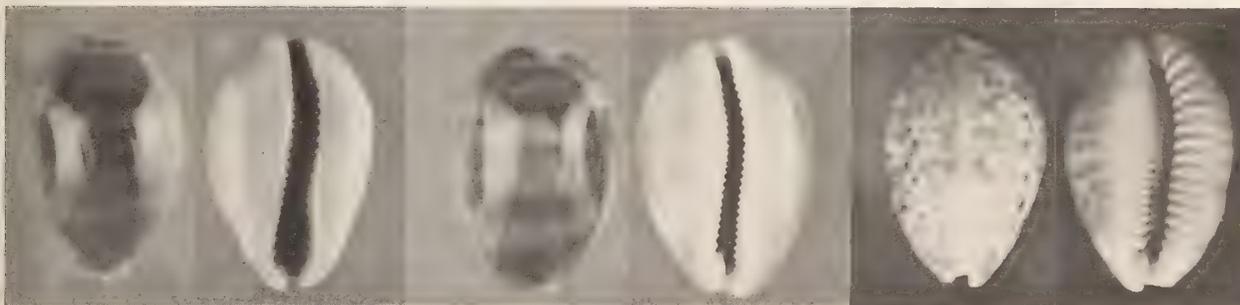


Figure 22

Figure 23

Figure 24



Figure 25

Figure 25 a

Figure 26



Figure 27

Figure 28

Figure 29

Animal: Sole of foot pale cream, edge irregularly mottled with black and brown; dorsum of foot cream. Mantle greenish-grey, minutely flecked with black in a few places. Papillae short, branched, black, mottled with white. Tentacles orange, eyes black; siphon pale grey, with 14 fringes at the end.

Distribution: Throughout Fiji. Very common. — South-west - Central - and West Pacific.

Discussion: An ecological variant from Fiji is slightly larger, subpyriform, with dark brown dorsum and transverse bands, without central dorsal blotch. Sides are heavily calloused, aperture is narrow and teeth are stronger on the columellar side. The variant occurs on a shore reef at Vuda Point (West Viti Levu). The reef structure consists of broken crushed dead coral, with hardly any sand pockets and no sea weeds. The reef is exposed during 2½ hours before and after low tide.

39. *Cypraea caurica* LINNAEUS, 1758
[*Erronea cauricathema* IREDALE, 1939]

(Plate 23, Figures 15, 15 a)

Cypraea caurica var. // *obscura* ROSSITER, 1882
Erronea caurica obscurata SCHILDER & SCHILDER, 1940

Shell: Shell cylindrical, elongate. Dorsum bluish-white, with numerous small brown specks, and three wide, darker bands, sometimes interrupted to form pale rectangles; extremities with large, blackish-brown terminal spots. Left side rounded, right side and extremities heavily margined, spotted with large, dark brown to black spots. Sides and base fawn to light brown. Aperture wide, dilated anteriorly; labial teeth large, more distant than columellar ones, and extending to the margins; interstices pale or bright orange. Fossula formed only by a slight notch in the coarse ribs.

Size: 40 (55), 16:15; extremes 23, 45 mm.

Animal: Sole of foot white; dorsum of foot white, with a pattern of black and white honey-combs. Mantle grey in appearance, caused by the alternate white and dark brown mottling. Papillae few, short, branched and white. Tentacles bright yellow, eyes black in white sockets, buccal bulb brown; siphon greyish-white, shaded with black, each side of siphon with 7 white, fairly long fringes.

Distribution: Throughout Fiji. Uncommon. — Torres Strait, South-west and Central Pacific, Cook Islands.

Discussion: The frequent occurrence in Fiji of a broad ecological variant of *Cypraea caurica* with heavily margined sides and more produced columellar teeth appears to confirm the SCHILDERS' opinion as to the cause of it (SCHILDER & SCHILDER, 1958 b, p. 404). *Cypraea* found in localities where strong surf-action is prevalent usually grow broader and heavier. *Cypraea caurica* from quiet

lagoons and sheltered bays grow cylindrical and elongate, with the left margin rounded.

SCHILDER & SCHILDER, 1940 replaced the pre-occupied *Cypraea caurica obscura* ROSSITER, 1882 by *Erronea caurica obscurata*. IREDALE, 1939, however, had already replaced ROSSITER's name by *Erronea caurica thema*; thus the SCHILDERS' *E. c. obscurata* became a junior synonym.

40. *Cypraea listeri* GRAY, 1824

[*Melicrona listeri melvilli* (HIDALGO, 1906)]

(Plate 25, Figure 38)

Cypraea listeri melvilli HIDALGO, 1906
Melicrona melvilli velesia IREDALE, 1939
Melicrona melvilli vatu STEADMAN & COTTON, 1943

Shell: Shell cylindrical, depressed. Anterior extremity blunt and rounded, both extremities with a pair of blackish terminal spots. Dorsum bluish-grey, densely freckled with olive-brown, crossed by four to five narrow, usually interrupted blackish bands; these bands are visible on the columellar side of the base and continue into the aperture. Sides cream to fawn, left side rounded, right side margined, with blackish spots. Base flat, whitish; aperture wide, dilated anteriorly. Teeth very short, those on the columella weakly formed and confined to the aperture; interstices dull. Fossula formed only by a slight notch in the ribs.

Size: 15 (56), 16:15; extremes 12, 21 mm.

Animal: Mantle thin, translucent, brownish-flesh, towards the foot pinkish, minutely spotted with brown, edge white with darker line inside; anteriorly the foot has a wavy edge. Siphon pale brown, fringed; tentacles brownish-red. (Long Reef, New South Wales, C. F. & J. LASERON in IREDALE, 1939)

Distribution: West to South and East Viti Levu. Rare. — East Australia, South-west and Central Pacific, Caroline Islands.

41. *Cypraea punctata* LINNAEUS, 1771

[*Palmadusta punctata iredalei* SCHILDER & SCHILDER,

(Plate 25, Figure 45)

Evenaria persticta IREDALE, 1939
1938]

Evenaria carula IREDALE, 1939

Evenaria punctata trizonata / STEADMAN & COTTON, 1943

Shell: Shell small, subpyriform to pyriform, posterior extremity slightly produced. Dorsum yellowish-white, with small dark brown spots, and occasionally three faint transverse bands. Extremities with pairs of dark terminal spots, the posterior spot on the labial side absent in most

specimens. Left side rounded, right side slightly margined; lateral spots blackish-brown, smaller than the dorsal spots. Base yellowish-white; aperture slightly narrow. Labial teeth orange, extending three quarters of the way to the margin; columellar teeth confined to aperture, orange lines extending halfway to the margin. Fossula concave and denticulate.

Size: 10 (58), 28:26; extremes 8, 13 mm.

Animal: Sole of foot pale salmon-pink; dorsum of foot is cream, thickly veined with orange in a honey-comb pattern. Mantle orange, with numerous white, minute, slightly raised nodules all over its surface. Papillae few, both simple and branched, pale grey at the base, becoming white towards the tips. Tentacles orange; siphon grey, with white fringes at the end; eyes black, set in pale yellow sockets.

Distribution: Throughout Fiji. Rare. — East Australia, South-west and Central Pacific.

42. *Cypraea asellus* LINNAEUS, 1758

[*Palmadusta asellus bitaeniata* (GERET, 1903)]

(Plate 26, Figure 47)

Cypraea asellus bitaeniata GERET, 1903

Evanaria asellus kawakawa STEADMAN & COTTON, 1943³

Shell: Shell pyriform, slightly constricted anteriorly. Dorsum white, with three broad, dark brown transverse bands which stop at the margins; the dorsal bands are visible on the columella and continue into the aperture; many specimens have fine, white, longitudinal hairlines on the dorsum. Left side rounded, right side margined, white in colour. Base white, hardly convex; aperture only slightly narrow. Labial teeth extend halfway to the margins; the first five to six posterior columellar teeth are produced halfway across the base, all others very short. Fossula wide, shallow and ribbed.

Size: 16 (59), 22:17; extremes 10, 22 mm.

Animal: Sole of foot dark grey, becoming darker towards the edges; dorsum of foot black. Mantle black; papillae few, very short, hardly branched, white. Tentacles orange; siphon black, fringed at the end.

Distribution: Throughout Fiji. Uncommon. — Torres Strait, South-west and Central Pacific, Jarvis Island.

³ IREDALE (1930) established the genus *Evanaria*. STEADMAN & COTTON spelled it *Evanaria* throughout their paper.

43. *Cypraea clandestina* LINNAEUS, 1767

[*Palmadusta clandestina candida* (PEASE, 1865)]

(Plate 25, Figure 44)

Cypraea clandestina candida PEASE, 1865

Palmadusta clandestina whitleyi IREDALE, 1939

Palmadusta clandestina extrema IREDALE, 1939

Shell: Shell subpyriform to pyriform, light in weight, anterior extremity slightly constricted. Dorsum ivory-white, with three large, ill-defined, orange-grey areas, usually separated by narrow zones of white; narrow, orange-brown zig-zag lines run from margin to margin. Sides and extremities white; base white, not quite flat. Aperture narrow; teeth white, extending halfway to the margins. Fossula shallow with uninterrupted ribs.

Size: 15 (58), 22:17; extremes 12, 20 mm.

Animal: Sole of foot blackish-grey; dorsum of foot black, minutely spotted with white. Mantle black, with a pattern of minute fleshy granules and a few white spots; some parts of the mantle have cream mottled areas with white rings. Papillae numerous, short, white, branched and simple; approximately 22 papillae are positioned around the anterior part of the animal, and are simple, black, tipped with white. Tentacles black, eyes black; siphon black, with long fringes at the end.

Distribution: Throughout Viti Levu. Uncommon. — East Australia, South-west - Central - and West Pacific, Cook Islands, Jarvis-Palmyra Islands.

44. *Cypraea humphreysii* GRAY, 1825

[*Palmadusta lutea humphreysi* (GRAY, 1825)]

(Plate 25, Figure 35)

Cypraea lutea GRONOW, 1781⁴

Cypraea lutea humphreysi GRAY, 1825

Cypraea nivea WOOD, 1828

Palmadusta lutea yaloka STEADMAN & COTTON, 1943

Shell: Shell small, ovate, sometimes pyriform. Dorsum ivory-white, freckled with small, numerous, irregular olive-green spots, and a few slightly larger black spots. Some specimens have two narrow, whitish transverse

⁴ *Cypraea lutea* GRONOW, 1781 is not available, as Op. 261 of I. C. Z. N. rejects Gronovius' *Zoophylacium Gronovianum* for nomenclatorial purposes. Unless the name has been validated subsequently (pertinent literature is unfortunately unavailable to me at present) the next available name appears to be *humphreysii* of GRAY, 1825.

Explanation of Plate 25

Dorsal views of Figures 30, 32, 39: x 1.0; Figures 31, 33, 34, 36, 37, 38, 41, 43, 44: x 1.2; Figures 35, 40, 45: x 1.5.
Figure 42: x 2.0. Ventral views slightly larger.



Figure 30

Figure 31

Figure 32

Figure 33

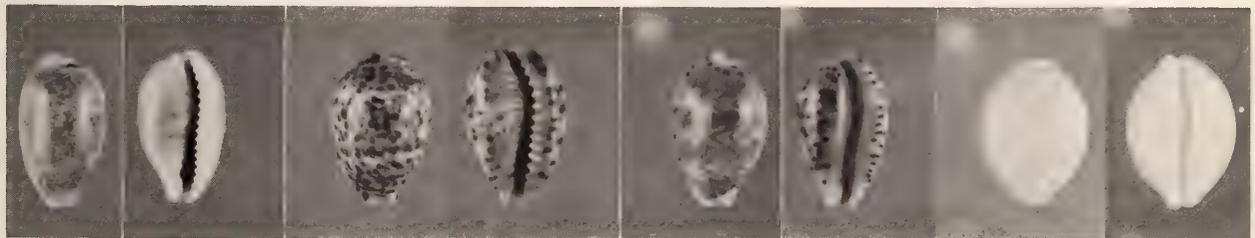


Figure 34

Figure 35

Figure 36

Figure 37



Figure 38

Figure 39

Figure 40

Figure 41

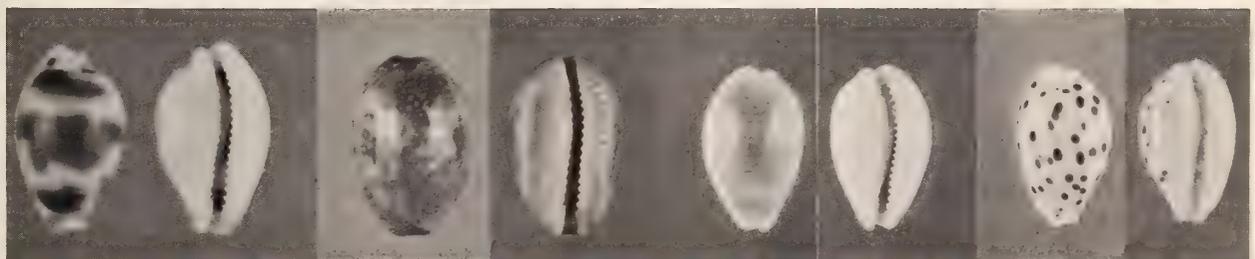


Figure 42

Figure 43

Figure 44

Figure 45

bands one third of the way from each extremity; these bands are occasionally faint or even obscured by the dorsal spotting. Left side rounded, right side margined; sides spotted with small, dark brown spots which extend onto the base. Base slightly convex and rich orange-brown. Aperture slightly wide; teeth coarse, labial ones extend halfway to the margin, columellar teeth short, first three posterior teeth slightly longer; teeth are a flesh colour, with interstices darker and dull. There is a dark brown spot at the end of each labial tooth. Fossula concave and denticulate.

Size: 18 (60), 19:18; extremes 11, 18 mm.

Animal: Sole of foot orange; dorsum of foot vermilion, sparsely spotted with minute brown dots. Mantle reddish-brown to reddish-orange, profusely spotted with brown. Papillae short, branched, translucent white. Siphon and tentacles dark orange.

Distribution: Throughout Fiji. Rare. — East Australia, New Caledonia, Fiji Islands, Tonga Island, Samoa.

Discussion: The preferred habitat of this species is a short, coarse weed with round leaves.

Fiji specimens are generally smaller than those from other localities; the average length is only 14 mm.

45. *Cypraea ziczac* LINNAEUS, 1758

[*Palmadusta ziczac vittata* (DESHAYES, 1831)]

(Plate 25, Figure 36)

Cypraea ziczac vittata DESHAYES, 1831

Palmadusta ziczac signata IREDALE, 1939

Shell: Shell pyriform, posterior extremity slightly produced. Dorsum light brown, crossed by three bluish-white transverse bands; orange-brown, V-shaped lines are set inside the transverse bands. Four or five small, dark brown spots extend up from the right anterior extremity, at an angle of 45 degrees; another six or seven similar spots form a half-circle around the spire pit. Extremities tinged with orange, area around spire pit bluish-white. Left side rounded, right side margined, bluish-white, spotted with dark spots. Base orange-brown, with numerous, blackish brown spots, those on the labial side more or less coinciding with the ends of the teeth. Aperture slightly wide, dilated anteriorly; labial teeth coarse, extending halfway to the margin; columellar teeth finer, confined to aperture; teeth interstices dull. Fossula wide, very shallow and ribbed.

Size: 16 (61), 22:21; extremes 12, 24 mm.

Animal: Sole of foot cream; edges and dorsum of foot orange. Mantle reddish-orange, profusely spotted with minute black spots. Papillae short, branched, well scattered, white, becoming very small towards the edges of

the mantle. Tentacles reddish-orange; siphon pale pink, with black fringes at the end.

Distribution: Throughout Fiji. Very rare. — East Australia, South-west Pacific, Fiji Islands, Tonga Island.

Discussion: This is the first report of *Cypraea ziczac* occurring in Fiji.

46. *Cypraea fimbriata* GMELIN, 1791

[*Palmadusta fimbriata unifasciata* (MIGHELS, 1845)]

(Plate 26, Figure 50)

Palmadusta waikikiensis SCHILDER & SCHILDER, 1933

Cypraea fimbriata unifasciata MIGHELS, 1845

Shell: Shell subcylindrical, depressed, anterior extremity broad. Dorsum lilac-grey, with distinct minute brown spots, and darker, reddish-brown patches, forming a clear but usually interrupted central transverse band; short, curved lines radiate towards extremities, which have a pair of lilac terminal spots, also extending onto the base. Left side rounded, right side slightly margined, white, unspotted. Base convex, white, dorsal bands visible on columella. Aperture wide, dilated anteriorly; teeth white, less numerous than in *Cypraea minoridens* and *C. microdon*; labial teeth extend one third to the margin, columellar ones confined to aperture. Fossula formed by a notch in the ribs which cross it.

Size: 11 (54), 23:21; extremes 10, 14 mm.

Animal: Mantle, foot and proboscis orange-red; dorsal surface of foot sprinkled with white freckles. Papillae simple, few and scattered, white. Siphon with a simple tentacular fringe. (Hawaii, KAY & WEAVER, 1963)

Distribution: Islands off Nadi coast (West of Viti Levu). Very rare. — Fiji Islands, Samoa, East - and North-east Pacific.

Discussion: This is the first record of this species West of Samoa.

47. *Cypraea minoridens* MELVILL, 1901

[*Palmadusta minoridens* (MELVILL, 1901)]

(Plate 26, Figure 49)

Opponaria minoridens blandita IREDALE, 1939

Paulonaria minoridens suvaensis STEADMAN & COTTON, 1943

Shell: Shell subcylindrical to cylindrical, depressed, small and fragile, extremities blunt. Dorsum light grey to purplish-grey, with numerous, fairly regular, orange-brown spots and three darker transverse bands; the dorsal bands are often interrupted. Extremities have a pair of purplish terminal spots, which extend onto the base. Sides white, unspotted, right side slightly margined. Base whitish,

with dorsal bands visible on columella; aperture wide, dilated anteriorly. Teeth fine, weakly formed; labial teeth extend one third of the way to the margins, columellar teeth confined to aperture. A diagnostic character is that the fossular ribs stand well out from the sides of the shell; the fossula consists of a wide notch in the ribs, considerably wider than that of *Cypraea fimbriata*.

Size: 8 (55), 27:26; extremes 7, 11 mm.

Animal: Mantle pale to dark orange and smooth. Other details not observed.

Distribution: West and South Viti Levu. Rare. — East Australia, South-west - Central - and West Pacific, Cook Islands, Tuamotus, Gambier and Henderson Islands.

Discussion: STEADMAN & COTTON (1943) accepted *Cypraea minoridens* as a distinct species. In their paper of 1946 the authors reversed their opinion and placed *C. minoridens* into the synonymy of *C. microdon* GRAY. The Fijian *C. minoridens*, originally described by STEADMAN & COTTON (1943) as *Paulonaria minoridens suvaensis*, was changed by the authors in 1946 to *Paulonaria fimbriata suvaensis*.

48. *Cypraea microdon* GRAY, 1828

[*Palmadusta microdon granum* SCHILDER & SCHILDER, 1938]

(Plate 26, Figure 51)

Shell: Shell small, pyriform, inflated, posterior extremity calloused. Dorsum orange-brown, with very small pale brown spots, and three transverse bands, extending to the aperture on the columellar side; in some specimens the dorsal bands are bordered by small, darker, evenly spaced squarish spots. Extremities have a pair of lilac terminal spots which extend around to the base. Left side rounded, right side slightly margined, white, with an occasional small, brown spot. Base convex, white; aperture narrow. Teeth finer than in *Cypraea fimbriata*; labial teeth weakly formed, hardly impressed on base, columellar teeth confined to aperture. Fossula is wider, deeper and steeper than that of *C. minoridens*.

Size: 9 (54), 32:29; extremes 8, 12 mm.

Animal: The foot is very pale orange, mantle dark orange. Other details not observed.

Distribution: Throughout Fiji. Very rare. — Torres Strait, South-west and Central Pacific, East Australia.

Discussion: STEADMAN & COTTON (1943), and ALLAN (1956) list Fiji as the type locality. The SCHILDERS' holotype, however, came from Mope, New Britain.

49. *Cypraea pallidula* GASKOIN, 1849

[*Bistolida pallidula rhinoceros* (SOVERBIE, 1865)]

(Plate 25, Figure 33)

Cypraea pallidula rhinoceros SOVERBIE, 1865

Blasicrura rhinoceros vivia STEADMAN & COTTON, 1943

Shell: Shell subcylindrical to cylindrical, anterior extremity blunt and rounded. Dorsum grey, freckled with small green spots, and with four darker transverse bands. Sides white, occasionally sparsely spotted; base white and flattened. Aperture fairly straight, slightly narrow; labial teeth extend three quarters of the way to the margin, columellar ones halfway to the margin. Fossula broad, fairly deep and denticulate.

Size: 18 (55), 23:18; extremes 16, 24 mm.

Animal: The mantle is blackish-grey. Other details not observed.

Distribution: West to South and East Viti Levu. Very rare. — Torres Strait, Queensland, South-west and Central Pacific.

Discussion: Fiji specimens appear to have a blunter and more rounded anterior extremity than do specimens from other Melanesian localities. The size formula here is 19 (54), 22:20.

50. *Cypraea summersi* (SCHILDER, 1958)

[*Bistolida summersi* SCHILDER, 1958]

(Plate 25, Figure 34)

Shell: Shell small, cylindrically-ovate; the constricted anterior extremity gives the shell a slightly drawn-out appearance. Dorsum bluish-white to grey, thickly freckled with olive-green spots, and with four very faint, but darker transverse bands; these bands are absent in most mature specimens. Left side rounded, right side slightly margined, cream in colour; some specimens have three or four pin-sized olive-green spots on the labial or columellar side. Base cream, aperture wide; teeth coarser than those of *Cypraea pallidula*, labial and columellar teeth extending three quarters of the way to the margins; interstices wide and dull. A brown spot appears on the anterior extremity (labial side), and less frequently on the posterior extremity; spire pit is blackish-brown. Fossula narrow, shallow and denticulate.

Size: 15 (56), 21:15 (mean size for 68 Fiji specimens; extremes 12, 21 mm.

Explanation of Plate 26

Dorsal views of Figures 46, 48, 53: x 1.5; Figures 47, 54, 55, 57, 58: x 1.2; Figures 49, 50, 51, 52: x 2.0; Figure 56: x 1.0.

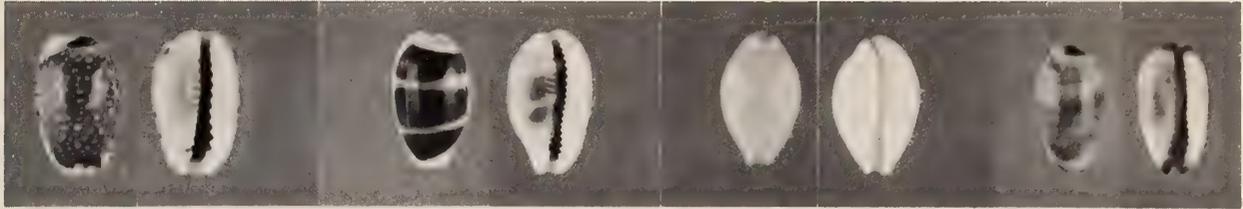


Figure 46

Figure 47

Figure 48

Figure 49



Figure 50

Figure 51

Figure 52

Figure 53



Figure 54

Figure 55

Figure 56

Figure 57



Figure 58

Animal: Sole of foot creamy-white; dorsum of foot cream, veined with black on the posterior part. Mantle dark grey, faintly veined with dark brown, edges of mantle flecked with black. Papillae numerous, short, cream tipped with white, and alternating between simple and branched. Tentacles orange, eyes black set in white sockets; siphon grey with fringes at the end pale yellow.

Distribution: Throughout Fiji. Rare live-collected; beach specimens frequent at Caboni and Nananu-i-Ra (North Viti Levu). — Fiji Islands, Tonga Islands.

Discussion: The species was collected as early as July 1926 by Jens Ostergaard (personal communication), near the old pier at Nukualofa, Tonga. It was recorded by OSTERGAARD (1935 : 29) as *Cypraea interrupta* GRAY, 1824. The shell was first described by SCHILDER (1958) as a subspecies of *C. pallidula*, and was believed endemic to Tonga. The species was first recorded in Fiji in early 1962. The occurrence of both *C. summersi* and *C. pallidula rhinoceros* in the same locality in Fiji, and the complete absence of any hybrids of the two forms, prove *C. summersi* to be specifically separable.

Three specimens collected in Fiji show a 3 mm to 3.5 mm long and 1 mm wide brown bar, situated latitudinally on the anterior extremity, instead of the usual brown spot.

51. *Cypraea teres* GMELIN, 1791

[*Bistolida teres subfasciata* (LINK, 1807)]

(Plate 25, Figure 32)

Cypraea teres subfasciata LINK, 1807

Talostolida teres pentella IREDALE, 1939

Talostolida subteres hermanni IREDALE, 1939

Talostolida subteres vava STEADMAN & COTTON, 1943

Shell: Shell subcylindrical to cylindrical. Dorsum grey to greyish-blue, crossed by three, usually discontinuous dark brown bands; the central band sometimes has a blotch-like appearance. Posterior extremity heavily calloused and umbilicate. Left side rounded, right side heavily margined, creamy-white with a few brown spots. Base white and convex; aperture narrow; extremities tinged with pinkish-brown. Labial teeth coarse and extending halfway to the margin, columellar teeth fine and confined to aperture; interstices dull; labial lip curves upwards posteriorly. Fossula wide and deep, and crossed by ribs.

Size: 25 (54), 24:23; extremes 18, 38 mm.

Animal: Foot, mantle, proboscis and tentacles orange-red, the mantle spotted with darker red. Papillae large, simple, rounded. Siphon with simple tentacular fringe, red but

spotted with white. (Hawaii, KAY & WEAVER, 1963)

Distribution: West to South and East Viti Levu. Rare. — East Australia, South-west and Central Pacific.

Discussion: STEADMAN & COTTON (1943) state that Fijian specimens seem to belong to the species *Cypraea subteres* WEINKAUFF, 1881. All specimens recorded from Fiji so far are, however, undoubtedly *C. teres* GMELIN.

52. *Cypraea kieneri* HIDALGO, 1906

[*Bistolida kieneri schneideri* (SCHILDER & SCHILDER, 1938)]

(Plate 25, Figure 40)

Blasicrura kieneri schneideri SCHILDER & SCHILDER, 1938

Evenaria ursellus marcia IREDALE, 1939

Evanaria ursellus vitiensis STEADMAN & COTTON, 1943

Shell: Shell ovate, depressed, anterior extremity blunt. The dorsum has erratically curved markings, forming irregular greyish patches, separated by whitish zones; the centrally placed dark brown transverse band is usually well visible near the columellar margin in the form of rectangular blotches. Extremities have a pair of blackish brown terminal spots. Dorsum is sprinkled with minute olive-brown specks, which extend to the margins. Sides white, with small brown spots, right side margined; base white and flattened. Aperture narrow, slightly dilated anteriorly; the first five to seven posterior columellar teeth are long, the others becoming very short anteriorly. This is a distinguishing point of the species; in *Cypraea hirundo* and *C. ursellus* all columellar teeth cross at least three quarters of the base. Fossula shallow and denticulate. Size: 12 (59), 19:16; extremes 10, 17 mm.

Animal: Sole of foot white; dorsum of foot white, sparsely spotted with minute black dots. Mantle translucent white; papillae few, short and branched, white. Tentacles bright yellow; siphon pure white, with two small black spots on the dorsal side near the edge; siphon thickly fringed.

Distribution: Throughout Fiji. Rare. — East Australia, South-west and Central Pacific.

Discussion: IREDALE (1939), STEADMAN & COTTON (1943) and ALLAN (1956), adopted the name *Cypraea ursellus* GMELIN, 1791 for this species. DODGE (1953), under *C. hirundo* LINNAEUS, gives a detailed account on the use of the name *C. ursellus* by earlier writers. He correctly points out that GMELIN's name of his "sub-pyri-form" *C. ursellus* cannot be applied to the ovate to sub-cylindrical shell known as *C. kieneri*.

53. *Cypraea hirundo* LINNAEUS, 1758
 [*Bistolida hirundo rouxi* (ANCEY, 1882)]

(Plate 25, Figure 41)

Cypraea hirundo rouxi ANCEY, 1882
Evenaria hirundo cameroni IREDALE, 1939
Evenaria peropima IREDALE, 1939
Evenaria coffea endela IREDALE, 1939
Evanaria hirundo korolevu STEADMAN & COTTON,
 1943

Shell: Shell ovate to subcylindrical, broadened centrally. Dorsum has greyish-blue, irregular patches, with ill-defined edges, separated by white zones; the size of these markings is variable, but the white zones are usually very narrow. The dorsum is sprinkled with small brown spots, and often has a blackish-brown, irregular central blotch. Anterior extremity narrow, posterior extremity produced, and both extremities have a pair of blackish-brown terminal spots. Sides slightly margined, white, with many small brown spots which extend a short way over the white base. Aperture narrow; teeth almost reach the margins, the central columellar ones being largest; interstices dull. Fossula wide and deep, crossed by ribs.

Size: 14 (59), 24:19; extremes 10, 23 mm.

Animal: Sole of foot creamy-white; dorsum of foot white, profusely spotted with small reddish-brown dots. Mantle translucent fawn, covered with small, dark brown spots; the whole mantle area consists of a pattern of small, raised pustules. Papillae numerous, long, whitish to translucent-yellow, branched, becoming sparse towards mantle edges. Tentacles bright orange, eyes black set in grey sockets; siphon creamy-white, thickly spotted with minute brown dots and fringed at the end.

Distribution: Throughout Fiji. Uncommon. — East Australia, South-west and Central Pacific, Rarotonga (Cook Islands).

Discussion: Specimens with the dorsal blotch distinct are only slightly more frequent than those without the blotch.

Fiji specimens of *Cypraea hirundo* differ slightly in size and tooth number from specimens found in other Melanesian localities. Fijian shells are narrower, with less numerous teeth. The mean average size and tooth count of 30 specimens from various Fijian localities is 15 (56), 21:17.

54. *Cypraea ursellus* GMELIN, 1791

[*Bistolida ursellus amoeba* (SCHILDER & SCHILDER, 1938)]

(Plate 25, Figure 42)

Blasicrura ursellus amoeba SCHILDER & SCHILDER,
 1938

Shell: Shell pyriform, slightly inflated; anterior extremity

narrow, posterior extremity produced; each with a pair of dark terminal spots. Dorsum with three bluish-grey zones, and an anterior spot of the same colour just above the columellar margin; the zones are variable in shape, and separated by whitish spaces. The dorsum has a few small, chestnut or reddish-brown specks, which extend to both margins. Sides and base white; aperture narrow. Teeth fine, extending almost to the margins. Fossula wide and deep, crossed by ribs.

Size: 10 (62), 27:20; extremes 8, 12 mm.

Animal: Not observed.

Distribution: West to South Viti Levu. Very rare. — Queensland, South-west Pacific, Fiji Islands, Tonga Islands.

Discussion: IREDALE, 1939, STEADMAN & COTTON, 1946 and ALLAN, 1956 adopted the name *Cypraea coffea* SOWERBY, 1870 for this species.

55. *Cypraea stolidia* LINNAEUS, 1758

[*Bistolida stolidia crossei* (MARIE, 1869)]

(Plate 24, Figure 26)

Cypraea stolidia crossei MARIE, 1869
Bistolida stolidia trakau STEADMAN & COTTON, 1943
Bistolida fluctuans nandronga STEADMAN & COTTON,
 1943

Shell: Shell ovate and squarish. Dorsum grey to blue-grey, freckled with small brown specks, and with an irregular, central, red-brown blotch, only occasionally connected to the margins by lines of brown, and expanding at their lower ends to form blotches. Extremities only slightly produced, and with reddish-brown terminal spots. Some specimens have two grey transverse bands, extending from the extremities a short distance up the dorsum. Left side rounded, right side margined, flesh-coloured and sparsely spotted with pale brown. Base white, slightly flattened; aperture slightly wide. Labial teeth extend three quarters of the way to the margin, the first five or six anterior ones reaching the margin; columellar teeth extend half to three quarters of the way to the margin, first four to six anterior ones very short. Fossula wide, fairly deep, crossed by ribs which are nearly interrupted by a longitudinal ridge.

Size: 26 (54), 19:17; extremes 20, 30 mm.

Animal: Sole of foot pale orange; dorsum of foot translucent fawn. Mantle smoky-grey; papillae numerous, branched, translucent fawn. Tentacles yellow; siphon pale cream, fringed at the end.

Distribution: Throughout Fiji. Rare. — New Caledonia, Central Pacific, Marshall Islands, Line Islands.

Discussion: Fiji specimens show a greater affinity to the Queensland race, *Cypraea stolidia brevidentata* SOWERBY, 1870, than to the Melanesian *C. s. crossei*. This is especially noticeable in the blunter posterior extremity of Fiji

specimens, and the absence or only slight indication of the reddish-brown lines connecting the dorsal blotch to the margins.

56. *Cypraea chinensis* GMELIN, 1791

[*Ovatipsa chinensis chinensis* (GMELIN, 1791)]

(Plate 24, Figure 24)

Cypraea cruenta / DILLWYN, 1817

Shell: Shell ovate, callous, anterior extremity slightly constricted. Dorsum bluish-white, marked with small rhomboidal orange-brown reticulations; dorsal line faint. Sides creamy-white, calloused, with dark violet spots which extend some way over the flesh-covered base. Aperture fairly wide; labial teeth large, coarse and almost extending to the margin; columellar teeth finer and short; interstices bright orange. Fossula wide, shallow, crossed by ribs.

Size: 32 (61), 17:16; extremes 30, 34 mm.

Animal: Mantle dark red, faintly lined by ribbons of white; proboscis, tentacles and foot dark red. Papillae granular knobs, orange to cream in colour and surrounded by an asterisk of white at the base. Siphon with a weak tentacular fringe. (Hawaii, KAY & WEAVER, 1963)

Distribution: Nadroga reef (South-west Viti Levu) and Lau Islands. Very rare. — Parts of Malaysia, Philippine Islands, Japan, South-west Pacific, Gilbert and Ellice Islands, Fiji Islands, West Pacific, Jarvis-Palmyra Islands, Hawaii.

Discussion: The only two specimens collected in Fiji (there are some unverified specimens in local collections) are broader and have fewer teeth than specimens from the Philippines.

57. *Cypraea cribraria* LINNAEUS, 1758

[*Cribraria cribraria orientalis* SCHILDER & SCHILDER, 1940]

(Plate 24, Figure 28)

Cribraria cribraria northi STEADMAN & COTTON, 1943

Cribraria cribraria melwardi / SCHILDER & SCHILDER, 1938

Shell: Shell ovate to pyriform. Dorsum yellowish-brown, orange-red or dark brown, with fairly close, round white spots; dorsal line situated slightly above the labial margin, and visible as a change in pattern. Sides, extremities and base white, right side margined. Base convex, aperture wide; labial teeth almost extending to the margin, central ones slightly shorter; columellar teeth confined to aperture. Fossula concave and denticulate.

Size: 22 (57), 20:19; extremes 15, 33 mm.

Animal: Sole and dorsum of foot pale orange. Mantle bright red, with faint pustules over the entire area; mantle area in between flecked with crescent-shaped black lines. Papillae numerous, short, simple, orange tipped with white; some papillae are pure white, and have a cluster of white patches at the base. Tentacles red; siphon red and not fringed.

Distribution: Throughout Fiji. Rare. — Parts of Malaysia, Philippine Islands, Japan, South-west - Central - and West Pacific, Line Islands.

Discussion: Only the last layer of the dorsum is brown. In Australian shells it is sometimes partly or entirely absent; the white form was incorrectly named as a species (*Nivigena melwardi*) by IREDALE, 1930.

APPENDIX

Cypraea subviridis REEVE, 1835

[*Erronea subviridis subviridis* (REEVE, 1835)]

(Synonym: ? *Solvadusta subviridis kesata* STEADMAN & COTTON, 1943)

STEADMAN & COTTON (1943) report a single specimen from the Suva reef. Their description of the shell seems to fit the West Australian *Cypraea subviridis dorsalis* (SCHILDER & SCHILDER, 1938), but not the New Caledonian *C. subviridis*. No authentic specimens have been taken in Fijian waters.

Cypraea cylindrica BORN, 1778

[*Erronea cylindrica cylindrica* (BORN, 1778)]

(Synonym: *Palangerosa cylindrica lenella* IREDALE, 1939, ? *Palangerosa cylindrica wangga* STEADMAN & COTTON, 1943)

STEADMAN & COTTON report 3 specimens from the Suva reef. No authentic specimens are known from Fijian waters.

Cypraea quadrimaculata GRAY, 1824

[*Bistolida quadrimaculata garretti* (SCHILDER & SCHILDER, 1938)]

The species was mentioned from Fiji by GARRETT, 1879. Dr. Schilder (personal communication) examined several shells (types) collected by Godeffroy, and listed by Schmeltz and Weinkauff; these were destroyed in the Museum of Hamburg. As range of the Malayan species extends as far as the Solomon Islands only and as the species seems to be absent from New Caledonia, its occurrence in Fiji is highly doubtful. It appears now that *Cypraea summersi* replaces *C. quadrimaculata* in Fiji.

STEADMAN & COTTON (1943) report two specimens as taken from Suva reef.

Cypraea goodalli SOWERBY, 1832[*Bistolida goodalli fuscomaculata* (PEASE, 1865)](Synonyms: *Cypraea adelinae* ROBERTS, 1885 and *C. dautzenbergi* HIDALGO, 1907)

The species was recorded by GARRETT, 1879 from Fiji, Tonga, and Samoa; the only reliable specimens are from Samoa (*leg.* Hervier). HIDALGO (1906/07) recorded *Cypraea goodalli* from Fiji, which indication seems to be erroneous and highly suspect. The eastern species could possibly reach Fiji, but it is doubtful. No authentic specimens are known from Fijian waters.

Cypraea gaskoini REEVE, 1846[*Cribraria gaskoini fischeri* (VAYSSIÈRE, 1910)]

The late Mr. Ditlev Thaanum (Hawaii) is reported to have found this species in Fiji (C. M. Burgess, personal communication). No details are available, but authentic specimens from Fijian waters are not known.

Records of other families of Cypraeacea from the Fiji Islands are not complete at the present time. A provisional list is given, enumerating species so far recorded from Fiji:

AMPHIPERATIDAE

Amphiperatinae

1. *Amphiperas* (*Amphiperas*) *ovum* (LINNAEUS, 1758)
Syn.: *Ovula oviformis* LAMARCK, 1810
2. *Amphiperas* (*Parlicium*) *costellatum* (LAMARCK, 1810)
Syn.: *Ovulum angulosum* LAMARCK, 1822, *O. tortile* REEVE, 1865
3. *Pseudosimnia* (*Diminovula*) *margarita* (SOWERBY, 1828)
Syn.: *Ovula umbilicata* SOWERBY, 1849
4. *Pseudosimnia* (*Diminovula*) *punctata* (DUCLOS, 1831) — First Fijian record.
5. *Primovula* (*Prosimnia*) *coarctata* (ADAMS & REEVE, 1848)
Syn.: *Ovula semperi* WEINKAUFF, 1881
6. *Calpurnus* (*Procalpurnus*) *lacteus semistriatus* (PEASE, 1862)
7. *Calpurnus* (*Calpurnus*) *verrucosus* (LINNAEUS, 1758)
8. *Prionovula fruticum* (REEVE, 1865) — First Fijian record.

PEDICULARIIDAE

Volvinae

9. *Volva volva* (LINNAEUS, 1758) — First Fijian record.

Pediculariinae

10. *Pedicularia* (*Pediculariona*) *pacifica pacifica* (PEASE, 1865) (or *P. pacifica stylasteris* HEDLEY, 1903 - ?)

ERATOIDAE

Eratoinae

11. *Proterato* (*Eratoena*) *corrugata* (HINDS, 1844)
12. *Proterato* (*Eratoena*) *sulcifera schmeltziana* (CROSSE, 1867)

Triviinae

13. *Trivirostra hordacea hordacea* (KIENER, 1843)
Syn.: ? *Trivia* (*Trivia*) *koroensis* LADD, 1934
14. *Trivirostra edgari edgari* (SHAW, 1909)
Syn.: *Cypraea grando* GASKOIN, 1848
15. *Trivirostra pellucidula* (GASKOIN, 1846) — First Fijian record
16. *Trivirostra exigua* (GRAY, 1831)
Syn.: *Trivia tremeza* DUCLOS, 1833
17. *Trivirostra oryza* (LAMARCK, 1810)
18. *Dolichupis producta* (GASKOIN, 1836) — First Fijian record

CONCLUSIONS

A total of 57 species of *Cypraea* from Fiji have been recorded in this paper. STEADMAN & COTTON, 1943 record three additional species from the same area. The following species were not listed by the authors: *Cypraea childreni*, *C. fimbriata*, *C. maculifera*, *C. mariae*, *C. summersi*, *C. ursellus*, *C. walkeri* and *C. ziczac*.

The shell listed by STEADMAN & COTTON (*l. c.*) as *Cypraea microdon granum* (SCHILDER & SCHILDER, 1938) was an eroded beach specimen, measuring 9 mm in length, and having 15 labial and columellar teeth. This tooth count does not agree with that of *C. microdon*, but appears to agree with that of *C. fimbriata*.

The following four species have been established from Fiji for the first time: *Cypraea maculifera*, *C. summersi*, *C. walkeri* and *C. ziczac*. The recent collection of *C. childreni*, *C. fimbriata*, *C. mariae* and *C. ursellus* confirms GARRETT's (1879) record.

A solitary specimen of *Cypraea ovum* GMELIN, 1791, was discovered in a local collection. The collector stated that the shell was collected on a reef in Southern Viti Levu and was said to be "common" there. As past and present collecting activity on this reef, as well as in other parts of Viti Levu failed to disclose any further specimens, the shell is regarded as a highly unreliable record. It could have reached Fiji through exchange with other collectors.

LITERATURE CITED

ALLAN, JOYCE

1956. Cowry shells of world seas. Georgian House, Melbourne. i-x; pp. 1-170; pls. 1-15.

BURGESS, C. M.

1962. *Cypraea cicercula* LINNAEUS, in Hawaii. Hawaiian Shell News 10 (12): 2

DODGE, HENRY

1953. A historical review of the mollusks of Linnaeus. Pt. 2, the class Cephalopoda and the genera *Conus* and *Cypraea* (Gastropoda). Bull. Amer. Mus. Nat. Hist. 103 (1): 1-134

GARRETT, ANDREW

1879. Annotated catalogue of the species of Cypraeidae collected in the S. Sea Islands. Journ. Conch. 2: 105-128

HIDALGO, J. G.

1906. Monografía de las especies vivientes del género *Cypraea*. Mem. Acad. Cienc. Madrid, 25: 1-240; (1907) 241-588; I to XV.

IREDALE, TOM

1930. Queensland molluscan notes, no. 2. Mem. Qld. Mus., Brisbane, 10 (1): 73-88; plt. 9
 1931. Australian molluscan notes, no. 1. Rec. Austral. Mus., 18 (4): 201-235; pls. 22-25
 1935. Australian cowries, pt. I. Austral. Zool., 8 (2): 96 to 135; pls. 8-9
 1939. Australian cowries: Part II. Austr. Zoolog. 9 (3): 297-322; 3 pls.

KAY, E. ALISON

1960. Generic revision of the Cypraeinae. Proc. Malac. Soc. London 33 (6): 278-287; 8 figs.
 1961. Anatomical characters which distinguish two species of *Cypraea*. Proc. Malacol. Soc. London, 34: 199-202

KAY, E. ALISON & CLIFTON S. WEAVER

1963. Hawaiian marine mollusks — The genus *Cypraea*. Hawaiian Shell News 11 (7), insert 2: 21-22

LADD, S. HARRY

1934. Geology of Viti Levu, Fiji. Bernice P. Bishop Mus. Bull. 119: 1-263; pls. 1-44

LADD, S. HARRY & J. E. HOFFMEISTER

1945. Geology of Lau, Fiji. Bernice P. Bishop Mus. Bull. 181: 362; plt. 51

OSTERGAARD, JENS MATHIAS

1935. Recent and fossil marine mollusca of Tongatabu. Bernice P. Bishop Mus. Bull. 131: 1-59; plt. 1

SCHILDER, FRANZ ALFRED

1939. Länge, Breite und Zahnzahl der Cypraeidae. Arch. Moll. 71 (2-3): 75-82; 2 text figs.

SCHILDER, FRANZ ALFRED

1941. Verwandtschaft und Verbreitung der Cypraeacea. Arch. Mollusk. 73 (2-3): 57-120; 2 pls.
 1957. Biometrische Studien an Porzellanschnecken. Wissenschaft. Zeitschr. Univ. Halle, Math. Nat. 6 (1): 97-116
 1958. Über drei seltene Cypraeacea. Arch. Moll. 87 (1-3): 81-87; 2 text figs.
 1958 a. Die Typen der von mir benannten Cypraeacea. Arch. Moll. 87 (4-6): 157-179
 1958 b. Neue Gesetzmäßigkeiten bei der Rassenbildung der Porzellanschnecken. Verhandl. Deutsch. Zool. Gesellschaft., Frankfurt/Main; pp. 404-406
 1961. Nachträge zum Katalog der Cypraeacea von 1941. Arch. Moll. 90 (4-6): 145-153
 1963. The overlapping distribution of *Erosaria eburnea*. The Cowry 1 (5): 69-70

SCHILDER, FRANZ ALFRED, & MARIA SCHILDER

1937. Revision of the genus *Monetaria* (Cypraeidae). Proc. Zool. Soc. London, 1936 (4): 1113-1135; pls. 1-2
 1938-1939. Prodrôme of a monograph on living Cypraeidae. Proc. Malacol. Soc. London, 23 (3-4): 119-231.
 1940. Die Verbreitung und Häufigkeit der rezenten Cypraeidae. Arch. Moll. 72 (2-3): 33-56
 1952. Ph. Dautzenberg's collection of Cypraeidae. Mém. Inst. Roy. Sci. Nat. Belgique (2) 45: 1-243; 4 pls.

STEADMAN, W. R., & BERNARD C. COTTON

1943. The cowries (Cypraeidae) of Fiji. Rec. South Austral. Mus. 7 (4): 319-336; 1 text fig.
 1946. A key to the classification of the cowries (Cypraeidae). Records South Austr. Mus. 8: 503-530; 6 pls.

GRIFFITHS, R. JOHN

1961. Iredale's Cypraeidae names. The Cowry 1 (2): 21-24.

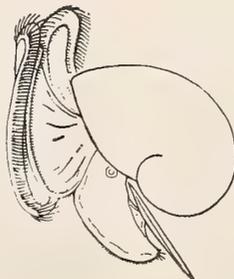
ADDITIONAL REFERENCES

JEWELL, G. HAROLD

1962. Marine mollusks from the Line Islands. Hawaiian Shell News 11 (2): 4

SCHILDER, FRANZ ALFRED

1939. Die Genera der Cypraeacea. Arch. Molluskenk. 71 (5-6): 165-201; 2 pls.



Studies on the *Mytilus edulis* Community
in Alamitos Bay, California:
II. Population Variations and Discussion
of the Associated Organisms

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(3 Text figures)

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INTRODUCTION

IN A PREVIOUS paper the author (1964) described the development and temporary destruction of a *Mytilus edulis* LINNAEUS, 1758, community on boat floats in the newly developed marina in Alamitos Bay. The primary consideration was to determine whether or not succession occurred on the floats. The other principal organisms were discussed in connection with the development of the community. These included the green alga *Ulva lobata* (KÜTZING, 1849) SETCHELL & GARDNER, the polychaete *Hydroides norvegica* (GUNNERUS, 1768), the ectoproct *Bugula neritina* (LINNAEUS, 1758), and the tunicates *Ciona intestinalis* (LINNAEUS, 1767) and *Styela plicata* (LESUEUR, 1823). The rôle of *M. edulis* and other large species in the fouling community has received a considerable amount of attention (ANONYMOUS, U.S. Navy Report, 1952), but, with one exception (NEWCOMBE, 1935) known to the author, the other members of the association have not been studied. NEWCOMBE (*l. c.*) described the general seasonal aspects of the intertidal *M. edulis* community in New Brunswick, Canada. The principal and associated species were listed according to their relationship in the community.

All organisms were identified, in so far as was possible, and counted in connection with the development of the *Mytilus edulis* community in Alamitos Bay. In the analyses of these data variations were noted in the occurrence of the associated organisms. The discussion of these data constitute the basis of this report. Since the seasonal occurrence of the principal organisms was discussed previously, they will be mentioned only briefly herein.

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MATERIAL AND METHODS

The methods of collection and the description of the boat floats were given in the previous paper. The collections were sorted and identified. Representative specimens of some of the groups were sent to specialists (named above) for identification; these specimens served as a reference collection for subsequent identification by the author.

DATA

Number of Species: The relationship between the number of species and water temperature has been summarized in Figure 1. A definite seasonal occurrence is noted in the number of species in the *Mytilus edulis* community. Peaks in the number of species were observed during August and September, 1960 to 1962, when the water temperature was highest. Conversely, the minimal periods in the number of species was during the winter months when the water temperature was lowest. The number of species collected averaged 11 when the water temperature was 13° C, 23 species at 16 to 18° C, and 28 species at 20 to 21° C.

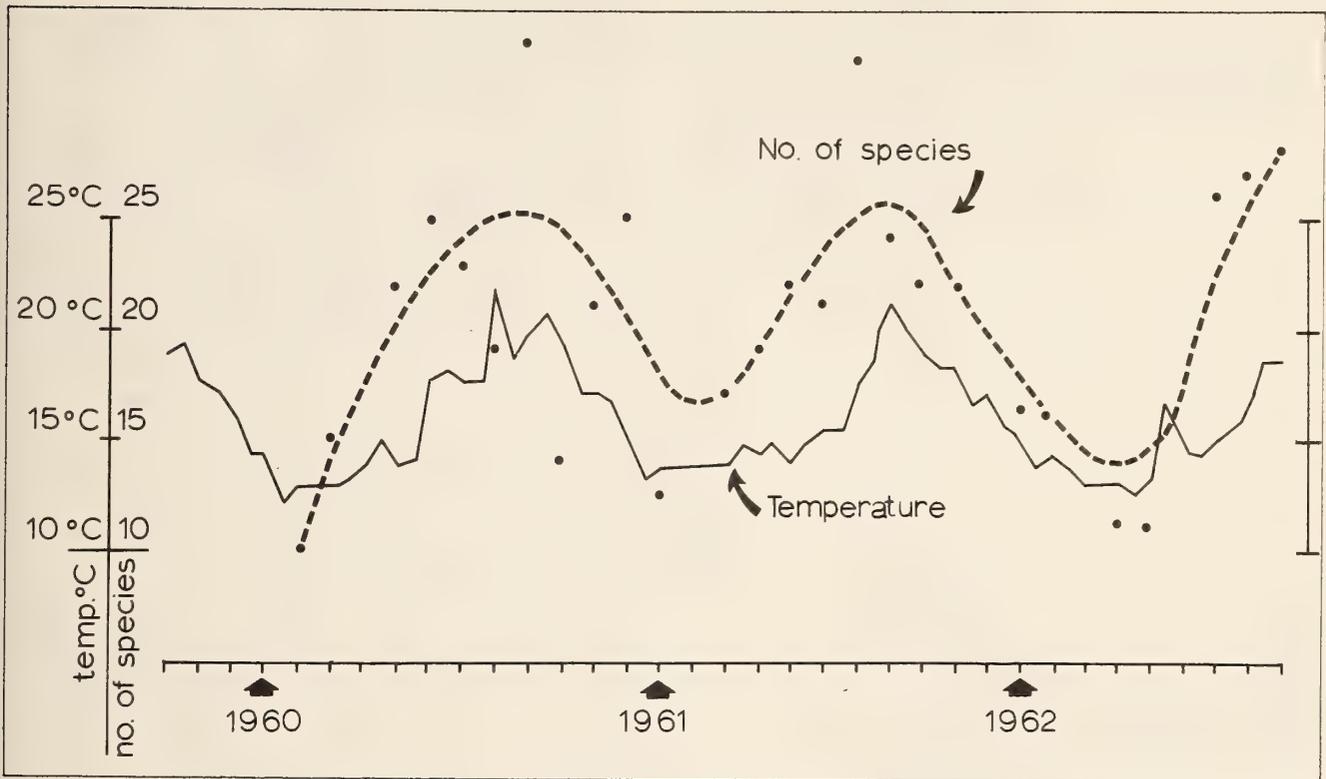


Figure 1: Seasonal Changes in the Number of Associated Species in the *Mytilus edulis* Community.

The graph shows the relationship between the number of associated species of the *Mytilus edulis* community and water temperature in Alamitos Bay Marina.

The same seasonal relationship exists as above if we consider the relationship of the biomass of the associated organisms, excluding the weight of *Mytilus edulis*. The weight of the associated organisms averaged only 50 grams during the months of January through March, but reached a maximum of 260 grams during the months of July through September each year. The biomass of the *M. edulis* fluctuated little after establishment of the community.

Algae. Five species of algae were taken from the floats during the 2.7 years of collecting. A surge of algal growth was noted in March with a peak in biomass in June each year. *Ulva lobata* was the dominant alga and second to *M. edulis* in biomass. The spring and fall peaks in occurrence of *U. lobata* were discussed previously. The other species of algae collected included the brown algae *Ectocarpus confervoides* forma *parvus* (SAUNDERS, 1898) SETCHELL & GARDNER and *Leathesia difformis* (LINNAEUS, 1755) ARESCHOUG and the reds *Antithamnion ? secundatum* GARDNER, 1927, and *Polysiphonia pacifica* HOLLENBERG, 1942. *Ectocarpus* cf. *parvus* was present, with one ex-

ception, only during the months of January through April, *Polysiphonia pacifica* was present during March through September.

Polychaetes. A total of 22 different species of polychaetes was collected during the 2.7 years of study. As a group they showed a definite seasonal occurrence with a peak in summer and a low during the winter months. Only four species were collected frequently; the occurrence and number of specimens taken have been summarized in Figure 2. *Halosydna johnsoni* (DARBOUX, 1899) is the only free-moving species of the four. It appeared in the *Mytilus edulis* community during the early spring months in each of the three years and was rarely taken during the winter months. The relationship of *Hydroides norvegica* to water temperature and seasonal occurrence has been discussed previously (REISH, 1961). *Platynereis bicanaliculata* (BAIRD, 1863) constructed mucoid tubes especially on the thalli of *Ulva lobata*. The occurrence of *P. bicanaliculata* was sporadic, but the majority of the specimens was taken during the spring months. *Polydora ligni* WEBSTER, 1879,

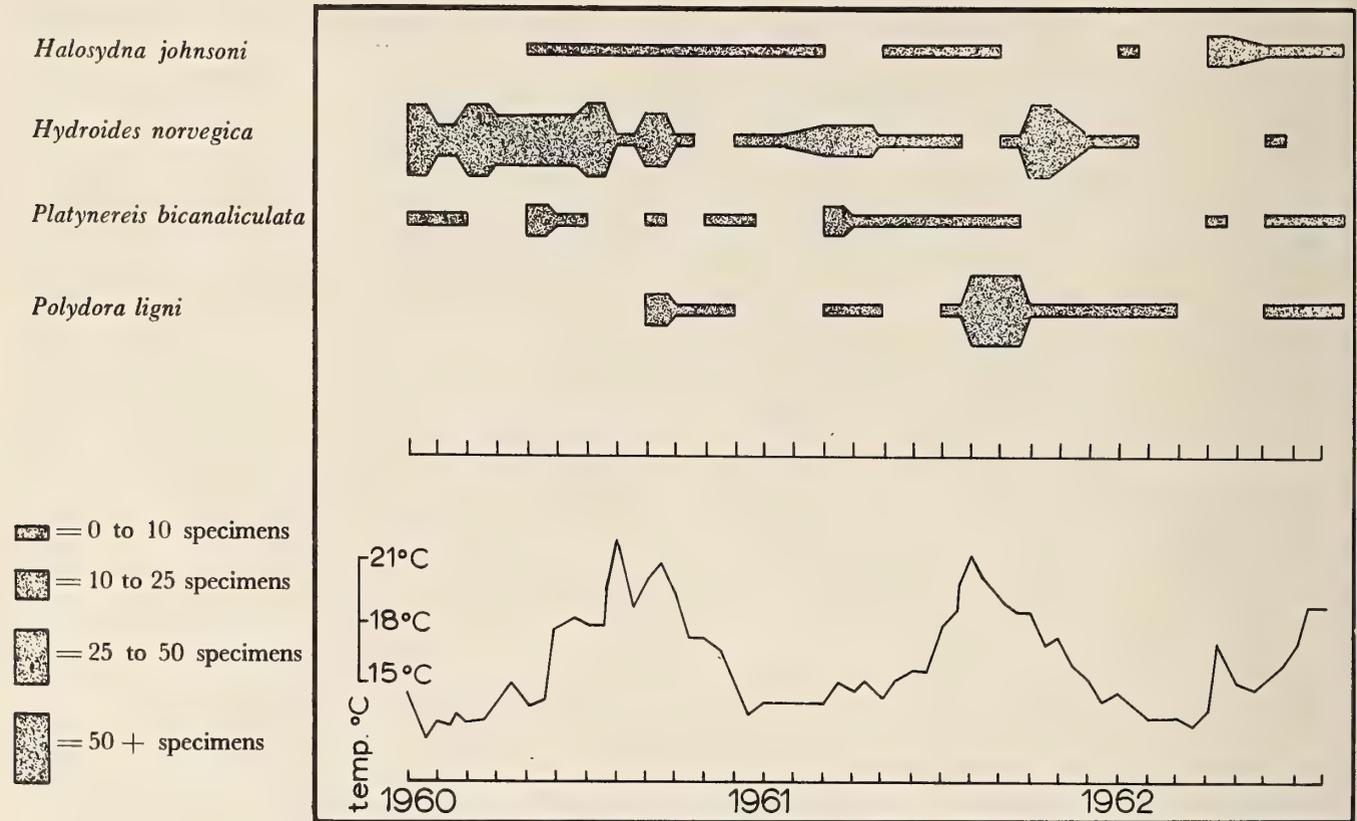


Figure 2: Seasonal Changes in the Polychaete Population associated with the *Mytilus edulis* Community. Diagrammatic representation of the relationship between the number of specimens of the principal species of polychaetous annelids and the water temperature.

built mud tubes on the thalli of *U. lobata* and among *M. edulis*. The majority of the specimens of *Polydora ligni* was taken during the summer months when the water temperature was highest. The other specimens of polychaetes collected included: *Armandia bioculata* HARTMAN, 1938, *Capitella capitata* (FABRICIUS, 1780), *Dorvillea articulata* (HARTMAN, 1938), *Eupomatus* sp., *Neanthes caudata* (DELLE CHIAJE, 1828), *Naineris dendritica* (KINBERG, 1867), *Nereis grubei* (KINBERG, 1866), *N. latescens* CHAMBERLIN, 1919, *Ophiodromus pugettensis* (JOHNSON, 1901), *Paleonotus bellis* (JOHNSON, 1897), *Pista alata* MOORE, 1909, *Polyopthalmus pictus* (DUJARDIN, 1839), sabellid, *Spirabranchnus spinosus* MOORE, 1923, spirorbinid, terebellid, and *Typosyllis* sp.

Amphipoda. Amphipods constituted the dominant group of animals in terms of numbers of specimens (Figure 3). Peaks occurred each summer with 1690, 17450, and 5121 specimens in 1960, 1961, and 1962, respectively. This is in striking contrast to minima of 3, 6,

and 71 specimens during the winter months for each of these three years. Nine species of amphipods were taken from the floats during the period of study; the seasonal occurrence and abundance of the five dominant ones are summarized in Figure 3. The correlation between the warmer water temperature and the abundance of these amphipods, and especially *Elasmopus rapax* COSTA, 1853, can be seen in Figure 3. *Corophium acherusicum* (COSTA, 1857) and *Jassa falcata* (MONTAGU, 1808) constructed sticky parchment tubes to which mud particles adhere. The tubes occurred on the thalli of *Ulva lobata* and between and on specimens of *Mytilus edulis*. *Ampithoe plumulosa* SHOEMAKER, 1938, *Caprella californica* STIMPSON 1857, and *E. rapax* moved freely about the community. The other species of amphipods taken were *Caprella equilibra* SAY, 1818, *Erichthonius brasiliensis* (DANA, 1853), *Leucothoides pacifica* BARNARD, 1955, and *Pontogeneia minuta* CHEVREUX, 1908. BARNARD (1958) found heavy settlement of amphipods on 16-week test blocks collected August 17, 1951, in Los Angeles

Harbor. Species in common with the present study included *C. acherusicum*, *J. falcata*, and *E. brasiliensis*.

Mollusca. Eleven different species of mollusks were present on the floats including species of gastropods, pelecypods, and a chiton. *Mytilus edulis* was the dominant member of the community; its abundance has been discussed earlier. As a group, but excluding *M. edulis*, the seasonal occurrence of the mollusks is striking. They are present abundantly during the spring and summer months but nearly absent during the fall and winter months. Such a cycle is noted with the pelecypod *Hiatella arctica* (LINNAEUS, 1771), and the gastropods *Acmaea limatula* CARPENTER, 1864, and *Crepidula onyx* SOWERBY, 1825. The other mollusks occasionally encountered included the

pelecypods *Ostrea lurida* CARPENTER, 1863, and *Leptopecten latiauratus* (CONRAD, 1837); the gastropods *Acmaea scabra* (GOULD, 1846), *Littorina planaxis* PHILIPPI, 1847, *L. scutulata* GOULD, 1849, and unidentified nudibranchs; and the chiton *Mopalia muscosa* (GOULD, 1846).

Ectoprocta. Six species of ectoprocts were present during the study. A slight increase of species was noted during the course of the year with a peak occurring during the summer months; this was followed by a sharp decrease in the fall months. This was especially true for the most frequently encountered species, *Schizoporella unicornis* (JOHNSTON, 1847). Other species included *Bugula californica* ROBERTSON, 1905, *B. neritina* (LIN-

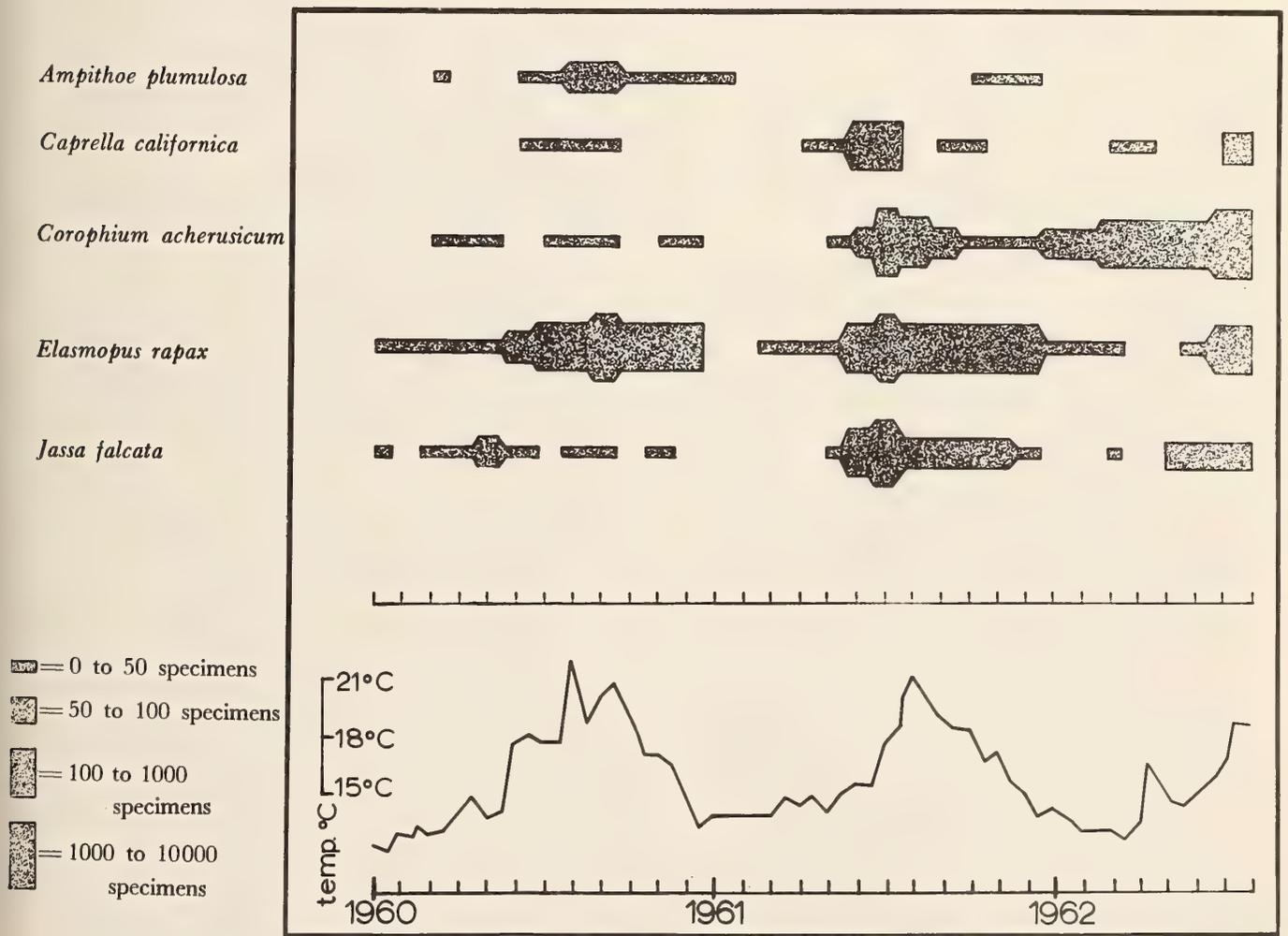


Figure 3: Seasonal Changes in the Amphipod Population Associated with the *Mytilus edulis* Community. Diagrammatic representation of the relationship between the number of specimens of the principal species of amphipods and the water temperature.

NAEUS, 1758), *Cryptosula pallasiana* (MOLL, 1803), *Holoporella brunnea* (HINCKS, 1884), and *Scrupocellaria bertholetti* (AUDOUIN, 1826).

Tunicata. Six species of tunicates exhibited definite seasonal differences with a peak in summer and a low in fall and winter. *Ciona intestinalis* was the most abundant one taken. While individual specimens can be seen generally more frequently during the summer, the larval settlement is earlier in the year when the water temperatures are lower. *Amaroucium californicum* RITTER & FORSYTH, 1917, *Botryllus* sp., *Diplosoma pizoni* RITTER & FORSYTH, 1917, and *Styela plicata* were limited to the months of May through September with only a few exceptions (13 per cent). *Styela montereyensis* (DALL, 1872) was present throughout the year.

The remaining species of animals, none present frequently and some only once, included two unidentified sponges, sea anemones, polyclad flatworms, nemertean, barnacles (*Balanus amphitrite* DARWIN, 1854, *B. crenatus* BRUGUIÈRE, 1789, and *B. glandula* DARWIN, 1854), an isopod, a shrimp, the crab *Hemigrapsus oregonensis* (DANA, 1851), and one juvenile sea urchin, *Strongylocentrotus purpuratus* STIMPSON).

DISCUSSION

The relationship between the number of species and the water temperature is clearly evident in Figure 1. The greater number of associated species was found during the summer months and the lesser number was collected during the winter months for three successive years. While comparative data are not available, it has been demonstrated throughout the world that the heavier attachments of fouling organisms take place in the warmer water (summarized in ANONYMOUS, U. S. Navy report, 1952). Presumably, the smaller associated animals would be more abundant at this time.

The reproduction, development, life history, and length of life are unknown for the majority of the organisms encountered. *Mytilus edulis* is undoubtedly the longest living member of the community. Some species of animals, for example *Ciona intestinalis*, have one life cycle a year in which the larvae settle in spring, grow in summer, and die in fall. Other organisms exhibiting this type of cycle probably include most of the other species of tunicates and the ectoprocts. Other species, and this is especially the case with amphipods, have many cycles during the spring and summer months. In this manner large populations are built up and undoubtedly the same female broods several successive generations. The population diminishes with the drop in water temperature in the fall. Undoubtedly a few larvae of a species, which are typical inhabitants of some other ecological niche,

may settle in the *Mytilus edulis* community. This is evident with the polychaetes; the majority of the polychaetes collected is more commonly encountered in the benthos.

The breeding period and subsequent settling period has been divided into four categories depending upon the seasonal aspects of attachment (ANONYMOUS, U. S. Navy report, 1952). These categories may be modified slightly and the more frequently encountered species grouped according to: (1) occurrence throughout the year without fluctuations: *Holoporella brunnea*, *Scrupocellaria bertholetti*, and *Styela montereyensis*; (2) occurrence throughout the year but with a definite spring or summer peak: *Halosydna johnsoni*, *Hydroides norvegica*, *Platynereis bicanaliculata*, *Polydora ligni*, *Elasmopus rapax*, *Corophium acherusicum*, *Schizoporella unicornis*, and *Styela plicata*; (3) occurrence limited to a definite period of the year which is usually either spring or summer: *Polysiphonia pacifica*, *Ectocarpus* cf. *parvus*, *Amphithoe plumulosa*, *Jassa falcata*, *Pontogenia minuta*, *Hiatella arctica*, *Acmaea limatula*, *Crepidula onyx*, *Bugula californica*, *B. neritina*, *Cryptosula pallasiana*, *Amaroucium californicum*, *Ciona intestinalis*, *Botryllus* sp., and *Diplosoma pizoni*; and (4) peaks occurring in the spring and fall: *Ulva lobata* and *Polyophthalmus pictus*.

SUMMARY

1. A seasonal quantitative study was made for 2.7 years of the associated species of the *Mytilus edulis* community of the boat floats in Alamitos Bay Marina, California.
2. The principal associated groups include species of polychaetes, amphipods, mollusks, ectoprocts, and tunicates.
3. A direct relationship between the number of species and water temperature was observed; the warmer the water, the greater the diversity of the organisms.
4. The occurrence of the principal species was arranged according to the following categories: (1) occurrence throughout the year without fluctuations (3 species) (2) occurrence throughout the year but with a definite spring or summer peak (8 species), (3) occurrence limited to a definite period which was usually spring or summer (15 species), and (4) peaks occurring in the spring and fall (2 species).

LITERATURE CITED

- ANONYMOUS
1952. Marine fouling and its prevention. U. S. Naval Inst. Annapolis; 388 pp.
- BARNARD, J. LAURENS
1958. Amphipod crustaceans as fouling organisms in Los

- Angeles - Long Beach harbors, with reference to the influence of sea water turbidity. Calif. Fish and Game 44: 161 - 170.
- NEWCOMBE, CURTIS L.
1935. A study of the community relationships of the sea mussel, *Mytilus edulis* L. Ecology 16: 234 - 243
- REISH, DONALD J.
1961. The relationship of temperature and dissolved oxygen

- to the seasonal settlement of the polychaetous annelid *Hydroides norvegica* (GUNNERUS). Bull. So. Calif. Acad. Sci. 60: 1 - 11
1964. Studies on the *Mytilus edulis* community in Alamitos Bay, California: I. Development and destruction of the community. The Veliger 6 (3): 124-131 (1 Jan. 1964)

A Note on the Synonymy of *Tellina subtrigona* SOWERBY, 1866 (Mollusca: Bivalvia)

BY

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(Plate 27, Figures 1, 1 a)

IN 1866, SOWERBY first described *Tellina subtrigona* in volume 17 of REEVE's *Conchologia Iconica*; the type figure is figure 9, plate 3 of *Tellina*; no locality datum was given. Later, in 1868, in the same monograph, he again described a species with the name *Tellina subtrigona* (plate 44, figure 259). After he discovered his error, he corrected the latter to *Tellina subangulata* in the index; *T. subangulata* is synonymous with the Indo-Pacific species, *T. juvenilis* HANLEY.

Recently, KEEN (1958) has suggested the probable identity of *Tellina erythronotus* PILSBRY & LOWE with *T. subtrigona* SOWERBY, 1866. HERTLEIN & STRONG (1949) in their remarks under *T. erythronotus*, did not mention *T. subtrigona*, but have listed the names of a number of species which are synonymous with or closely related to *T. subtrigona*. In 1852, C. B. ADAMS described *T. puella* from the Pacific coast of Panama; this name was unfortunately preoccupied by *T. puella* HANLEY 1846. SALISBURY (1934) recognized *T. puella* ADAMS as a junior homonym and renamed it *T. puellula*. TURNER (1956) selected and figured the lectotype of *T. puella* ADAMS. KEEN (1958) considered *T. puellula* as valid but mentioned that it was very close to *T. erythronotus*. OLSSON (1961) recognized that *T. puella* ADAMS and its substitute name, *T. puellula* SALISBURY, were synonymous with *T. erythronotus*.

Presently, we are able to include *Tellina subtrigona* SOWERBY, 1866 in this synonymy, and this name will replace *T. erythronotus*. An examination of the type material has indicated the identity of the following: *Tellina*

subtrigona SOWERBY, 1866; *T. puella* C. B. ADAMS; *T. puellula* SALISBURY; and *T. erythronotus* PILSBRY & LOWE. Plate 27, figures 1 and 1 a illustrate the holotype of *T. subtrigona* SOWERBY, 1866 and the following is the synonymy of the species:

Tellina subtrigona SOWERBY, 1866 [in] REEVE, *Conchologia Iconica*, vol. 17, *Tellina*, pl. 3, fig. 9 (type locality unknown; holotype, BMNH, no catalog number; 22 mm in length and 13 mm in height), *non* SOWERBY, 1868.

Tellina puella C. B. ADAMS, 1852, *Ann. and Lyceum Nat. Hist. New York*, 5: 507 and 546 (reprint pagination, 283 and 322); TURNER, 1956, *Occ. Pap. Moll., Harvard University*, 2 (20): 77, pl. 19, figs. 13, 14 (type locality, Panama [Pacific coast]; lectotype, selected by TURNER, 1956, MCZ 186305; 22 mm in length, 13 mm in height and 7 mm in diameter), *non* HANLEY, 1846.

Tellina erythronotus PILSBRY & LOWE, 1932, *Proc. Acad. Nat. Sci. Philadelphia*, 84: 94, pl. 12, fig. 7 (type locality, Panama, east of the city; holotype, ANSP 115010; 19.5 mm in length, 10.7 mm in height, and 5 mm in diameter).

Tellina puellula SALISBURY, 1934, *Proc. Mal. Soc. London*, 21 (2): 86 (new name for *T. puella* C. B. ADAMS, 1852, *non* HANLEY, 1846).

LITERATURE CITED

- ADAMS, C. B.
1852. Catalogue of shells collected at Panama, with notes on synonymy, station, and habitat. *Ann. and Lyceum Nat. Hist. New York* 5: 507 and 546.

HERTLEIN, LEO G. & A. M. STRONG

1949. Eastern Pacific expeditions of the New York Zoological Society. Mollusks from the west coast of Mexico and Central America. Part 7. *Zoologica* 34 (2): 63 - 97; 1 pl.

KEEN, A. MYRA

1958. Sea shells of tropical west America; marine mollusks from Lower California to Colombia. Stanford Univ. Press, xi + 624 pp.; illus. Stanford, Calif.

OLSSON, AXEL A.

1961. Mollusks of the tropical Eastern Pacific. Panamic-Pacific Pelecypoda. Paleont. Res. Inst., Ithaca, N. Y., 574 pp.

PILSBRY, HENRY AUGUSTUS & HERBERT N. LOWE

1932. West Mexican and Central American mollusks collected by H. N. Lowe 1929-31. *Proc. Acad. Nat. Sci. Philadelphia* 84: 33 - 144; 6 figs.; pls. 1 - 17; 2 photographs

SALISBURY, A. E.

1934. On the nomenclature of Tellinidae, with descriptions of new species and some remarks on distribution. *Proc. Mal. Soc. London* 21 (2): 74 - 91; pls. 9 - 14.

TURNER, RUTH D.

1956. The eastern Pacific marine mollusks described by C. B. Adams. *Occ. Pap. Moll., Harvard Univ.*, 2 (20): 21 to 135; pls. 5 - 11.

The Status of *Scrobicularia viridotincta* CARPENTER

(Mollusca: Bivalvia)

BY

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(Plate 27, Figures 2, 2 a)

IN 1856, P. P. CARPENTER described a new species of bivalved mollusk as '*Scrobicularia virido-tincta*.' The type specimen was collected by Mr. T. Bridges in the Bay of Panama and was later deposited in the collection of Mr. Hugh Cuming. Presently the holotype is in the type collection of the British Museum (Natural History).

Notwithstanding the incomplete description and the lack, until recently (see PALMER, 1963), of an illustration of the holotype, there have been virtually no questions concerning the identity of *Scrobicularia viridotincta*. DALL (1900) created a new section, *Scrobiculina*, of the subgenus *Arcopagia* with *Scrobicularia viridotincta* CARPENTER as type, and nearly all modern authors have followed this scheme in systematic treatments of the TELLINIDAE. DALL considered that *Tellina* (*Peronaoderma*) *ochracea* CARPENTER, 1864 also belonged to the section *Scrobiculina* and, further, that the species *T. ochracea* and *S. viridotincta* were distinguished from each other by the umbo, the former species being ochraceous or somewhat yellow-orange while the latter was greenish. However, an examination of the type of *Scrobicularia viridotincta* CARPENTER shows this species to possess macomid characteristics, and the following figures, description and remarks attempt to clarify the definition of *S. viridotincta* CARPENTER and *Scrobiculina* DALL.

DESCRIPTION OF

Scrobicularia viridotincta CARPENTER

Original description: ?*S. testa*. ?*S. productae simili; sed latiore, ovali tenuiore, magis planata, antice haud producta, alba; umbonibus viriditinctis.*

Redescription of holotype (Plate 27, figures 2, 2 a): Shell 51.8 mm in length and 35.1 mm in height; diameter, 16.0 mm; distance from anterior margin to umbonal axis, 28.5 mm, distance from anterior margin to anteriormost extension of the pallial sinus, 12.8 mm. Shell white and ovate, slightly inequivalve with the right valve larger and of greater convexity, slightly inequilateral and with a slight posterior flexure to the right, inflated anteriorly and somewhat compressed posteriorly. Umbones just behind the middle, blunt, with conspicuous dark grey-green coloration, slightly elevated and somewhat inflated, with a deep umbonal cavity beneath. Anterior margin rather broadly and smoothly rounded; ventral margin slightly arcuate and convex; posterior margin but slightly produced, rather narrowly rounded. Sculpture consisting of closely spaced weak concentric lirae; no true radial sculpture evident. Right valve with a posterior ridge, left valve with a corresponding furrow. Ligament light brown in color, sunken and subtended by a strong calcareous element or resilium, shorter than the ligament

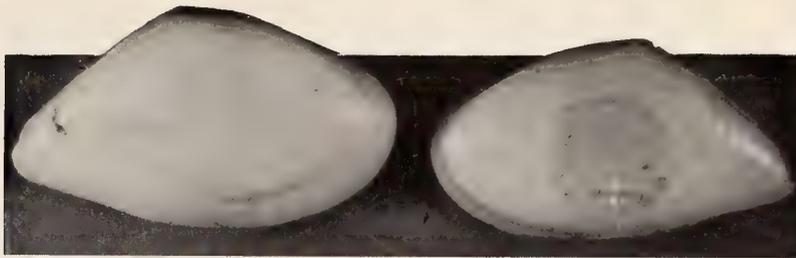


Figure 1

Figure 1 a

Figure 1, 1a: The holotype of *Tellina subtrigona* SOWERBY, 1866 (about x 2.3).

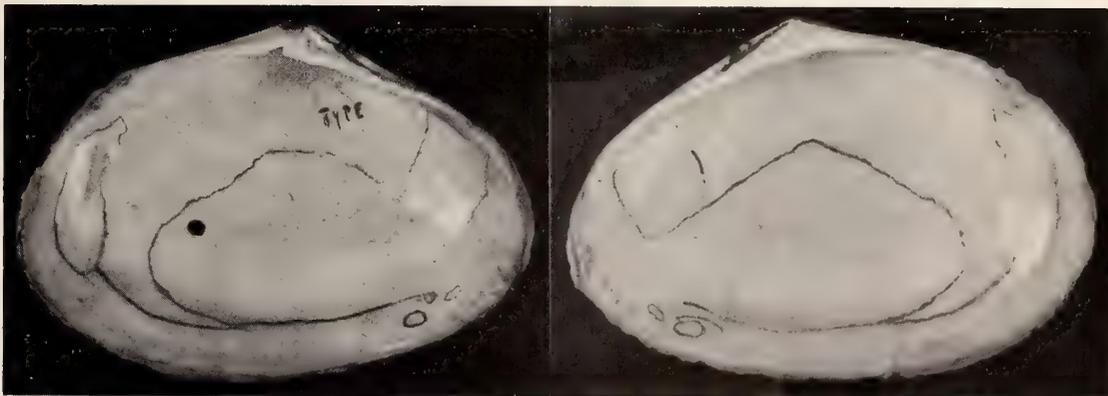


Figure 2

Figure 2 a

Figures 2 and 2 a: The holotype of *Scrobicularia viridotincta* CARPENTER in the type collection of the British Museum (Natural History); Reg. No. 19621115. Figure 2: Right valve internal; Figure 2 a: Left valve internal (both about x 1.4).



proper. Cardinal complex in the left valve consists of a short narrowed anterior bifid tooth with more or less equal lobes and of an elongate posterior laminate tooth which is obsolete and adpressed to the calcareous element of the ligament; no lateral teeth present. Cardinal complex in the right valve consists of a short posterior bifid tooth with subequal lobes and of an anterior laminate tooth; the single anterior laminate cardinal tooth is broken as is part of the hinge plate which supports it; no lateral teeth present. Anterior adductor muscle scar elongate and narrow, weakly lunate; posterior adductor scar transversely quadrate, nearly rhomboid. Pallial sinus rising behind to an apex beneath the umbo but not higher than the dorsalmost extension of the posterior adductor muscle scar; the sinus descending in an arcuation toward the pallial line, paralleling it for a distance and then becoming confluent with it well in front of the umbonal axis, about the beginning of the hinge plate. Cruciform muscle scars unequal, the anterior scar subquadrate and the posterior one more nearly rounded; the terminus of the pallial line arcuate and near to the posterior cruciform muscle scar.

Remarks: The most important characteristic to be considered in the holotype is the complete absence of lateral teeth. Although a portion of the shell is broken in the vicinity of the anterior lateral hinge plate in the right valve, enough structure is evident to indicate that no lateral tooth was present. It is only possible for the broken anterior portion to have contained the most distal part of the anterior laminate cardinal tooth. The lack of any lateral teeth, the thickness, coloration and dullness of the shell, and the deep placement of the ligament indicate that this species is a member of the genus *Psammotreta* of the subfamily Macominae. By no stretch of definitions could it be considered a *Tellina* or a *Semele*.

OLSSON (1961) elevated *Psammotreta* to the generic level, while HERTLEIN & STRONG (1949) considered it a subgenus. The latter authors listed two species in this taxon, *Macoma (Psammotreta) aurora* (HANLEY, 1844) and *M. (P.) pacis* (PILSBRY & LOWE, 1932). OLSSON listed *P. aurora* (HANLEY, 1844), *P. dombei* (HANLEY, 1844), *P. grandis* (HANLEY, 1844), *P. asthenodon* (PILSBRY & LOWE, 1932), and *P. gubernacula* [sic] (HANLEY, 1844), under which *M. (P.) pacis* (PILSBRY & LOWE) is treated as a synonym. KEEN (1962) maintained *Psammotreta* DALL at the generic level and indicated that *Psammotreta (P.) pacis* (PILSBRY & LOWE) is not synonymous with *P. (P.) gubernaculum* (HANLEY, 1844), an interpretation which is followed here. Of all the species in *Psammotreta*, it appears that *Scrobicularia viridotincta* CARPENTER is a senior synonym of *Psammotreta pacis* (PILSBRY & LOWE).

The discovery of the correct identity of *viridotincta* of CARPENTER upsets the traditional usage of *Scrobiculina*. DALL (1900) established *Scrobiculina* as well as *Psam-*

motreta, but *Scrobiculina* has page priority over *Psammotreta*. However, Article 24 (a) of the International Code of Zoological Nomenclature insures that if more than one name for a single taxon has been published simultaneously, relative priority and the choice of one of the names to represent the taxon may be determined by the first person to point out the synonymy. Further, Recommendation 24 A of the Code instructs the first reviser to select the name 'that will best ensure stability and universality of nomenclature.' In this particular case, I hereby select *Psammotreta* as the name to be preserved and *Scrobiculina* is assigned the status of a junior synonym.

DALL's concept of *Scrobicularia viridotincta* CARPENTER does not actually represent a valid species. An examination of the material of *Tellina ochracea* and the so-called '*viridotincta* CARPENTER' of DALL in the British Museum (Natural History), the Museum of Comparative Zoology, and the United States National Museum indicates that *T. ochracea* is a polymorphic species in which green and yellow colored specimens are identical morphologically and represent nothing more than color variations.

The closest relative to *Tellina ochracea* is the western Atlantic species, *T. laevigata* LINNAEUS, 1758, which also possesses a wide range of color variation. Probably *T. ochracea* was derived from *T. laevigata* after the closure of the Central American isthmus in the Pliocene. *Tellina laevigata* appears to be more heavily shelled and more tumid; its color is generally red and often disposed in rays, although colorless individuals are frequently encountered in populations.

A problem arises in subgenerically placing *Tellina ochracea*. *Laciolina* IREDALE, 1937, based on *T. quoyi* SOWERBY, suitably fills the need. In addition to *T. quoyi*, *T. chloroleuca* LAMARCK, 1818 also represents *Laciolina* in the Indo-Pacific, and both are very similar to *T. laevigata* and *T. ochracea*. Their common ancestry becomes immediately evident when samples of each species are compared.

In summary, the status of *Scrobicularia viridotincta* CARPENTER is discussed. An examination of the holotype shows this species to be synonymous with *Psammotreta pacis* PILSBRY & LOWE. The sectional or subgeneric name *Scrobiculina* DALL, based upon *Scrobicularia viridotincta* CARPENTER, is herein designated (interpreted) as a junior synonym of *Psammotreta*. DALL's *S. viridotincta* 'CARPENTER' is synonymous with the species *Tellina ochracea* CARPENTER. *Laciolina* IREDALE is an available subgenus into which are placed *T. ochracea* CARPENTER, *T. laevigata* LINNAEUS, *T. quoyi* SOWERBY and *T. chloroleuca* LAMARCK.

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LITERATURE CITED

- CARPENTER, PHILIP PEARSALL
 1856. Proc. Zool. Soc. London, pt. xxiii, p. 160.
 1864. Ann. Mag. Nat. Hist., Ser. 3, 13: 312.
- DALL, WILLIAM HEALEY
 1900. Synopsis of the family Tellinidae and of the North American species. Proc. U. S. Nat. Mus., 23: 285-326: pls. 2-4.
- HERTLEIN, LEO G. & A. M. STRONG
 1949. Eastern Pacific expeditions of the New York Zoological Society. Mollusks from the west coast of Mexico and Central America. Part 7. Zoologica 34 (2): 63-97; 1 pl.
- KEEN, A. MYRA
 1962. Nomenclatural notes on some West American mollusks, with proposal of a new species name. The Veliger 4 (4): 178-180.
- OLSSON, AXEL A.
 1961. Mollusks of the tropical Eastern Pacific. Panamic-Pacific Pelecypoda. Paleont. Res. Inst., Ithaca, N. Y., 574 pp.
- PALMER, KATHERINE VAN WINKLE
 1963. Type specimens of marine mollusca described by P. P. Carpenter from the west coast of Mexico and Panama. Bull. Amer. Paleo. 46: 289-408.

Notes on the Terebridae of the Philippine Islands (Mollusca: Gastropoda)

BY

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THE INCREASING NUMBER of students and collectors of Mollusca and the several collecting expeditions of the past decade have resulted in the addition of new records for terebrid species in the Philippine fauna. As this collecting is extended to the northern islands of the archipelago, it is to be expected that additional species, especially those known from the Japanese and Malaysian areas, will be encountered. It should be noted that several such species of wide distribution which have been collected at such diverse localities as Hawaii, Japan, Israel, and South Africa have not yet been seen by this author in the Philippine material examined to date.

These notes are the result of the examination of more than 4000 specimens of Terebridae collected exclusively at Philippine localities. Through the courtesy of Mr. John E. duPont and the Delaware Museum of Natural History, I have had the opportunity to examine Terebridae collected by the late Colonel John Root and those later collected by Mr. duPont and Dr. R. T. Abbott. A large quantity of specimens collected at Luzon, Samar, and Sulu were generously made available for study by Dr. Alan Solem and the Chicago Natural History Museum. Dr. Arthur Clarke and the National Museum of Canada have provided specimens collected by the Norton Expe-

dition to Alabat Island. A number of Philippine students and collectors have given valuable assistance by making their personal collections available, providing quantities of specimens with exact locality data. Numerous private collections have been examined for specimens of the area.

It has been sixty years since, in 1904, J. G. Hidalgo published the "*Catálogo de los molluscos testaceos de las islas Filipinas, Joló y Marianas*" in which he listed the species cited from the area to that time. It has seemed desirable that this list be followed in the present notes; therefore all of the species he listed are repeated here with the new records incorporated in the alphabetical arrangement. Those familiar with Hidalgo's publication will notice that some liberties have been taken in making this arrangement; his appended list under "Other species cited" has also been incorporated. Specimens from Guam and the Marianas Islands have not been included here, nor have several species which have eluded identification.

The most recent publication of species from this area appears to be that of LEOPOLDO A. FAUSTINO (1928), Summary of Philippine Marine and Fresh-water Mollusks. In this extensive list an attempt is made to include the original citation and locality records for the area; however, many species are cited only from HIDALGO'S

Catalogue of Shells, and no attempt is made to verify the citations listed. This summary resulted in the addition of only a single species, *Terebra tuberosa* HINDS, 1844; on the other hand, six species listed by HIDALGO were omitted, as follows: *T. argus* HINDS, 1844, *T. nebulosa* KIENER, 1839, *T. pallida* DESHAYES, 1859, *Hastula lanceata* (LINNAEUS, 1767), *H. philippiana* (DESHAYES, 1859), and *H. verreauxi* (DESHAYES, 1859). Also excluded were all of the species listed by HIDALGO in his appended "Other species cited". This summary contains an excellent bibliography for the area.

In the present notes no attempt is made to repeat the locality records or citations of either of the two mentioned authors. Only a general collecting locality for the species listed here is given; more accurate data are available for those interested. All species listed have been compared with the original descriptions and figures; with photographs of several of the holotypes or paratypes; with some species in the author's collection which came originally from the Cuming Collection; and with many homeotype specimens from the Philippines, Australia and Japan. The references and figures cited by both HIDALGO and FAUSTINO have also been compared with the specimens at hand.

Much of the synonymy for species listed remains to be investigated and I have, for this reason, included all of the specific names of the two lists mentioned above. A comparison will show that a number of these names have been placed in the synonymy. It is apparent that additional changes will be necessary in the specific nomenclature of several of the listed species. Corrections in nomenclature made here are of the less well-known species, and it is expected that others more familiar to the general collector will be individually reviewed in the future.

These notes are not intended as a systematic arrangement of the species. For the present purpose, it has seemed sufficient to list the species in alphabetical order, placing them in the broad generic groups of *Duplicaria*, *Hastula*, and *Terebra*, with appropriate sub-genera. For those who prefer the more detailed arrangements, a list of the generic names used, with author, date of publication, and type species follows the list of species.

All species cited by lot number will be found, as indicated, in the collections listed below. In order to incorporate these new records with those of HIDALGO, the following symbols and abbreviations have been used:

- * = species listed by HIDALGO
- (x) = species not verified by HIDALGO
- CM = Chicago Natural History Museum, Chicago, Illinois.
- DM = Delaware Museum of Natural History, Greenville, Delaware.

- O = Olivera Collection, Quezon City, Philippines.
- B = Burch Collection, Houston, Texas

Duplicaria

*(x) *D. (? Pristiterebra) badia* (DESHAYES, 1859): Proc. Zool. Soc. London, p. 300, no. 132; Fig.: Thes. Conch., 1844, T., Pl. 43, fig. 59.

Terebra castanea HINDS, 1844: HINDS in SOWERBY, Thes. Conch. 1: 161, pl. 43, fig. 59 (*non* KIENER, 1839).

T. ligneola REEVE, 1860: Conch. Icon. T., pl. 7, no. 25. This species from western Africa has not been among specimens examined.

*(x) *D. (Duplicaria) bernardi* (DESHAYES, 1857): Journ. Conchyl., p. 84, pl. 4, fig. 10.

This species, commonly collected in Queensland and northern Australia (B no. 412), has not been included in the collections examined.

* *D. (Duplicaria) duplicata* (LINNAEUS, 1758): Syst. Nat., Ed. 10, p. 742, no. 419; KIENER: Icon. Coq. Viv., 1839, T., pl. 9, fig. 19 and pl. 12, figs. 26 (both)

Terebra chalybeus (MARTINI, 1780): Conch. Cab., p. 301, pl. 155, fig. 1455.

* *T. lamarcki* KIENER, 1839, Icon. Coq. Viv., T., p. 30, no. 25, pl. 9, fig. 19.

T. reevei DESHAYES, 1857: Journ. Conchyl., p. 88, pl. 4, fig. 14.

? *T. japonica* E. A. SMITH, 1873: Ann. & Mag. Nat. Hist. 11 (ser. 4): 265.

A wide range of color and color pattern is exhibited by this species, the sculpture remaining constant except for the varying width of the axial ribs. Specimens of an unusual dark-gray color with maroon flammules are collected rarely at Batangas Bay (B no. 212).

*(x) *D. (Duplicaria) dussumieri* (KIENER, 1839): Icon. Coq. Viv., T., p. 31, no. 26, pl. 8, fig. 17.

This species of Formosa (B no. 131) and Japan (B no. 423) has not been included among the specimens examined.

*(x) *D. (Duplicaria) evoluta* (DESHAYES, 1859): Proc. Zool. Soc. London, p. 292, no. 88; Fig.: REEVE; Conch. Icon. 1860 T., pl. 8, no. 55.

The single specimen seen in the Olivera Collection, was collected at Batangas Bay.

D. (Duplicaria) raphanula (LAMARCK, 1822): Anim. sans Vert. 7: 288, no. 16; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 10, fig. 20.

An uncommon species. Samar, Sulu, Luzon. (CM no. 127146, DM no. 3558, B no. 035).

Hastula

* *H. (Hastula) aciculina* (REEVE, 1860): Conch. Icon., T., pl. 23, figs. 121 (all) (*non* LAMARCK, 1822).

REEVE has incorrectly figured three distinct species under this name, all of which had been described as new species by HINDS. Two of these, *Hastula casta* and *H. inconstans*, are indigenous to the area; the third, *H. stylata*, has not been among specimens examined, although it is found in Japan (B no. 516). E. A. SMITH's *H. confusa* (Ann. & Mag. Nat. Hist., 19 (ser. 4): 229, 1877) is founded on two of the species figured by REEVE.

H. (Punctoterebra) anomala (GRAY, 1834): Proc. Zool. Soc. London, p. 62; Fig.: HINDS in SOWERBY, Thes. Conch., T., 1844, pl. 44, fig. 97.

Uncommon at Alabat Island (B no. 179).

H. (Impages) bacillus (DESHAYES, 1859): Proc. Zool. Soc. London, p. 285, no. 49.

This small species is very close to juvenile forms of *H. caerulescens* (LAMARCK, 1822). Common in several localities. Luzon. (B. no. 442).

* *H. (Impages) caerulescens* (LAMARCK, 1822): Anim. sans Vert. 7: 288, no. 12; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 6, fig. 12 a, 12 b, 12 c.

Terebra hectica (LINNAEUS, 1758) (in part possibly): The description is too vague and includes several species. (*non* CHEMNITZ, 1780; *non* WOODARCH, 1822, *non* KÜSTER, 1841).

? *T. edentula* (GMELIN, 1790): Syst. Nat., Ed. 13, p. 3505, no. 155.

? *T. nivea* (GMELIN, 1790): l. c., p. 3504 (*non* pp. 3471 and 3495).

? *T. bifasciata* (DILLWYN, 1817): Descr. Cat., 2: 651, no. 155.

T. terebralis (MENKE, 1828): Synops. Moll., p. 84.

T. otaitensis (LESSON, 1830): Voy. Coq., 2 (1): 407.

T. nimbose HINDS, 1844: Proc. Zool. Soc. London, p. 151.

T. flammulata MARTENS, 1880: Mauritius, p. 230, pl. 20, fig. 5.

H. hectica alba DAUTZENBERG, 1935: Mem. Mus. Hist. Nat. Belg., 17 (ser. 2): 42, pl. 2, fig. 4.

H. hectica fusca DAUTZENBERG, 1935, l. c., p. 42, pl. 2, fig. 2

Extremely variable in color arrangement. Not uncommon. Cebu, Luzon. (CM no. 127144; DM no. 3552; B no. 450).

* *H. (Hastula) casta* (HINDS, 1844): Proc. Zool. Soc. London for 1843: 156; Fig.: HINDS in SOWERBY, Thes. Conch., 1844, T., pl. 44, fig. 84.

* (x) *T. albula* MENKE, 1843: Moll. Nov. Holl., p. 30, no. 163; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 45, fig. 126. MENKE's description of

this colorless variety would appear to have priority.

T. bipartita DESHAYES, 1859: Proc. Zool. Soc. London, p. 284, no. 47.

* (x) *T. incolor* DESHAYES, 1859: Proc. Zool. Soc. London, p. 283, no. 44.

* (x) *T. philippiana* DESHAYES, 1859: Proc. Zool. Soc. London, p. 289, no. 68 (*non* DALL, 1920).

* *T. aciculina* REEVE, 1860: Conch. Icon., T., pl. 23, (in part) fig. 121 a only (*non* LAMARCK, 1822).

T. medipacifica PILSBRY, 1921: Marine Moll. Hawaii, p. 308, pl. 12, figs. 8, 9, 10. In this somewhat more obese variety the axial ribs extend from suture to suture on each whorl.

T. medipacifica melior PILSBRY, 1921: l. c., p. 308, pl. 12, fig. 11. Described from a larger specimen of the preceding.

H. casta natalensis E. A. SMITH, 1903: Proc. Mal. Soc., 5 (6): 360.

Variable in color, sculpture and form. Color often completely absent as in *H. albula* or distinct and coalesced as in *H. philippiana*. Sculptural and form variations appear in about equal numbers in specimens taken from the same colony by divers. A common species in all localities (CM no. 127140; DM no. 3538; B no. 259; Olivera Collection contains superior examples of the *philippiana* variety).

* (x) *H. (Hastula) cinerea* (BORN, 1778): Mus. Vind., p. 267, pl. 10, figs. 11, 12.

Terebra aciculina LAMARCK, 1822: Anim. sans Vert. 7: 290, no. 22 (*non* HINDS, 1844; *non* REEVE, 1860).

Common in Florida (B no. 128), the Gulf of Mexico, northern Panama (B no. 183) to Rio de Janeiro, Brazil (B no. 535). Many Indo-Pacific species have been incorrectly placed in the synonymy.

H. (Hastula) concinna (DILLWYN, 1817): Descr. Cat., p. 647, no. 144; Fig., BORN; Mus. Vind., 1778, p. 264, pl. 10, fig. 10 (*non* DESHAYES, 1857).

* *T. strigilata* (LINNAEUS, 1758): Syst. Nat., Ed. 10, p. 741, no. 418 (the description is too brief, and the species cannot be determined with any certainty).

T. strigilata (BORN, 1778): Mus. Vind., p. 264, pl. 10, fig. 10. This specific name is a homonym and was replaced by DILLWYN. The figure fails to show the prominent axial ribs distinctive of this species, which superficially resembles several other forms (*non* CHEMNITZ, 1780; *non* GMELIN, 1790, *non* KIENER, 1839).

T. striatula KIENER, 1839: Icon. Coq. Viv., T., pl. 9, (in part) fig. 18

T. acumen DESHAYES, 1859: Proc. Zool. Soc. London, 287, no. 58.

T. argenvillei DESHAYES, 1859: l. c., p. 286, no. 56.

? *T. modesta* DESHAYES, 1859: l. c., p. 288, no. 64.

- * ?*T. matheroniana* DESHAYES, 1859: *l. c.*, p. 287, no. 60.
- * *T. verreauxi* DESHAYES, 1859: *l. c.*, p. 286, no. 55.
- A widely distributed species which exhibits a remarkable range of color variations; yellow, fawn, white, light-blue, dark-gray, and in Queensland, Australia, an unusual green color without the white line on the body whorl. Individual specimens will occasionally make a transition from yellow to dark gray in mid-growth. The sculpture remains constant except for the varying width and number of axial ribs. A common species. Sulu; Luzon (CM no. 127163; DM no. 3557; B no. 458).
- * (x) *H. (Hastula) dispar* (DESHAYES, 1859): Proc. Zool. Soc. London, p. 284, no. 46; Fig.: REEVE; Conch. Icon., 1860, T., pl. 25, no. 137.
- This species is commonly collected at Broome, Western Australia (B no. 317), but has not been among Philippine specimens examined.
- H. (Impages) exacuminata* SACCO, 1891: I Moll. d. Terr. Terz. Piem. e Liguria, pt. 10, T., p. 18.
- T. acuminata* REEVE, 1860: Conch. Icon., T., pl. 26, no. 143 (*non* BORSON, 1820).
- An uncommon species. Batangas Bay, Luzon (B no. 161).
- * *H. (Hastula) hastata* (GMELIN, 1791): Syst. Nat., Ed. 13, p. 3502; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 10, fig. 23.
- This common species of Florida and the Caribbean Sea areas (DM no. 1746; B no. 312) has not been among specimens in the collections examined.
- H. (Hastula) inconstans* (HINDS, 1844): Proc. Zool. Soc. London for 1843: 156; Fig.: HINDS in SOWERBY, 1844, Thes. Conch., T., pl. 44, fig. 83.
- * *T. aciculina* REEVE, 1860: Conch. Icon., T., pl. 23, (in part), figs. 121 b, 121 d, 121 e (*non* LAMARCK, 1822).
- H. confusa* E. A. SMITH, 1877: Ann. & Mag. Nat. Hist., p. 299; Fig.: REEVE; Conch. Icon., 1860, T., pl. 23 (in part), fig. 121 d; (*non* vars. 121 c, 121 f).
- T. inconstans confusa* PILSBRY, 1921: Marine Moll. Hawaii, p. 301.
- Uncommon in Batangas Bay, Luzon (B no. 441).
- * *H. (Hastula) lanceata* (LINNAEUS, 1767): Syst. Nat., Ed. 12, p. 1206, no. 486; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 10, fig. 22 (*non* figs. 22 a, 22 b).
- A common species; Luzon; Sulu (CM no. 127145; DM no. 3554; B no. 205).
- H. (Punctoterebra) lauta* (PEASE, 1869): Am. Journ. Conch. 5: 66; Fig.: WEAVER; Hawaiian Mar. Moll., 1 (8): 30, no. 2.
- Alabat Island; Luzon (DM no. 3574; B no. 049).
- H. (Punctoterebra) nitida* (HINDS, 1844): Proc. Zool. Soc. for 1843: 152; Fig.: HINDS in SOWERBY; Thes. Conch., T., 1844, pl. 45, fig. 103.
- T. plicatella* DESHAYES, 1857: Journ. Conchyl., p. 96, no. 32, pl. 3, fig. 5.
- T. cernica* SOWERBY, 1893: Proc. Mal. Soc., 1: 43, pl. 4, fig. 1.
- T. nitida* var. *sicyodes* MELVILL & SYKES, 1898: Proc. Mal. Soc. 3 (1): 43, pl. 3, fig. 8.
- T. clappi* PILSBRY, 1921: Mar. Moll. Hawaii; Proc. Acad. Nat. Sci. Phila. 69: 306; Fig.: WEAVER; Hawaiian Mar. Moll. 1 (6): 22, 1960 (juvenile and sub-adult forms).
- Uncommon in Batangas Bay, Luzon (Olivera; B no. 555).
- H. (Hastula) penicillata* (HINDS, 1844): Proc. Zool. Soc. London for 1843: 157; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 44, fig. 91.
- * (x) *T. venosa* HINDS, 1844: Proc. Zool. Soc. London for 1843: 157; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 44, fig. 90.
- T. lanceata* KIENER, 1839: Icon. Coq. Viv., T., pl. 10, figs. 22 a, 22 b (*non* fig. 22).
- T. crossi* DESHAYES, 1859: Proc. Zool. Soc. London, p. 289, no. 67.
- A species of wide distribution, described by Hinds from the Seychelles Islands and recorded at Mauritius by Viader. It also occurs in Japan (B no. 505), New Guinea (B no. 297) and at Easter Island (B no. 169), all Pacific localities. I have not yet seen it in Philippine material.
- * *H. (Punctoterebra) plumbea* (QUOY & GAIMARD, 1832): Voy. Astrolabe, Moll., p. 470, pl. 36, figs. 29, 30.
- T. bourguignati* DESHAYES, 1859: Proc. Zool. Soc. London, p. 288, no. 66.
- T. hoffmeyereri* ABBOTT, 1952: Nautilus 65 (3): 78, pl. 5, figs. 5 to 9.
- A variable species in that occasional specimens do not have the punctate sulcus; some are quite without spiral sculpturing, while others from the same colony are microscopically striate. Mindanao; Luzon (DM no. 3572; B no. 376).
- H. (Hastula) solida* (DESHAYES, 1857): Journ. Conchyl., p. 78, pl. 3, fig. 11.
- T. clarkei* M. SMITH, 1912: Nautilus 26 (6): 75, pl. 4, fig. 18.
- Common in Cebu; Luzon (CM no. 127153; DM no. 3537; B no. 201).
- * (x) *H. (Hastula) stylata* (HINDS, 1844): Proc. Zool. Soc. London for 1843: 152; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 44, fig. 79.
- H. confusa* E. A. SMITH, 1877: Ann. & Mag. Nat. Hist., p. 299; Fig.: REEVE; Conch. Icon., 1860, T., pl. 23, (in part), figs. 121 c, 121 f, only).
- "Philippines" and "Japan" given as localities by HINDS.

The species has not been among specimens examined, although it is collected, rarely, at Ogasawara Island, Japan (B no. 516).

Terebra

Terebra (Cinguloterebra) adamsi E. A. SMITH, 1873: Ann. & Mag. Nat. Hist., 6: 264. Unfigured.

Some resemblance in superficial appearance to *T. serotina* ADAMS & REEVE. Rare in Batangas Bay, Luzon. (Olivera; B no. 085).

* *T. (Decorihastula) affinis* GRAY, 1834: Proc. Zool. Soc. London, p. 60; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 44, fig. 78 (non TURTON, 1932).

T. striata QUOY & GAIMARD, 1832: Voy. Astrol., p. 468, pl. 36, figs 23, 24 (non BASTEROT, 1825; non GRAY, 1834).

T. pertusa KIENER, 1839: Icon. Coq. Viv., T., pl. 11, fig. 24 b only. (non BORN, 1780).

Common in many localities; Cebu; Luzon; Alabat Island (CM no. 127138; DM no. 3570; B no. 370).

* (x) *T. (Dimidacus) albomarginata* DESHAYES, 1859: Proc. Zool. Soc. London, p. 314, no. 212; Fig.: REEVE; Conch. Icon., 1860, T., pl. 15, fig. 65.

Apparently a rare species. Luzon. (DM no. 3539, in part).

T. (Dimidacus) amanda HINDS, 1844: Proc. Zool. Soc. London for 1843: 154; Fig.: HINDS in SOWERBY; Thes. Conch. 1844, T., p. 166, no. 46, pl. 45, fig. 100.

A rare species. Batangas Bay, Luzon (Olivera Collection).

T. (Strioterebrum) ambrosia MELVILL, 1912: Proc. Mal. Soc. 10: 250, pl. 11, fig. 10.

A rare species. Batangas Bay, Luzon (B no. 249).

T. (Perirhoe) anilis (RÖDING, 1798): Mus. Bolt., p. 95, no. 46; Fig.: CHEMNITZ; Conch. Cab., (4), pl. 155, no. 1456.

T. strigilata CHEMNITZ, 1780: Conch. Cab., above fig. (non LINNAEUS, 1758).

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T. cancellata RÖDING, 1798): Mus. Bolt., p. 95, no. 47; Fig.: CHEMNITZ; Conch. Cab., above fig. (non QUOY & GAIMARD, 1832; non GRAY, 1834; non COSSMAN, 1900).

T. myuros LAMARCK, 1822: Anim. sans Vert., 7: 289; no. 18; Fig.: (in part) Conch. Cab., above fig. (non KIENER, 1839; non REEVE, 1860).

* *T. straminea* GRAY, 1834: Proc. Zool. Soc. London, p. 62; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 42, figs. 22, 23.

T. acuta DESHAYES, 1857: Journ. Conchyl. 6: 100, pl. 4, figs. 4, 5.

T. circinata DESHAYES, 1857: *ibid.*, p. 99, pl. 4, figs. 6, 7.

Common in many localities. Luzon (CM no. 127130; DM no. 3542; B no. 220).

T. (Perirhoe) archimedes DESHAYES, 1859: Proc. Zool. Soc. London, p. 314; Fig.: SCHEPMAN; Siboga Exped., 1913, pt. 5, Toxoglossa, pl. 25, fig. 12. Batangas Bay, Luzon (CM no. 127136; B no. 458).

T. (Subula) areolata (LINK, 1806): Besch. Nat. Samm. Univ. Rostock, p. 128; Fig.: CHEMNITZ; Conch. Cab., 1780, (4), T., pl. 153, fig. 1441 and pl. 154, fig. 1443 (non ADAMS & REEVE, 1850).

T. subulata (MARTINI-CHEMNITZ, 1780): Conch. Cab., pl. 153, fig. 1441 (non LINNAEUS, 1767).

* *T. muscaria* LAMARCK, 1822: Anim. sans Vert. 7: 285, no. 5; Fig.: CHEMNITZ; Conch. Cab., 1780, (4), T., pl. 153, fig. 1441; pl. 154, fig. 1443 (non KIENER, 1839, pl. 3, fig. 4 b only; non KÜSTER, 1841; non DALL, 1915).

Common throughout the area. Cebu; Luzon (CM no. 127160; DM no. 5228; B no. 424).

* *T. (Subula) argus* HINDS, 1844: Proc. Zool. Soc. London for 1843: 160; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 23, fig. 64.

? *T. candida* (BORN, 1780): Mus. Vind., p. 263, pl. 10, fig. 8.

T. nebulosa KIENER, 1839: Icon. Coq. Viv., T., p. 23, no. 18, pl. 10, fig. 21 (non SOWERBY, 1825; non LOROIS, 1858).

A common species. Luzon; Sulu (CM no. 127164; DM no. 3571; B no. 189).

* *T. (Perirhoe) babylonia* LAMARCK, 1822: Anim. sans Vert., 7: 287, no. 9; Fig.: KIENER, Icon. Coq. Viv., 1839, T., pl. 14, (in part), fig. 35 only.

T. striata GRAY, 1834: Proc. Zool. Soc. London, p. 60 (non BASTEROT, 1825; non QUOY & GAIMARD, 1832).

A common species. Batangas Bay, Luzon (CM no. 127158; DM no. 773; B no. 192).

* (x) *T. (? Hastula) caliginosa* DESHAYES, 1859: Proc. Zool. Soc. London, p. 287, no. 62; Fig.: REEVE; Conch. Icon., 1860, T., pl. 20, no. 100.

Has not been among specimens examined.

* *T. (Strioterebrum) cancellata* QUOY & GAIMARD, 1832: Voy. Astrol., Moll., 2: 471, pl. 36, figs. 27, 28 (non RÖDING, 1798; non GRAY, 1834).

In the Manual of Conchology, Vol. 7, 1885, Tryon has placed some eleven specific names in the synonymy of this species; almost all of them are in error. Common in several localities. Luzon (DM no. 3576; B no. 444).

* *T. (Abretiella) cerithina* LAMARCK, 1822: Anim. sans Vert. 7: 288, no. 15; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 11, fig. 25.

T. pulchra HINDS, 1844: Proc. Zool. Soc. London for 1843: 151; Fig.: HINDS in SOWERBY; Thes. Conch.,

- 1844, T., p. 178, pl. 45, fig. 129.
Common at Cebu; Luzon; Sulu (CM no. 127159; DM no. 3541; B no. 182).
- * *T. (Oxymeris) chlorata* LAMARCK, 1822: Anim. sans Vert. 7: 288, no. 14; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 4, figs. 8, 8 a (*non* MARTENS, 1902).
T. knorri GRAY, 1834: Proc. Zool. Soc. London, p. 59.
Common at Cebu; Luzon; Sulu (CM no. 127162; DM no. 4397; B no. 106).
- *(x) *T. (Dimidacus) cingulifera* LAMARCK, 1822: Anim. sans Vert., 7: 289, no. 17; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 13, fig. 30.
T. punctulata SOWERBY, 1825: Tank. Cat. App., p. 24.
T. punctatostriata GRAY, 1834: Proc. Zool. Soc. London, p. 61.
T. pallida DESHAYES, 1857: Journ. Conchyl., p. 87, no. 22, pl. 4, fig. 3.
T. chinensis DESHAYES, 1859: Proc. Zool. Soc. London, p. 309, no. 189.
T. columnaris DESHAYES, 1859: *ibid.*, p. 310, no. 195.
T. crenifera DESHAYES, 1859: *ibid.*, p. 298, no. 115.
Common at Luzon; Samar (CM no. 127156; DM no. 4480; B no. 211).
T. (Decoriastula) columellaris HINDS, 1844: Proc. Zool. Soc. London for 1843: 151; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 44, fig. 77.
T. areolata ADAMS & REEVE, 1850: Voy. Samarang, p. 30, no. 4, pl. 10, fig. 23 (*non* LINK, 1806).
? *T. propinqua* PEASE, 1869: Amer. Journ. Conch., 5: 66.
Common. Batangas Bay, Luzon (CM no. 127150; DM no. 3540 in part; B no. 217).
- *(x) *T. (Dimidacus) consobrina* DESHAYES, 1857: Journ. Conchyl., p. 72, pl. 3, fig. 3.
This species of the Red Sea area (B no. 431) is easily confused with some sculptural variations of *T. subulata* (LINNAEUS). It has not been included among specimens examined.
T. (Subula) consors HINDS, 1844: Proc. Zool. Soc. London for 1843: 150; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 42, fig. 26.
T. virginea DESHAYES, 1857: Journ. Conchyl., p. 83, no. 18, pl. 4, fig. 12.
T. glabra DESHAYES, 1857: *ibid.*, p. 101, no. 37, pl. 5, fig. 13.
Apparently an uncommon-to-rare species. Closely resembling *T. dimidiata* (LINNAEUS), it can be recognized by the less-subulate form, much weaker color pattern, and more prominent subsutural collar (Olivera; B no. 500).
- *(x) *T. (Decoriastula) conspersa* HINDS, 1844: Proc. Zool. Soc. London for 1843: 153; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 44, fig. 74.
Rare among specimens examined, a single specimen collected at Luzon, representing the only example seen from this area. It is a not uncommon species in Fiji Islands localities (B no. 227). Batangas Bay (Olivera).
- * *T. (Oxymeris) crenulata* (LINNAEUS, 1758): Syst. Nat., Ed. 10, p. 741, no. 416; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 5, figs. 9, 9 a.
T. dentata (PETIVER, 1767): Anim. Amboin.; pl. 8, fig. 13.
T. varicosa (GMELIN, 1791): Syst. Nat., Ed. 13, p. 3505, no. 165 (*non* HINDS, 1844).
T. coronatus (HUMPHREY, 1797): Mus. Calonn., p. 31.
T. maculata PERRY, 1811: Conch. 5: pl. 16, fig. 2 (*non* LINNAEUS, 1758).
*(x) *T. fimbriata* DESHAYES, 1857: Journ. Conchyl., p. 71, pl. 5, fig. 1.
*(x) *T. interlineata* DESHAYES, 1859: Proc. Zool. Soc. London, p. 277, no. 8.
T. crenulata var. *booleyi* MELVILL & SYKES, 1898: Proc. Mal. Soc. Lond., 3: 44, pl. 3, fig. 5
Common in almost all localities. Luzon; Samar; Sulu (CM no. 127142; DM no. 4296; B no. 145).
- *(x) *T. (Strioterebrum) cumingi* DESHAYES, 1857: Journ. Conchyl., p. 66, no. 2, pl. 3, fig. 1.
Uncommon in Batangas Bay, Luzon, where two color forms are found; both noted by DESHAYES (Olivera; B no. 036).
- * *T. (Subula) dimidiata* (LINNAEUS, 1758): Syst. Nat., Ed. 10, p. 420, no. 420; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 2, figs. 2, 2 a.
T. pantherina (HUMPHREY, 1797): Mus. Calonn., p. 31.
T. carnea PERRY, 1811: Conch. 5: pl. 16, fig. 1.
*(x) *T. splendens* DESHAYES, 1857: Journ. Conchyl., p. 73, pl. 5, fig. 11.
T. chlorata MARTENS, 1902: Rumphius Ged., p. 120 (*non* LAMARCK, 1822).
T. dimidiata var. *pallida* DAUTZENBERG, 1935: Mem. Mus. Hist. Nat. Belg., Ser. 2, 17: 23 (*non* DESHAYES, 1857).
T. dimidiata var. *circumvoluta* DAUTZENBERG, 1935: *ibid.*, p. 22, pl. 1, fig. 4.
Common in many localities. Luzon; Samar; Sulu (CM no. 127161; DM no. 3099; B no. 176).
- T. (Oxymeris) felina* (DILLWYN, 1817): Cat. Shells, p. 644, no. 135; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 3, fig. 4 b only (*non* fig. 4).
T. tigrina (GMELIN, 1791): Syst. Nat., Ed. 13, p. 3502 (*non* p. 3475); (*non* CHENU, 1859).
T. tigrina DESHAYES, 1844: Anim. sans Vert., 2nd. Ed., p. 252, no. 26.
T. suffusa PEASE, 1869: Am. Journ. Conch. 5: 65.
Not uncommon. Cebu; Luzon; Samar (CM no. 127149; DM no. 3550; B no. 120).

- * (x) *T. (Strioterebrum) fenestrata* HINDS, 1844: Proc. Zool. Soc. London for 1843: 153; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 44, fig. 86.
- * (x) *T. caelata* ADAMS & REEVE, 1850: Voy. Samarang, Moll., p. 30, pl. 10, fig. 22.
Very uncommon. Maqueda Bay, Samar; Batangas Bay, Luzon (Olivera; B no. 037).
- T. (Decorihastula) fijiensis* (E. A. SMITH, 1873): Ann. & Mag. Nat. Hist. 11 (ser. 4): 266; unfigured.
Closely resembles *Terebra undulata* GRAY, *T. columellaris* HINDS and *T. paucistriata* E. A. SMITH in superficial appearance. The slender form, style of coloration and more numerous spiral striae serve to assist in identification. Uncommon in Batangas Bay, Luzon (B no. 221).
- * (x) *T. (Terebra) flammea* LAMARCK, 1822: Anim. sans Vert., 7: 284, no. 2; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 5, fig. 10.
This name is a synonym for *Terebra taurina* SOLANDER, 1786; LIGHTFOOT has recently been recognized as the author of the Portland Catalogue in which this name is first applied to the species (Bibliog. Nat. Hist., 4 (1): 30 to 34, 1962). The species ranges through the Gulf of Mexico and to northern Brazil (B no. 159) but is not known from the Philippine area.
- T. (Strioterebrum) flavescens* DESHAYES, 1859: Proc. Zool. Soc. London, p. 299, no. 122; Fig.: REEVE, Conch. Icon., 160, T., pl. 14, fig. 59.
Very uncommon. Subic Bay (Ames Collection, San Diego, California; B no. 214).
- * (x) *T. (Clathroterebra) fortunei* DESHAYES, 1857: Journ. Conchyl., p. 79, pl. 4, fig. 1.
Not uncommon in Japan (B no. 320); the species has not been among specimens seen from Philippine localities.
- * *T. (Perirhoe) funiculata* HINDS, 1844: Proc. Zool. Soc. for 1843: 153; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 43, fig. 63.
A common species. Luzon; Samar; Alabat Island (CM no. 127129; DM no. 3562; B no. 001).
- T. (Terebra) guttata* (RÖDING, 1798): Mus. Bolt., p. 14, no. 1214; Fig.: CHEMNITZ; Conch. Cab., 4, 1780, pl. 153, fig. 1442.
- T. varia* (MEUSCHEN, 1787): Mus. Gevers., p. 294 (non MARTYN, 1784).
- T. maculata* var. c. (GMELIN, 1790): Syst. Nat., Ed. 13, p. 3499, no. 130 (non LINNAEUS, 1758).
- * *T. oculata* (DILLWYN, 1817): Descr. Cat., 2: 642, no. 133. LAMARCK, 1822, repeated this name and cited same figures.
- T. nebulosa* LOROIS, 1858: Journ. Conchyl. 7: 90, pl. 1, fig. 4 (non SOWERBY, 1825, non KIENER, 1839).
- T. loroisi* DESHAYES, 1859: Proc. Zool. Soc. London, p. 313, no. 211.
- T. ornata* (MARTYN, 1784): Univ. Conch., pl. 33, fig. 1 (invalid) (non GRAY, 1834).
Not uncommon. Batangas Bay, Luzon (DM no. 3565, juvenile specimen; B no. 097).
- T. (Perirhoe) laevigata* GRAY, 1834: Proc. Zool. Soc. London, p. 61; Fig.: HINDS in SOWERBY; Thes. Conch. 1844, T., pl. 44, fig. 93.
Uncommon. Luzon; Samar (CM no. 127137; DM no. 3544; B no. 233).
- T. (Strioterebrum) lima* DESHAYES, 1857: Journ. Conchyl., p. 69, pl. 4, fig. 2.
Rare in Batangas Bay, Luzon (CM no. 127135; B no. 457).
- * *T. (Decorihastula) livida* REEVE, 1860: Conch. Icon., T., no. 116, pl. 22.
Rare at Bataan and Batangas Bay, Luzon (CM no. 127131; DM no. 3573; Olivera).
- * (x) *T. (Decorihastula) longiscata* DESHAYES, 1859: Proc. Zool. Soc. London, p. 294, no. 94; Fig.: REEVE; Conch. Icon., 1860, T., no. 103, pl. 21.
- T. swainsoni* DESHAYES, 1859: Proc. Zool. Soc. London, p. 299, no. 126; Fig.: REEVE; Conch. Icon., 1860, T., no. 118, pl. 22.
Very uncommon. Batangas Bay, Luzon (CM no. 127133; DM no. 4572; B no. 178).
- * *T. (Oxymyris) maculata* (LINNAEUS, 1758): Syst. Nat., Ed. 10, p. 741, no. 415; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 1, fig. 1).
Common. Luzon; Mindoro; Sulu (CM no. 127143; DM no. 4395; B no. 454).
- * (x) *T. (? Strioterebrum) mamillata* WATSON, 1886: Voy. Challenger, 15: 381, no. 15, pl. 16, fig. 1.
I have not seen this species among the specimens examined.
- * *T. (Cinguloterebra) monilis* QUOY & GAIMARD, 1832: Voy. Astrol., Moll., 2: 467, pl. 36, figs. 21, 22 (non LINNAEUS, 1771; non MENKE, 1830).
Not uncommon. Cebu; Luzon; Alabat Island (CM no. 127132; DM no. 3568; B no. 011).
- * (x) *T. (Decorihastula) nebulosa* SOWERBY, 1825: Tank. Cat. Append., p. 25 (non KIENER, 1839; non LOROIS, 1858).
Common in most localities. Luzon; Sulu (CM no. 127148; DM no. 3561; B no. 215).
- T. (Decorihastula) paucistriata* (E. A. SMITH, 1873): Ann. & Mag. Nat. Hist. 11: 269. Unfigured.
Superficially resembles sub-adult specimens of *T. undulata* GRAY. It can be distinguished by the smaller size, more slender form, spiral sculpture, and style of coloration. Rare in Batangas Bay, Luzon (B no. 588).
- T. (Decorihastula) pertusa* (BORN, 1780): Mus. Vind., p. 267, pl. 10, fig. 13 (non BASTEROT, 1825; non KIENER, 1839; non SOWERBY, 1897).

- T. undata* DEFRANCE, 1829: Dict. Sci. Nat.
- T. bermonti* LOROIS, 1857: Journ. Conchyl., 2nd. ser., p. 389, pl. 12, fig. 2. The figure does not fit the description.
- The single specimen seen was collected at Luzon (DM no. 3101).
- * (x) *T. (Decorihastula) picta* HINDS, 1844: Proc. Zool. Soc. London for 1843: p. 156; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 45, fig. 105. Very uncommon. Luzon; Alabat Island (Olivera; B no. 007).
- * (x) *T. (Strioterebrum) polygyrata* DESHAYES, 1859: Proc. Zool. Soc. London, p. 301, no. 138; Fig.: REEVE; Conch. Icon., 1860, T., pl. 26, no. 146.
- * *T. polyanata* PAETEL, 1888: Cat. Conch.-Samml., p. 253.
- Uncommon. Luzon (DM no. 3236; B no. 513).
- * (x) *T. (Myurella) pretiosa* REEVE, 1842: Proc. Zool. Soc. London, p. 200; Fig.: REEVE; Conch. Icon., 1860, T., no. 30, pl. 8.
- This species of Japan (B no. 191) has not been among Philippine specimens examined.
- * (x) *T. (? Strioterebrum) pulchella* DESHAYES, 1857: Journ. Conchyl., p. 94, pl. 5, fig. 4 (*non* RÖDING, 1798; *non* ADAMS & ANGAS, 1863).
- Not among the specimens seen.
- * (x) *T. (Strioterebrum) roseata* ADAMS & REEVE, 1850: Voy. Samarang, Moll., p. 30, pl. 10, fig. 24.
- Rare. Bataan, Luzon (CM no. 127134).
- T. (Myurella) scabrella* LAMARCK, 1822: Anim. sans Vert., 10: 247, no. 19; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 14, fig. 34 a only.
- T. myuros* KIENER, 1839: Icon. Coq. Viv., T., pl. 14, fig. 34 a; *non* fig. 34.
- T. myuros* REEVE, 1860: Conch. Icon., T., no. 31, pl. 8 (*non* LAMARCK, 1822).
- A single specimen collected at Luzon (DM no. 3560).
- * (x) *T. (Cinguloterebra) serotina* ADAMS & REEVE, 1850: Voy. Samarang, Moll., p. 30, pl. 10, fig. 20.
- This species of Japan (B no. 329) has not been among specimens examined.
- * (x) *T. (Oxymeris) strigata* SOWERBY, 1825: Tank. Cat. App., p. 25 (*non* GMELIN, 1790).
- Ranging the eastern area from Mexico (B no. 276) to Peru, this species has not been among specimens examined.
- * *T. (Terebra) subulata* (LINNAEUS, 1767): Syst. Nat., Ed. 12, p. 1205, no. 480; Fig.: KIENER, Icon. Coq. Viv., 1839, T., pl. 4, fig. 6.
- T. cornu* (BONANNI, 1773): Mus. Richter., p. 98, pl. 3, fig. 118.
- T. varia* (MARTYN, 1784): Univ. Conch., CHENU Ed., 1845, pl. 33, fig. 2 a (*non* MEUSCHEN, 1787).
- T. leopardalis* (HUMPHREY, 1797): Mus. Calonn., p. 31.
- Terebrum tigreum* MONTFORT, 1810: Conch. Syst., 2: 430, fig. 2.
- T. fusca* PERRY, 1811: Conch., T. 16, fig. 3 (*non* MARTYN, 1784).
- T. tigrina* CHENU, 1859: Man. Conch. 1: 219, fig. 1207. Common at Cebu; Luzon; Samar (CM no. 127141; DM no. 4470; B no. 175).
- * (x) *T. (Dimidacus) succinea* HINDS, 1844: Proc. Zool. Soc. London for 1843: 149; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 42, fig. 40.
- This species, also cited from Japan (OYAMA, Venus, 21 (4): 454, 1961), has not been among specimens examined.
- * *T. (Strioterebrum) textilis* HINDS, 1844: Proc. Zool. Soc. London for 1843: 156; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 44, fig. 73.
- While the species is wide-ranging and not uncommon in the Indo-Pacific, it has not been among the Philippine specimens seen.
- * *T. (Triplostephanus) triseriata* GRAY, 1834: Proc. Zool. Soc. London, p. 61; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 45, fig. 119.
- T. praelonga* DESHAYES, 1859: Proc. Zool. Soc. London, p. 315, no. 221; Fig.: REEVE; Conch. Icon., 1860, T., pl. 8, fig. 28.
- Very uncommon. Batangas Bay, Luzon (DM no. 3551; B no. 032).
- T. (? Strioterebrum) tuberosa* HINDS, 1844: Proc. Zool. Soc. London for 1843: 291; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 45, fig. 99.
- This species has not been among the specimens examined.
- * (x) *T. (Strioterebrum) undatella* DESHAYES, 1859: Proc. Zool. Soc. London, p. 300, no. 129; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 44, fig. 80.
- This is *T. cancellata* QUOY & GAIMARD, 1832 (*non* RÖDING, 1798).
- * *T. (Decorihastula) undulata* GRAY, 1834: Proc. Zool. Soc. London, p. 61; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 43, fig. 55 (*non* GRATELOUP, 1841).
- T. pertusa* KIENER, 1839: Icon. Coq. Viv., T., pl. 11, fig. 24 c only.
- T. approximata* DESHAYES, 1859: Proc. Zool. Soc. London, p. 299, no. 125.
- T. undulata* var. *laevior* SCHEPMAN, 1913: Siboga Exp., Toxoglossa, pt. 5, p. 372, no. 21, pl. 25, fig. 9.
- Common. Luzon; Samar (CM 127155; DM 4295; B no. 159).
- * (x) *T. (Strioterebrum) variegata* GRAY, 1834: Proc. Zool. Soc. London, p. 61; Fig.: KIENER; Icon. Coq. Viv., 1839, T., pl. 2, fig. 3.

A species of western Mexico (B no. 171); not among Philippine specimens seen.

* (x) *T. (Clathrotrebra) violascens* HINDS, 1844: Proc. Zool. Soc. London for 1843: 154; Fig.: HINDS in SOWERBY; Thes. Conch., 1844, T., pl. 45, fig. 98.

This small species was described from the "Philippines," but it has not been among specimens of the area, seen by the author to date. It has been recorded in New Guinea (HINDS, Voy. Sulphur), Mauritius (VIADER, Maur. Inst. Bull. 1 (2)) and the Fijis (CATE & BURCH, The Veliger 6 (3)).

Several of the above unverified species were described from the "Philippines" or have been reported as collected in that area. When possible, I have attempted to provide a general locality for those listed species which have not been among specimens seen during this study.

Generic and sub-generic names, with authors and type species, are as follows:

Abretiella BARTSCH, 1923: *T. ccrithina* LAMARCK, 1822.
Cingulotrebra OYAMA, 1961: *T. hedleyana* PILSBRY, 1905
Clathrotrebra OYAMA, 1961: *T. fortunei* DESHAYES, 1857.

Decorihastula OYAMA, 1961: *T. affinis* GRAY, 1834.
Dimidacus IREDALE, 1929: *T. melamans* (IREDALE, 1929).

Terebrina BARTSCH, 1923: *T. cingulifera* LAMARCK, 1822.

Duplicaria DALL, 1908: *T. duplicata* (LINNAEUS, 1758).
Diplomeriza DALL, 1919: *T. duplicata* (LINNAEUS, 1758).

Hastula H. & A. ADAMS, 1853: *H. concinna* (DILLWYN, 1817); Syn.: *T. strigilata* (LINNAEUS, 1758) in part.

Acuminia DALL, 1908: *T. lanceata* (LINNAEUS, 1767).
Hastulina OYAMA, 1961: *H. casta* (HINDS, 1844).

Impages E. A. SMITH, 1873: *H. caerulea* (LAMARCK, 1822).

Myurella HINDS, 1844: *T. myuros* LAMARCK, 1822.
Noditrebra COSSMAN, 1896: *T. geniculata* TATE, 1886.

Oxymeris DALL, 1908: *T. maculata* (LINNAEUS, 1758).
Acus HUMPHREY, 1840; non MÜLLER, 1767.

Perirhoe DALL, 1908: *T. circumcincta* DESHAYES, 1857.
Pristitrebra TAKI & OYAMA, 1954: *T. tsuboiana* YOKOYAMA, 1922; = *T. bifrons* HINDS, 1844.

Punctotrebra BARTSCH, 1923: *T. nitida* HINDS, 1844.
Striotrebrum SACCO, 1891: *T. basteroti* NYST, 1843.

Subula SCHUMACHER, 1817: *T. dimidiata* (LINNAEUS, 1758).

Terebra BRUGUIÈRE, 1789: *T. subulata* (LINNAEUS, 1767)
Triplosthephanus DALL, 1908: *T. triseriata* GRAY, 1834.

ACKNOWLEDGMENTS

Perhaps the most difficult part in a project such as this is to get access to the necessary original reference material, and I am particularly grateful to Dr. R. W.

Barker of Bellaire, Texas, for the unreserved use of his personal library; also to Mr. and Mrs. C. N. Cate of Los Angeles, California, and Dr. W. J. Clench and the Museum of Comparative Zoology at Harvard University for photostats and loans of original references used in this study. Dr. Louis M. Brand of Houston, Texas, has generously made available specimens originally from the Cuming Collection.

The kindness of those who have made their collections available is acknowledged with gratitude. In addition to the large collections cited here, many friends have contributed specimens and information without which this project could not have been completed. Since comparison specimens from other than Philippine areas were necessary in order to establish satisfactory identification of some species, the assistance of students and collectors in other areas has been invaluable. In addition to the species cited from the collection of Mr. Baldomero M. Olivera, large quantities of specimens with excellent locality data have been provided by Mrs. Nieves Dayrit, Mr. Pedro de Mesa and Mr. Donald Dan of the Philippines. Among the larger of the world-wide collections of Terebridae loaned for study were those of Mr. Walter Eyerdam of Seattle, Washington, and Mr. Harold P. Post of Lantana, Florida. Specimens and collections from more restricted localities which have been important in establishing identifications were generously loaned or donated by Dr. Tokyo Shikama and Mr. Akibumi Teramachi of Japan; Mr. and Mrs. C. H. Ames, currently of San Diego, California, generously loaned their large collection made in Japan and at Guam. Also from Guam were many specimens collected by Mr. Herbert T. Ward. Other specimens used in making identifications were sent in quantity with excellent data by Mrs. Mary Elborne of Queensland and Mr. Ted Crake of Western Australia, by Mrs. Isobel Pert of New Guinea, and by Mrs. Mary Saul of Sabah (formerly North Borneo). To all of these and the many others who generously gave of their time, assistance and advice, I wish to express my gratitude.

LITERATURE CITED

HIDALGO, JOAQUIN GONZALES

1904. Catálogo de los moluscos testáceos de las islas Filipinas, Joló y Marianas. Rev. Real. Acad. Cien. 1 (5): *Terebra* pp. 345-349 (no figs.). (Sept. 1904)

FAUSTINO, LEOPOLDO A.

1928. Summary of Philippine marine and fresh-water mollusks. Bur. Sci., Manila, No. 25: *Terebra*, pp. 305-310. (no figures) (30 Oct. 1928)



A New Species of *Mitra* from the Western Indian Ocean

(Mollusca: Gastropoda)

BY

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(Plate 28)

IN MID-JULY OF 1962 I was sent a large and unusual specimen of *Mitra* for identification. The data with it and subsequent correspondence concerning it proved as interesting as the shell itself; it is *ex pisce*, collected off Durban, South Africa, by the same individual who has from time to time furnished, also *ex pisce*, such rare molluscan species as *Voluta (Alcithoe) ponsonbyi* E. A. SMITH, 1901, *V. (A.) africana* REEVE, 1856, *Cypraea (Bernaya) fultoni* SOWERBY, 1903 and others, mostly of unknown habitat. Along with some additional conchological rarities, the mitre was obtained in January 1962 by Mrs. Helen Boswell, who was at that time living in Johannesburg.

Unable to identify this unfamiliar mitrid from the literature and comparative material available to her, Mrs. Boswell forwarded it to Mr. S. P. Dance at the British Museum (Natural History), who some months later sent it on to me at Mrs. Boswell's suggestion. Mr. Dance's letter accompanying the shell stated that nothing like it existed in the collections at the British Museum, and that after a thorough search there he was now convinced it must be an undescribed species.

In September 1962 Mrs. Boswell had the opportunity to visit the British Museum personally, at which time she also carefully looked through the *Mitra* collection without being able to locate a specimen resembling her own, thus verifying Mr. Dance's earlier conclusion that it was probably an unknown species. Meanwhile, I had been searching through all the specialized literature on Mitridae available to me, as well as checking other collections — always with the same result. A few possibilities came to mind while I was studying the type figures of certain species unfamiliar to me; Mr. Dance very kindly rechecked these in the British Museum's type collection and eliminated them a second time, stating emphatically that they were quite different from Mrs. Boswell's shell.

Although they have done more work on this problem than I have, both Mrs. Boswell and Mr. Dance have requested that I describe the species, since it comes within the scope of my particular interest. We realize it is not ordinarily considered good malacological practice to describe a new species from a unique specimen, especially

a dead one from an unknown locality — but the fact that the incomparable mollusk collection at the British Museum, which probably houses at least three-fourths of the type material in Mitridae, has on two occasions been thoroughly searched for a similar species without success, and further, that nothing like it can be found in existing literature, make the deviation from the unwritten rule in this case seem justifiable. It therefore gives me a great deal of pleasure to describe the newly-discovered form as

Mitra (Mitra) boswellae J. CATE, spec. nov.

(See Plate 28, figures 1, 2)

Shell large (70.5 mm long, 24.1 in greatest diameter, 38.8 mm aperture length), smooth; apex white, slightly eroded; 7 post-nuclear whorls convex, shining; sutures impressed and slightly crenulated. Early whorls finely spirally puncto-striate; spiral punctations obsolete on last three whorls except immediately below the sutures, where 3 to 4 faint impressed lines may be seen.

Aperture longer than the spire; outer lip smooth, though chipped posteriorly and broken off at abapical end. Columella with four strong oblique folds and one weak fold abapically; columellar lip thin, translucent.

Color of shell generally rusty-brown, with pale mauve irregular patches and smooth, narrow spiral lines of a deeper rust-brown at more or less regular intervals. The brown lines coincide with some of the impressed punctate striae, except where these become obsolete; possibly in live-collected specimens all of the brown lines may be punctate. The aperture is a uniform medium beige color.

The type locality of *Mitra boswellae* is off Durban, Natal, southeast Africa (29° 51' So. Lat., 31° 00' E. Long.); however, when living specimens are found it may be necessary to designate a different type locality, more appropriate for this mollusk, rather than its predator fish.

The holotype has been deposited in the type collection of the South African Museum, Capetown, where it is catalogued as S. Afr. Mus. Reg. no. A 29799.

This unique shell seems to be in a fairly good state of

preservation, though without additional material for comparison it is impossible to know whether its color and pattern are typical of those in living animals, and whether the surface ornament may have become eroded through contact with the stomach fluids of the fish. There are two or three unidentified small barnacles and a minute coral growth within the abapical end of the aperture, which would indicate that the specimen may have been dead when ingested by the fish; it is not possible to tell how long it had been dead nor how long it was retained in the fish stomach — and both these circumstances could have an important influence on the condition of the specimen. The fishes generally acknowledged as predatory on the rare molluscan forms already mentioned are migratory species with relatively wide-ranging habits of travel; furthermore, the fishes themselves are rare enough that their usual migratory patterns have not been established and therefore no accurate surmise may be made as to where the mollusks were picked up.

There are only three species even remotely comparable to *Mitra boswellae* that are figured in the various monographs on Mitridae. These are *M. nubila* (GMELIN, 1791) (*M. versicolor* MARTYN, 1784), *M. nebulosa* REEVE, 1844 (non BRODERIP, 1836), and *M. bretteinghami* E. A. SMITH, 1906 (*M. propinqua* SOWERBY, 1874, non A. ADAMS, 1853). Mr. Dance has compared *M. boswellae* with the first two of these; his reply states "I have checked on *Mitra versicolor* MARTYN — figures and specimens so-labelled in B. M. Coll. — it is not the same as Mrs. B's shell and not really very similar either. It is not *M. nebulosa* BROD. either. In fact it's like nothing in our collections as far as I can see. As such a large shell would not be easily overlooked in collections or in the literature it would indicate a n. sp."

I compared *Mitra boswellae* with a fine example of *M. bretteinghami* in the collection of E. W. Ulrich of Long

Beach, California, and found it different from that species also, being less obese than *M. bretteinghami*, with a smoother and less flaring lip, and with a more patchy, map-like pattern, whereas *M. bretteinghami* has a wavy, strigate pattern.

I am honored by the compliments implicit in having been consulted regarding this problem, and am grateful to both Mrs. Boswell and to Mr. Dance for allowing me the privilege of collaborating with them.

LITERATURE CITED

ADAMS, ARTHUR

1853. Descriptions of fifty-two new species of the genus *Mitra* from the Cumingian Collection. Proc. Zool. Soc. London, pt. 19: 132 - 141 (29 June 1853)

BRODERIP, W. J.

1836. (*No title!*) Proc. Zool. Soc. London for 1835, Pt. 3: 193 - 198. (April 8, 1836)

* GMELIN, J. F.

1791. Caroli Linnaei systema naturae per regna tria naturae. Editio decima tertia. Leipzig, vol. 6.

* MARTYN, THOMAS

1784. The universal conchologist.

REEVE, LOVELL A.

- 1844 - 1845. Conchologia Iconica. Monograph of the genus *Mitra*. 10: pls. 1 - 39

SMITH, EDGAR ALBERT

1906. Notes on some species of Mitridae, with the description of *M. Bretteinghami*, n. sp. Proc. Mal. Soc. London 7 (3): 124 - 125

SOWERBY, GEORGE BRETtingham

1874. Thesaurus Conchyliorum. Monograph of the genus *Mitra*. 4: 1 - 46; pls. 1 - 28.

* denotes a bibliographic reference not seen in the original

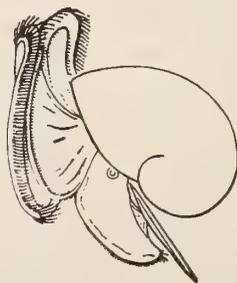




Figure 1 a

Figure 1 b

Ventral and dorsal aspects of
Mitra (Mitra) boswellae J. CATE, spec. nov.



The Cowrie *Mauritia eglantina* (DUCLOS, 1833) in Fiji

BY

FRANZ ALFRED SCHILDER

AND

MARIA SCHILDER

University of Halle, German Democratic Republic

(1 Map)

MR. WALTER O. CERNOHORSKY, Vatukoula, Fiji, was so kind to send us, since 1961, about 2500 cowries collected by himself on the reefs surrounding Vitilevu, the largest island in the Fiji Islands. Most shells contained the animals well preserved in alcohol so that we could ascertain the sex of adult specimens and study the features of the radula.

Mauritia (Arabica) eglantina (DUCLOS, 1833) is the most frequent species in these collections, represented by 647 specimens, 548 of which are adult with the sex well recognizable. This great number justifies a special study of variation by statistical methods.

Our map shows the exact place of 12 localities from which Mr. Cernohorsky has sent us satisfying numbers of cowries. In Table 1 these 12 localities have been listed in

a counter-clockwise sequence, beginning with the east coast of the island of Vitilevu and ending with the small island of Vatulele about 20 miles off its south coast.

We did not think it necessary to publish the sum of each frequency distribution, nor the standard error of each mean, though we have calculated these figures. In discussing the mathematical significance of differences we have indicated the index t , which expresses the difference divided by its mean error, so that in our large populations

$t > 2.0$ indicates $P < 0.05$

$t > 2.6$ indicates $P < 0.01$

$t > 3.0$ indicates $P < 0.0027$

$t > 3.4$ indicates $P < 0.001$

(see BANCROFT, 1959, p. 174); differences with $t > 3.0$ should be regarded as absolutely significant.

Table 1

column number	1	2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
indicating	sp.	%	%	♀	♂	♀%	L	L%	BL	LT	CT	col.	mar.	spi.	pen.	rows	med.
E Lodoni	50	19	19	23	25	48	49.2	97	58.5	<i>u.5</i>	<i>t.5</i>	3.5	3.7	4.5	51.4	12.0	8.2
N Vitilevu Bay	132	35		62	50	55	44.2	87	59.0	<i>u.1</i>	<i>t.3</i>	3.3	3.9	4.2	54.2	12.0	8.1
Nananu-i-ra	90	37		44	40	52	50.4	99	59.1	<i>u.2</i>	<i>t.5</i>	3.1	3.5	4.3	50.6	12.6	8.2
Caboni (No. 2)	17	31	} 36	9	3		55.4	109	58.9	<i>u.7</i>	<i>t.4</i>	3.3	3.7	4.6	(50.0)	(11.5)	(8.0)
Manava Island	18	14		5	11		56.1	110	58.4	<i>u.5</i>	<i>t.9</i>	3.2	3.3	3.6	54.4	12.3	8.1
Vatia Wharf	191	44		81	67	55	57.1	112	58.5	<i>u.5</i>	<i>t.7</i>	3.2	3.2	4.5	47.7	11.7	7.8
Twin Rocks	11	37		5	6		49.1	96	59.2	<i>u.7</i>	<i>t.5</i>	3.2	3.5	4.8	(49.2)	(11.1)	8.2
W Vuda Point	91	19	} 20	47	29	62	47.5	93	58.8	<i>u.9</i>	<i>u.0</i>	3.4	3.2	4.5	45.2	12.5	7.8
Momi	10	33		5	5		48.1	94	60.1	<i>u.4</i>	<i>t.1</i>	4.0	2.9	3.9	(58.0)	12.1	8.4
S Cuvu	28	17		10	15		51.8	102	58.6	<i>u.1</i>	<i>t.2</i>	3.3	3.0	3.3	42.7	12.2	7.0
St. Annes-on-the-Sea	6	3	} 8	4	2		(55.0)	108	(58.5)	(<i>u.0</i>)	(<i>u.2</i>)	3.3	(3.0)	4.8	(57.7)	(11.8)	(8.0)
Lomalagi	—	0		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vatulele Island	3	14		—	—	—	(47.3)	93	(58.0)	(<i>t.4</i>)	(<i>r.3</i>)	(4.0)	(2.3)	4.0	—	—	—
Total	647	26		295	253	54	50.9	100	58.7	<i>u.4</i>	<i>t.6</i>	3.3	3.5	4.3	50.1	12.1	8.0

DISTRIBUTION AND FREQUENCY

Mauritia eglantina spreads from the Ryukyu Islands and North West Australia to Samoa so that it reaches in

Fiji almost its eastern limit. Nevertheless it is the most frequent species collected in Vitilevu, as it represents about one quarter of the cowries sent us by Mr. Cernohorsky. In various localities, however, the relative frequency of *M.*

eglantina is very different, varying from total absence in Lomalagi (among 89 cowries) to almost one half of all cowries (Vatia Wharf).

This fact has been illustrated by columns 1 and 2 of Table 1: column 1 gives the number of *Mauritia eglantina* present in each population, whereas column 2 expresses this in per cent of the sum of all cowries we have received from the locality.

Sixten Bock in 1917).

The centre of abundance of *Mauritia eglantina* evidently lies on the north coast of Vitilevu, where the environments of Vatia Wharf seem to be most favorable for this species; on the east and west coasts its frequency decreases, and on the south coast *M. eglantina* generally is less than a quarter as frequent as on the north coast, though it occurs around the entire island (Namuka, *leg.*

SEX

In Table 1, columns 3 and 4 indicate the number of female and male specimens respectively; the difference between the sum of the two sexes and the figure given in column 1 is due to young animals and empty shells. Column 5 expresses the number of females in per cent of the sum of both sexes; in populations containing too few *Mauritia eglantina* to yield a statistically reliable figure, the percentage of females (easily calculated) has been replaced by a point. The number of females slightly exceeds that of males, as we noted before in other cowrie species; only the population of Lodonu seems to be contradictory.

SIZE

The length of the shells has been measured in tenths of a millimeter; the mean length of adult shells (those of unknown sex included) has been indicated in column 6 of Table 1.

A rather large difference between the means of several populations is noteworthy: in fact the difference between Vitilevu Bay and Vuda Point, between Nananu-i-ra and Vatia Wharf, and between Vitilevu Bay and Vatia Wharf are mathematically significant ($P < 0.001$) as the index t is 6.6, 12.4, and even 28.3, respectively; several other differences, however, cannot be proved statistically. Similar differences in size have also been reported for other cowrie species from Fiji by ourselves as well as by CERNOHORSKY (1963) who suggests them to be caused by food supply. Additionally, there seems to exist also a general tendency of growing large in some regions: column 7, which contains the means expressed in per cent of the total mean 50.9 mm, shows that the populations of *Mauritia eglantina* living in the north east of Vitilevu and along its west coast are small, while those living on the south coast and particularly in the north western

localities exceed the average size: these facts may possibly be an indication that currents are also responsible for the differences in size. Specimens from reefs far off the coast of Vitilevu do not differ constantly from those living at the coasts themselves: *M. eglantina* from Vatulele Island is small, that from Manava Island is large.

The variation in size within each population is rather large; we limit ourselves to indicate the variation of the four most numerous populations in classes of 5 mm (e. g. 40 = 38 to 42 mm):

millimeters:	40	45	50	55	60	65	70	75
Vitilevu Bay	43	71	15	3	—	—	—	—
Nananu-i-ra	—	21	48	18	2	1	—	—
Vatia Wharf	—	—	30	72	72	13	3	1
Vuda Point	10	40	27	14	—	—	—	—
Total	59	159	175	143	92	15	3	1
including:								
females	24	67	82	73	42	6	1	—
males	27	72	70	48	31	5	—	—

The two lowermost lines indicate that there is a slight difference in size between the sexes: as in most cowries, the females are slightly larger than the males, the difference between the means (51.06 and 50.05) is, however, not significant ($t = 1.9$); in these four large populations the value of t varies only between 0.8 and 2.1, but the females are always the larger sex.

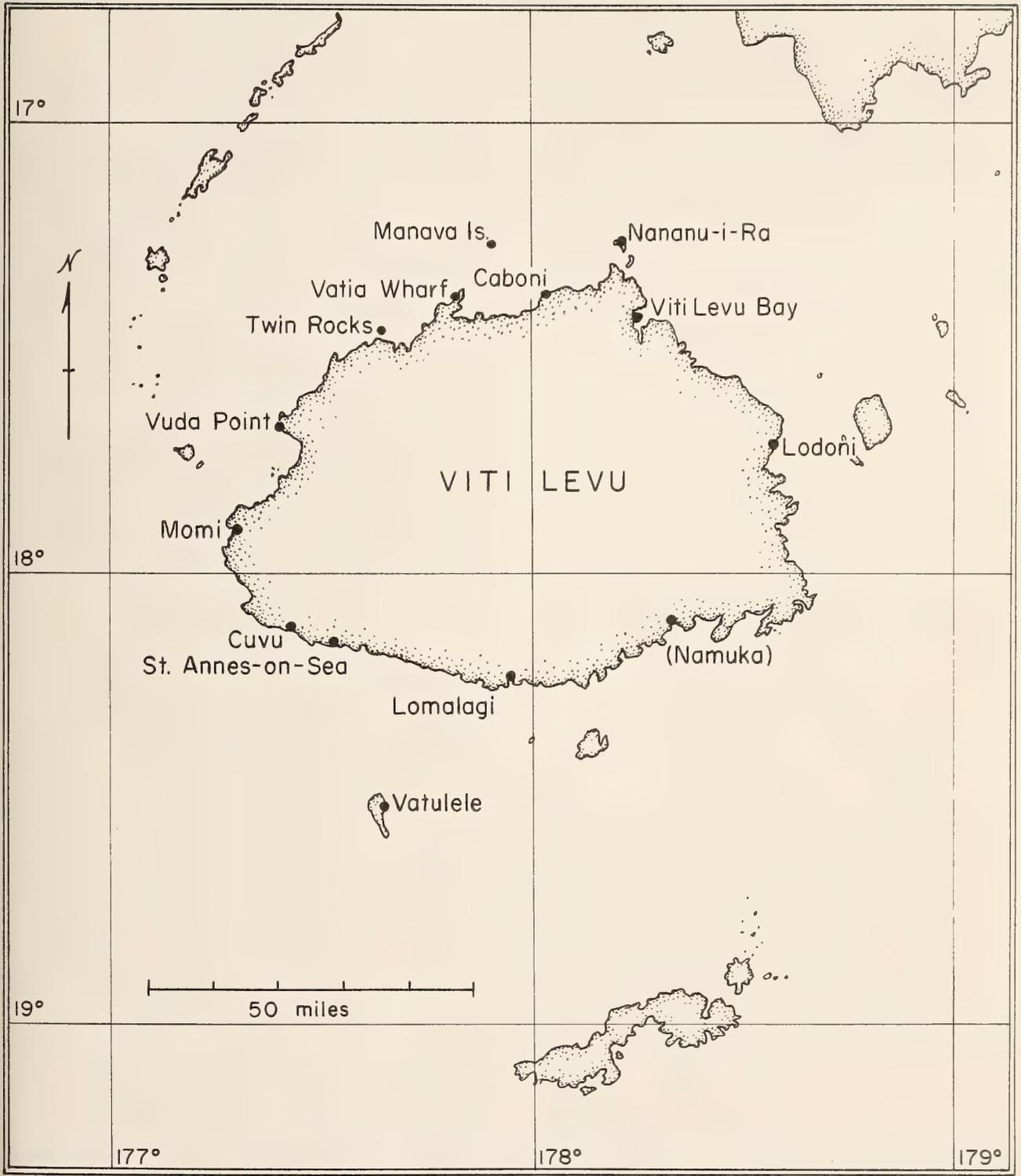
BREADTH

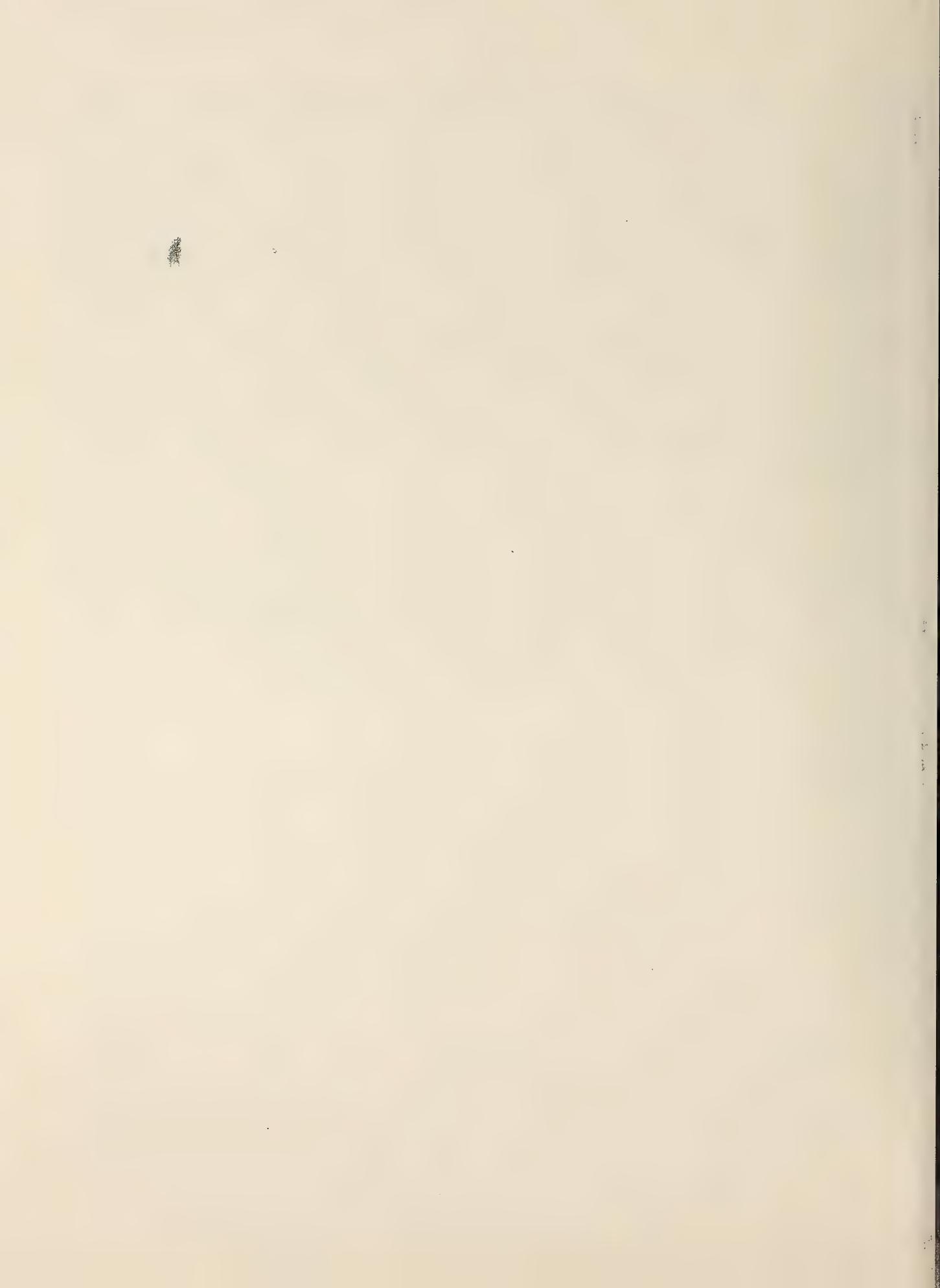
The relative breadth, expressed in per cent of the length, has been indicated in column 8 of Table 1. The differences between populations are rather small, though the shells from Manava Island and from Vatia Wharf are rather narrow, those from Momi rather broad: this fact may be influenced by the length of the shells, as in cowries generally large specimens tend to be less broad than small shells. The total variation of relative breadth in 627 adult shells is rather small, so that the general appearance of *Mauritia eglantina* is fairly uniform; the difference of sexes, however, is obvious:

relative breadth:

	53	54	55	56	57	58	59	60	61	62	63	64	65
Total	1	9	15	43	92	115	135	101	77	29	8	1	1
including:													
♀ ♀	—	2	4	13	26	44	65	63	52	19	5	1	1
♂ ♂	1	6	10	27	53	61	49	27	14	5	—	—	—

The difference between the mean of females (59.3) and that of males (58.0) is significant ($t = 9.2$), as are the differences also in the three largest populations ($t = 3.5$ to 5.3).





DENTITION

The relative closeness of labial teeth (LT) and of columellar teeth (CT) has been recorded in column 9 and 10 of Table 1, respectively, by letters with decimal figures according to SCHILDER, 1958; there is no significant difference between populations. The total variation and that of sexes is as follows:

class:	p	q	r	s	t	u	v	w	x	y	z
Total: LT	—	2	7	21	125	173	207	80	26	2	2
Total: CT	1	10	37	103	154	166	104	59	9	1	1
LT: ♀♀	—	1	2	10	56	82	99	34	9	—	2
LT: ♂♂	—	1	3	7	50	71	75	35	10	1	—
CT: ♀♀	—	4	11	46	67	81	53	30	2	—	1
CT: ♂♂	1	4	19	43	71	56	34	18	6	1	—

The teeth of both lips are rather identical in closeness, as the mean of each lip is about *u* (*u*.41, *t*.60). The sexes, however, show a curious discrepancy: the closeness of labial teeth is absolutely identical in both sexes (mean = *u*.40), but the columellar teeth of females (*t*.72) are distinctly closer than those of males (*t*.47), though the difference hardly can be called significant (*t* = 2.0).

COLOR

The color of the dorsal markings has been classified in six degrees (see SCHILDER, 1964, table 2): 1 = pale fulvous; 2 = fulvous; 3 = fulvous brown; 4 = chestnut; 5 = dark brown; 6 = blackish. The variation is rather slight, as the Fijian specimens vary from class 2 to class 4 only, and the means of populations vary from 3.1 to 4.0, according to column 11 of Table 1. The total and sexual variation are as follows:

class	1	2	3	4	5	6	Mean
Total	—	81	333	157	44	—	3.3
including:							
females	—	38	153	78	21	—	3.3
males	—	33	144	58	15	—	3.2

Generally, paler shells (class 2 to 3) are slightly more frequent than darker ones. There is no sexual difference in this character.

The color of the base varies from yellowish or pinkish white to dark greyish brown or bluish grey; the frequent differences between the two lips and the multiplicity of tints make a statistical treatment of this character almost impossible.

DORSAL MARKINGS

In adult *Mauritia eglantina* the dorsum is covered by brown longitudinal lines which become interrupted by

roundish lacunae; in these lacunae the transversal zones and the zigzag lines of young shells are still better visible than between the longitudinal striae. According to SCHILDER *et al.*, 1964 (Table 2), we have distinguished six classes: 1 = lacunae almost absent so that the dorsum is striate; 2 = lacunae scarce; 3 = lacunae less scarce, but striae still slightly predominant; 4 = the areas covered by lacunae are about equal to the striate areas; 5 = lacunae more numerous or larger; 6 = lacunae predominant, striae reduced and often dilacerate. According to column 12 of Table 1 the populations are similar to each other, except the ten shells from Momi in which the striae are more predominant than in other populations. The total and the sexual variation are as follows:

class	1	2	3	4	5	6	Mean
Total	44	173	41	238	36	80	3.47
including:							
females	23	72	24	111	21	37	3.51
males	15	74	13	103	12	31	3.47

The constant irregularity in these distributions of frequency has been caused by using the main classes 2, 4, and 6 more frequently than the intermediate classes 3 and 5. In our *Mauritia eglantina* the striae occupy a slightly larger area than the lacunae; the sexual difference must be regarded as accidental (*t* = 0.3).

SPIRE BLOTCH

In *Mauritia eglantina* there is a dark brown blotch on the labial border of the spire; it is said to be characteristic for this species as it is in *M. histrio* (GMELIN, 1791), *M. mappa* (LINNAEUS, 1758), and *M. grayana* SCHILDER, 1930, while it is always absent in other allied *Mauritia*, viz. *M. arabica* (LINNAEUS, 1758), *M. maculifera* SCHILDER, 1932, *M. depressa* (GRAY, 1824), and *M. scurra* (GMELIN, 1791). The size of this blotch has been classified in six degrees (according to SCHILDER, 1964, Table 2): 1 = absent; 2 = obsolete; 3 = small; 4 = rather large; 5 = typically large; 6 = extremely large. Column 13 of Table 1 shows the differences of populations; the total and the sexual variation are as follows:

class	1	2	3	4	5	6	Mean
Total	12	21	79	182	277	47	4.35
including							
females	3	8	37	87	130	24	4.40
males	7	8	28	73	117	17	4.34

The most frequent class is 5 ("normal") in both sexes, though the mean tends towards the class 4 on account of the five per cent of adult shells in which the spire blotch is absent or obsolete.

SHELL ABNORMALITIES

Among the 647 *Mauritia eglantina* from Fiji there are two slightly subrostrate shells (Vitilevu Bay, Vuda Point) and one rather melanistic female (Momi), but no truly melanistic rostrate shell has been sent us by Mr. Cernohorsky from Fiji, whereas such shells are rather frequent in New Caledonia. One male from Nananu-i-ra is rather pellucid in texture. Four shells are pathologically suffused by green enamel, and one shell by greyish enamel, each from different localities. Besides, particles of mud are enclosed in the dorsal enamel, or forming whitish tiny holes in the surface of at least 25 specimens from 6 localities, chiefly from Vatia Wharf and from Lodoni: 20 such specimens are females which number far exceeds the probability of random distribution. In one male from Vatia Wharf the dorsum is much worn like in beach shells though the animal was living when collected; three live specimens show the juvenile zigzag markings uncovered though the lateral and basal callosities are at least as developed as in other adult shells. One female from Vitilevu Bay shows a dark blotch on the inner lip, comparable to that of *M. maculifera* SCHILDER. In many shells there are the usual holes, traces of bites, or fractures suffered in juvenile stages, all wounds healed during the animal's later life; one shell from Vuda Point shows the columellar margin inflated, though to a lesser degree than figured by SCHILDER, 1936, figure 3.

YOUNG SHELLS

Among the 647 shells sent by Mr. Cernohorsky, 26 are

dozens	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Total	1	2	5	6	9	35	90	124	102	52	15	4	1	—	—	—	1
including:																	
females	1	—	3	2	4	7	25	61	71	46	12	4	1	—	—	—	1
males	—	2	2	4	5	28	65	63	31	6	3	—	—	—	—	—	—

But according to column 15 of Table 1, the means of populations vary rather little around the total mean of 12.06 (i. e. exactly 145 rows), viz. from 11.7 to 12.6 dozens (if one omits the figures put in brackets as these populations include less than ten complete radulae); however, the difference between the two extremes (Vatia Wharf and Nananu-i-ra) should be regarded as significant ($t = 3.4$).

The females possess more rows than the males, as the difference between the total means (12.67 and 11.46) is very significant ($t = 8.2$), and it is also mostly significant in each large population, viz.:

mean of	females	males	<i>t</i>
Vitilevu Bay	12.24	11.59	2.0
Nananu-i-ra	13.45	11.59	5.5
Vatia Wharf	12.17	11.19	3.1
Vuda Point	12.91	11.68	3.2

not fully grown (i. e. 4 per cent); following SCHILDER (1938, page 123) they should be classified as: 7 subjunior, 4 junior, 14 juvenis and 1 perjuvenis. Besides there are 4 oliviform shells not included in the total mentioned above.

PENIS

The length of the penis, expressed in per cent of the length of the shell, varies from about 20 to 85 per cent in 240 specimens, as follows:

%	20	25	30	35	40	45	50	55	60	65	70	75	80	85
♂ ♂	2	—	6	11	30	54	60	28	20	17	2	6	2	2

This surprisingly considerable variation may be caused partially by different erection of the penis at the moment of the death of the animal in alcohol, partially by different times elapsing between collecting, preserving, and examining the specimens. The mean, however, undoubtedly is 50.1 per cent of the shell length; the local differences of means are relatively small (see column 14, Table 1).

ROWS OF THE RADULA

According to SCHILDER, 1960 and 1961, the number of rows of the radula has been expressed in dozens (e. g. 5 = 54 to 66 rows); it is evidently independent from the size of the shell. The range of variation is rather large, ranging from 5 to 21 dozens (the single specimen with 21 dozen rows may be pathological):

MEDIAN TOOTH

The relative size of the median tooth of the radula has been expressed, as in previous papers (SCHILDER, 1960) by an index representing 200 times the maximum transverse diameter of the median tooth, divided by the length of the shell. The variation of this index is as follows:

index	4	5	6	7	8	9	10	11
Total	1	8	24	158	185	92	48	9
including:								
females	—	1	19	137	112	12	—	—
males	1	5	5	21	73	80	48	9

The local means (column 16, Table 1) generally approach the total mean (7.96) rather closely so that the differences between the populations are mostly not signi-

ficant; however, the difference between Nananu-i-ra and Vatia Wharf or Cuvu is significant, as $t = 3.0$ and 5.4 respectively.

The sexual differences in the size of the median tooth are very considerable: the median of the females is much narrower than that of males, as the two means (7.39 and 8.63) differ in a highly significant way ($t = 15.1$); the difference becomes also distinctly significant at least in relatively large populations, for example:

index	females	males	t
Vitilevu Bay	7.66	8.82	6.7
Nananu-i-ra	7.68	8.89	7.7
Vatia Wharf	7.27	8.50	8.1
Vuda Point	7.20	8.62	6.7

ROWS AND MEDIAN

There is a negative correlation between the number of rows and the size of the median tooth, as the number of rows is larger in females than in males, but the median tooth is less broad in females than in males although of similar shape. It may be illustrated by Table 2 in which the figures for females and for males have been separated by the symbol / (the aberrant specimen with 21 dozen rows and the median index 7 has been omitted):

terized by a reduced radular ribbon which shows exceptionally few rows and very small medians: we suspect them to be pathological. If it is true, the normal range of variation is less wide: 5 to 11 instead of 4 to 11 relative to the size of the median tooth, and 8 to 17 instead of 5 to 21 relative to the number of rows.

CORRELATION BETWEEN POPULATIONS AND BETWEEN CHARACTERS

All figures in Table 1 can also be expressed in per cent of the mean of *Mauritia eglantina* in Fiji, as we have done in column 7 with regard to the length of the shells. Table 3 contains the positive and negative differences between these percentages and 100, so that positive figures indicate figures exceeding the total mean, while negative figures indicate lesser values. We have limited Table 3 to the ten populations with sufficient numbers of specimens; figures calculated from insufficient material have been put in brackets [].

As we have stated above, the length of shells (column 6) from the north (D to F, i. e. Caboni to Vatia Wharf) is large. The breadth (8) is rather similar in all localities. The teeth (9 to 10) tend to be close and numerous in the north-east (E to H). The dorsal color (11) is darker in the east (A to B) and west (H to I) than elsewhere. The

Table 2

		Index of the Median Tooth							
		4	5	6	7	8	9	10	11
dozens of rows	17	.	.	.	1/—	.	.	.	.
	16	.	.	.	4/—	.	.	.	.
	15	.	.	1/—	5/2	6/—	—/1	.	.
	14	.	.	.	22/1	23/1	1/3	—/1	.
	13	.	.	5/—	34/4	28/12	4/12	—/3	.
	12	.	1/—	3/1	26/3	29/24	2/23	—/12	.
	11	.	.	2/1	10/4	9/16	4/26	—/14	—/4
	10	.	.	.	6/2	1/5	—/5	—/13	—/3
	9	.	1/1	2/—	1/1	.	—/1	.	—/2
	8	.	—/1	1/2	1/1	.	.	.	.
	7	—/1	—/1	3/—	.	.	.	.	.
6	.	—/2	.	.	.	.	.	.
5	.	1/—	.	.	.	.	.	.

One will observe the negative correlation mentioned above, in that the females cluster on the left in Table 2 (classes 7 to 13), the males in the right center (classes 9 to 11); but off from this main sequence of typical specimens there are about 16 specimens listed in the left lower corner (mean about in classes 5 to 7). These 16 specimens originating from various localities are charac-

dorsal lacunae (12) become more prevalent in the north-east (A to D). The spire blotch (13) is rather small in E and in I to K. The penis (14) is relatively long in the north-east (A to E) and in I. The average number of radular rows (15) varies irregularly, but the size of the median tooth (16) varies in a way comparable to the penis (14).

Table 3

column no.	6	8	9	10	11	12	13	14	15	16
indicating:	L	BL	LT	CT	col.	mar.	spi.	pen.	rows	med.
A Lodon	-3	0	0	-1	+6	+6	+5	+3	-1	+2
B Vitilevu Bay	-13	0	-1	-2	0	+11	-2	+8	-1	+1
C Nananu-i-ra	-1	+1	-1	-1	-6	0	0	+1	+4	+2
D Caboni (No. 2)	+9	0	+1	-1	0	+6	+7	[0]	-5	[0]
E Manava Island	+10	+1	0	+2	-3	-6	-16	+9	+2	+1
F Vatia Wharf	+12	0	0	+1	-3	-9	+5	-5	-3	-2
G Twin Rocks	-4	+1	+1	0	-3	0	+12	[-2]	[-8]	+2
H Vuda Point	-7	0	+2	+2	+3	-9	+5	-10	+3	-8
I Momi	-6	+2	0	-3	+21	-17	-9	[+16]	0	+5
K Cuvu	+2	0	-1	-2	0	-14	-23	-15	+1	-13

Therefore, some adjacent populations seem to be linked by a common development of various characters. The characters themselves, however, seem to be independent from each other, with the following exceptions:

There is some parallelism in closeness of labial and columellar teeth (9 and 10), as one would expect; but there is also some parallelism between the size of the penis (14) and of the median tooth of the radula (16), indicating that the size of the whole animal (represented by these two characters) is not constant in comparison with the shell, but there are populations with relatively small or large animals within shells of equal size.

COMPARISON WITH PENRITH ISLAND

In our paper on the cowries of Penrith Island off Mackay, Queensland (SCHILDER *et al.*, 1964) we have compared 56 *Mauritia eglantina* with the mean of 272 specimens from Fiji, all localities included. Since we wrote this paper last year, the number of *M. eglantina* from Fiji has been more than doubled, but the means of characters remained practically unchanged. Now we can investigate which characters of the *M. eglantina* from Penrith Island lie amidst the means of various Fijian populations, and which characters exceed the extreme means of any Fijian locality.

To the former group belong the percentage of sexes, the average length of shells, the dorsal markings, and the size of the median tooth of the radula, which four characters may be called identical in Penrith Island and in Fiji.

In seven characters, however, there is a distinct difference between animals from Penrith Island and from Fiji: With regard to the closeness of teeth, the less close labial and the more close columellar teeth of the population from Penrith Island exceed the limits of all populations from Fiji, but each with one exception concerning the poorest Fijian series (Vatulele Island and St. Anneson-Sea, respectively). With regard to the other characters,

however, there is no exception: *Mauritia eglantina* from Penrith Island are less broad, slightly darker, with the spire blotch less accentuated, the penis relatively much shorter, and the rows of the radula more numerous than in any population from Fiji.

However, the single population from Penrith Island examined so far does not reveal general differences between *Mauritia eglantina* from Queensland and from Fiji: it is still necessary to examine several populations from Australian waters, such as we were fortunate enough to receive from Vitilevu through the kindness of Mr. Cernohorsky.

LITERATURE CITED

- BANKROFT, HULDAH
1959. Introduction to biostatistics. Reprint (New York): 210 pp.; 44 tables; 37 diagrams
- CERNOHORSKY, WALTER OLIVER
1963. Environments and size variation in Fiji. *The Cowrie* 1 (5): 73-74
- SCHILDER, FRANZ ALFRED
1936. Some interesting monstrosities in Cypraeidae. *Journ. of Conch.* 20: 222-223; 1 pit.
1958. Bezeichnung der Zahndichte der Cypraeacea. *Arch. Molluskenk.* 87 (1-3): 77-80; 3 tables.
- SCHILDER, FRANZ ALFRED, & MARIA SCHILDER
1938. Prodrôme of a monograph on living Cypraeidae. *Proc. Malacol. Soc. London*, 23 (3): 119-180; (1939) 23 (4): 181-231; 1 text fig.; 9 maps.
1960. Geschlecht, Radula und Schale der Porzellanschnecken. *Naturwissenschaften* 47 (13): 309-310; 1 diagram
1961. Zur Kenntnis der Cypraeidae. 3. Länge und Reihenzahl der Radula. *Arch. Molluskenkunde* 90 (1-3): 33-42; 5 tables; 2 diagrams
- SCHILDER, FRANZ ALFRED, MARIA SCHILDER & GARFIELD HOUSTON
1964. The cowrie fauna of Penrith Island. *The Veliger* 6 (3): 155-161; 4 tables; 1 text fig. (1 Jan. 1964)

Snails and Other Invertebrates from Indian Village Sites, Principally Contra Costa County, California

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IN 1957 THE SENIOR AUTHOR described *Speleodiscoides spirellum*, a new snail genus and species from North America (SMITH, 1957). The description was based upon specimens collected in two limestone caves in Amador County, California, by speleologists of the Stanford Grotto National Speleological Society. The typical adult specimen has a small, tightly-coiled, flat, whitish shell with six to seven whorls and is one-quarter of an inch in diameter. No living snails of this species have as yet been found.

The species is of special interest because it had been collected sparingly in the San Francisco Bay region as early as 1872 by the western naturalist C. D. Voy, and later by the ornithologist W. Otto Emerson, and the conchologist Professor William J. Raymond of the University of California. In at least one instance shells were reported in an Indian mound (SMITH, 1957: 37). There are no records of occurrence between the localities reported in the San Francisco Bay region and those in the limestone caves of Amador County — a curious instance of discontinuous distribution that is not usual with species of California land snails.

The finding of *Speleodiscoides spirellum* recently during the excavation of three Indian village sites in Contra Costa County by the junior author, an archeologist, and her colleague, David A. Fredrickson, therefore seems worth reporting, considering the relative rarity of shells of the species in museum collections. Data from the three archeological sites are as follows:

CCo-309. Site in Walnut Creek, Contra Costa County, California, on the east side of Tice Creek, two miles from downtown Walnut Creek. The specimens were collected from a special excavation unit, S-36, that received fine screening ($\frac{1}{8}$ inch mesh) and laboratory sorting. The pit yielded cultural material to about 24 inches. The remains

of a child's cremation were recovered in a sub-midden pit in S-36, which was located in an area where other cremations and burials were found. Grave offerings of shell artifacts, most of them burned, consisted of *Olivella biplicata*, *Saxidomus nuttalli*, and *Haliotis sp.* beads and ornaments (the site is archeologically dated in the Late Horizon, 1500 to 1790 A. D.). Remains of mollusca used for food were plentiful in the midden, the most common being *Mytilus edulis*, *Macoma nasuta*, and *Ostrea lurida*.

Of the total of ten snails recovered in S-36, three were found at 12 to 18 inches, one at 18 to 24 inches, five at 24 to 30 inches (and here we entertain the possibility that they were dispersed cremation material) and one in the sub-midden cremation material itself at 30 to 35 inches below surface.

The snails were also observed in other cremation and burial areas during excavation, but were not collected. In other parts of the site, where such features were absent, the snails were not recorded as being present.

The ten dead, bleached *Speleodiscoides spirellum*, adult or nearly so, were accessioned in the California Academy of Science, Department of Geology Collection, Loc. No. 38823. Other land snails taken from unit S-36 include one dead adult specimen of the small, carnivorous *Haplotrema durantei continentis* H. B. BAKER (C. A. S. Geology Coll. Loc. No. 38822), a single dead shell of *Helminthoglypta nickliniana bridgesi* (NEWCOMB), two dead adult *H. diaboloensis* (COOPER), and several dead juveniles, probably of one or both of these latter species. Also identified were examples of the common sessile barnacle, *Balanus nubilis*, which were observed attached to many of the *Mytilus* shells mentioned above.

CCo-308. Site at Alamo, on the west side of the then existing channel of San Ramon Creek, Contra Costa

County, California. While numerous land snails were seen during excavation, only a sample was retained for analysis and identification.

The material from this small sample consisted of two fragments of the freshwater mussel, *Margaritifera margaritifera falcata* (GOULD) and three small dead, bleached land snails. Two of the snails are *Speleodiscoides spirellum* (C. A. S. Geol. Coll. Loc. No. 38822); the third is a very young *Helminthoglypta* cf. *H. diabloensis* (COOPER).

The snails were recovered in a burial area of the site at depths from 45 to 60 inches below the surface (Note: At least 12 inches at the surface was recent alluvium. The archeological context provides a date of about 100 B. C. to 300 A. D.).

CCo-30. The third site in the same general area is located one-half mile south of CCo-308 and is also in the community of Alamo. Sorting of the shell refuse produced five dead shells of *Speleodiscoides spirellum* (C. A. S. Geol. Coll. Loc. No. 38826). Three of the five were recovered in or near burials; one lay in the top 0 to 6 inch-excavation level; and the fifth was found in an area of concentrated food-shell debris.

Recovered also at CCo-30 were fragments of the whale barnacle (*Cryptolepas rachianecti* DALL), described in 1872 from specimens imbedded in the flippers of a California Gray Whale (*Eschrichtius glaucus*). The presence of these fragments in an Indian village in interior Contra Costa County presents an interesting archeological problem.

Also of interest is the occurrence of the dead shells of *Haplotrema durantei continentis* H. B. BAKER in fair quantity in an Indian village site (Lak-261), located two miles south of Lower Lake, near Copsey Creek, in Lake County, California. The site was excavated by Fredrickson in 1961; dating of the site has as yet not been completed. In this instance the shells were found in the $\frac{1}{8}$ inch screenings to a depth of 36 inches in a cemetery area. The frequency of occurrence of the shells generally decreased with depth. (These shells have also been accessioned in the C. A. S. Geol. Coll. Loc. No. 38824.)

The finding of dead snails in Indian village sites is cause for speculation. As MATTESON (1959) points out, one possible theory can be based on the fact that all snails need a certain amount of lime for building their shells. Therefore, they might gravitate naturally to a location where the lime content in the soil is greater. In an Indian village site containing the remains of marine and fluvial shells brought in for food, decoration, or whatever other purposes, the lime content would be higher than in the surrounding area. Land snail collectors nearly always find more interesting and better collecting in limestone areas. As the snails in question are not known ordinarily to be deep burrowers, even when in estivation, an explanation

for their occurrence as deep as five feet must be sought.

It is apparent that the smaller snail shells, which are delicate and light in weight, are late intruders in the sites. In the contexts described above they would have tended to disintegrate after any extended period of time unless a special situation existed leading to actual fossilization, which is evidently not found at the cited localities. At sites CCo-308 and Lak-261 shell beads and ornaments, deriving from the same depths as most of the snails, were found badly eroded; and these decorative items were made from much hardier shells.

If the occurrence of the snails at the depths reported is due to fortuitous causes, two possibilities can be suggested: 1) they fell down rodent burrows, and 2) they were transported by the re-working of the soil over a considerable period of years by small burrowing mammals. The high incidence of rodent activity in softer soils of archeological sites has often been noted in the literature.

It can also be suggested that the live snails used open burrows to reach specific types of localities as is indicated in the sites described above. However, it must be pointed out that exceptional care is taken both in the field and laboratory with material from burial and cremation areas. This special attention may weight the picture somewhat in favor of locating the small snails in these areas.

This occurrence of *Speleodiscoides spirellum* raises other questions for which answers need to be sought. Why is it, in a period of about ninety years, during which there has been more or less assiduous collecting of land snails in central California, that this species has been taken only four times, the present occurrence being the fifth? Why should it be so rare? Why should it turn up in such an assortment of widely separated localities? Why has it not yet been found living? Are we in this instance dealing with a relict genus and species that, for some unknown reason, has not been able to adjust to possible changes in ecological conditions and is practically at the point of extinction?

At least three facts about this rare shell can be stated with some confidence. One is that the shells found to date are not fossil, although earlier malacologists thought they might be. Another is that with more diligent collecting in the limestone areas of California's Mother Lode it possibly can be discovered alive. A third is that the species in all probability is indigenous and not adventitious. Nothing quite like it has ever been reported, at least from North America, although South American species seem to be close in appearance, if not definitely related morphologically.

Thanks are due to David A. Fredrickson, who supplied many of the archeological data and who reviewed the manuscript.

LITERATURE CITED

BAKER, FRANK COLLINS

1930. The use of animal life by the mound-building Indians of Illinois. *Trans. Illinois Acad. Sci.* 22: 41 - 64.

MATTESON, MAX R.

1953 a. Fresh-water mussels used by Illinoian Indians of the Hopewell culture. *The Nautilus* 66: 130 - 138; 67: 25 - 26.

1953 b. Land-snail shells found in a kitchen midden of Illinoian Indians of the Hopewell culture. *Trans. Illinois Acad. Sci.* 46: 208 - 211.

1959. Snails in archaeological sites. *Am. Anthropologist* 61 (6): 1094 - 1096.

SMITH, ALLYN GOODWIN

1957. Snails from California caves. *Proc. Calif. Acad. Sci.* 4th Ser., 29 (2): 21 - 46; pls. 1, 2. (28 January)

NOTES & NEWS

The Department of Invertebrate Zoology of the California Academy of Sciences

BY

ALLYN G. SMITH

Associate Curator of Invertebrate Zoology
California Academy of Sciences
Golden Gate Park, San Francisco 18, California

THE DEPARTMENT OF INVERTEBRATE ZOOLOGY of the California Academy of Sciences in San Francisco has established a new repository for type specimens of marine, land, and freshwater invertebrates preserved in alcohol or formalin. The need for such action became apparent upon reactivation of the Department in July, 1960, with responsibility for the curation and systematic arrangement of the Academy's large and steadily growing collection of invertebrates, including a number of types.

Preserved invertebrate type specimens of both primary and secondary rank are deposited in the new type series. Types are numbered serially, regardless of phylum, beginning with No. 1. A detailed card catalogue is maintained covering all pertinent data including citations to publications. Cards are filed alphabetically, by species, and include references to case and tray location.

Larger invertebrate types are curated in accordance with department standards in suitable-sized glass containers with a hard, plastic (or other) closure and a thin polyethylene insert to inhibit evaporation. Smaller specimens will be: (a) sealed permanently in glass tubing

with a contained label; or (b) placed in standard containers in long-style shell vials plugged with cotton and placed into the containers upside down.

Microscope slide mounts relating to invertebrate types are filed separately in standard plastic slide boxes, 100 slides to a box. These are stored with the slides horizontal to prevent possible drifting of the mount. Mounted serial sections of a type animal, or a part of it, will carry a single file number that has been assigned to the rest of the animal, if preserved separately.

Recent mollusk types preserved dry will continue to be deposited in the Academy's Geology Type collection. Invertebrate types, other than mollusks, which are preserved dry, will be given special storage treatment.

Specialists in invertebrate phyla are invited to deposit type specimens in the Academy's Invertebrate Type Series. They can have the assurance that their material will be handled and stored with care, with adequate provisions for future safety and security. Specimens in this Type Series may be studied by experts and qualified students upon advance arrangement with the Department's Curator.

This work is aided by N. S. F. grant GB-1535.

A. M. U.

Pacific Division

THE SEVENTEENTH ANNUAL MEETING of the American Malacological Union, Pacific Division, is to be held this year June 18 to 21 (Thursday to Sunday), inclusive, at Asilomar Conference Grounds, Pacific Grove, California. Already the program is beginning to take shape: a film is promised, on shellfish management in Europe; and two paleontologists who are taking part in marine expeditions this winter and spring have agreed to report on their experiences in the Indian Ocean and the Galapagos Islands.

The meeting is open to anyone interested in the study of mollusks, whether or not a member of the A. M. U. Reservation forms for housing may be obtained from the Secretary, Mrs. Lucille Zellers, 714 Elm Street, El Cerrito, California 95432; non-members should send her 50 cents for mailing costs. Reservations should be in by May 15 but will be accepted later if space remains available.

Anyone having unusual or interesting shell material that may be exhibited should contact the exhibit chairman, Mr. Howard Fletcher, 1008 La Hermosa Drive, Redlands, California, who will help with the planning and placing of the exhibits.

Dr. Edwin Allison, Vice-Chairman, is assisting me in the planning of the program, and offers of papers may also be sent to him. These should be in before May 15 and should be on the "Call for Papers" form sent out by the Secretary.

We hope — as do all slates of officers each year — that this will be a banner meeting, and it can be with our combined efforts. Let's see *you* at Asilomar!

Myra Keen, Chairman

Errata

BY

FRANZ ALFRED SCHILDER

University of Halle, German Democratic Republic

In "The Cowrie Fauna of Penrith Island" published in *The Veliger* 6(3): 155-161, the following passages should be emended:

In the list of species on pp. 155-156: *Erosaria labrolineata*, *Palmadusta gracilis* and *Bistolida pallidula* were established in 1849, not in 1848; IREDALE (1939, *Austral. Zoologist* 8(2): 99) has pointed out that GASKOIN's paper in *Proc. Zool. Soc. London* for 1848 was published March 13, 1849. *Erronea listeri* GRAY was published in 1824, while the preoccupied name *listeri* GRAY 1825 is a synonym of *Erosaria marginalis* DILLWYN 1827 (see SCHILDER, 1922, *Proc. Malacol. Soc. London* 15(2/3): 118).

In Table 1, pp. 158-159 the figures on the fifth line (pertaining to *Monetaria moneta*) must be changed as follows:

column r/12	- 10.0 > 9.1	(instead of 8.0 = 8.1)
m/L	- 10.5 > 9.1	(11.7 > 9.8)
dr/L	- 9.5 > 8.3	(9.9 > 8.0)
♀ %	- 64 = 64	(41 < 51)

Finally, there is a transposition of names in the last two lines of the first column: instead of *Calpurnus verrucosus* in the penultimate line read *Palmadusta gracilis* and in the last line read *Calpurnus verrucosus* instead of *Palmadusta gracilis*.

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BOOKS, PERIODICALS, PAMPHLETS

Notices of New Eastern Pacific Mollusca. - V

by S. STILLMAN BERRY in Leaflets in Malacology, Editor and Publisher, S. Stillman Berry, Redlands, California, vol. 1, no. 23, pp. 139 to 146, September 30, 1963.

This paper continues a series of preliminary accounts of west American mollusks that was initiated in 1957. According to the preface to the first report, detailed descriptions and illustrations are in preparation and are promised by the author for subsequent publication elsewhere.

In this paper, a diagnosis, the type locality, and brief comparisons are given for ten new species, namely: *Pecten lunaris*, *Tellidorella cristulata*, *Crenimargo electilis*, *Tranzenella caryonautes*, "*Acmaea*" *concreta*, *Cirsotrema pentedesmium*, *Crucibulum castellum*, *Crucibulum subactum*, *Solenosteira gatesi*, *Olivella (Dactylidella) cymatilis*. Two generic names, *Tellidorella* and *Crenimargo*, are proposed for *T. cristulata* new species and *C. electilis* new species, respectively. Unfortunately, the descriptions of these generic taxa lack definite type designations.

Under the present International Code of Zoological Nomenclature [Articles 13 (b) and 68 (a,i)], genus-group names published after 1930 must have a definite fixation of a type species. Therefore, these generic taxa and five other generic taxa that were proposed in previous articles in this series are unavailable and must stand as *nomina nuda* until a type species is properly proposed for each taxon.

W. K. Emerson.

The Miocene Mollusca from Quilon, Kerala (India)

by A. K. DEY. Memoirs of the Geological Survey of India, Palaeontologia Indica, New Series, volume 36, pp. i to vii plus 1 to 129, plates 1 to 10. 1961 (on title page), 1962 (on cover).

This paper contains a discussion of a marine molluscan fauna collected from strata near Quilon, Kerala, India. The author describes 165 forms (43 pelecypods, 1 scaphopod, 121 gastropods); 59 new species, 96 identified with previously known species and 10 identified only as to genus. Of the total number of species, 31.5% are living in the seas today. A Vindobonien, late Miocene, age is assigned to this fauna. The affinities of the species in this assemblage are predominantly with the Recent and fossil mollusks of the Indopacific province.

The record of the new species *Pitar (Hyphantosoma) simonnei* (p. 35, pl. 2, figs. 5, 6) in this assemblage of late Miocene age in India furnishes an interesting addition

to the known occurrences of *Hyphantosoma*. Species referred to this subgenus have been reported previously from Oligocene to Pliocene in southeastern United States and in the West Indies, in the Miocene of New Zealand, in Pleistocene and Recent in the eastern Pacific and probably Recent in the East Indies.

LGH

Rearing of Bivalve Mollusks

by VICTOR L. LOOSANOFF and HARRY C. DAVIS. in: Advances in marine biology, vol. 1; pp. 2 to 138; 43 figs. Academic Press Inc., London, 1963.

This lucidly written and well illustrated summary of work carried out by the senior author and his associates over many years, may well be a "classic" of the future. Many puzzles of taxonomic relationships can be solved only by careful breeding experiments. Marine mollusks have presented a series of obstacles which now appear to be resolved — at least for the bivalves (or, to be still more cautious, for some bivalves). Future work will have to establish how the Loosanoff Method can be modified in its application to the gastropods.

RS

A New Species of *Acmaea* (Archaeogastropoda) from the Pleistocene of San Nicolas Island, California.

by JERE H. LIPPS. Los Angeles County Mus. Contr. in Sci., no. 75, 15 pp., 6 figs.

This paper describes and well illustrates a new species of limpet, *Acmaea mitchelli*, from the Pleistocene terrace on San Nicolas Island off the coast of Southern California. Interesting paleo-ecologic interpretations about this new species suggest that it lived in the high intertidal zone. Seven other California species of the genus *Acmaea* are illustrated and compared with the new species. A fine piece of work, marred only by the dark (over-inked?) reproductions of what seem to be excellent photographs.

RS

Type specimens of Marine Mollusca described by P. P. Carpenter from the West Coast of Mexico and Panama

by KATHERINE V. W. PALMER. Bull. Amer. Paleont., vol. 46, no. 211; pp. 289 to 408; pls. 58 to 70.

This is a companion volume to the earlier work by Dr. Palmer (1958: Type specimens of marine mollusca described by P. P. Carpenter from the West Coast (San Diego to British Columbia). Like the earlier work, this very important contribution will be of inestimable value to all students of mollusks from the eastern Pacific.

RS

Studies on Tertiary and Recent Giant Limidae

by HAROLD E. VOKES. in: Tulane Studies in Geology, vol. 1; pp. 73 to 92; pls. 1, 2. 18 January 1963

A new species, *Lima (Acesta) bullisi*, is described from 300 and 600 fathoms off Mobile Bay, Alabama. This represents the first reported occurrence of *Acesta* in the western Atlantic and contiguous basins. A catalogue of the recognized species of the Cenozoic subgenus *Acesta* includes 13 modern species and 31 fossil species distributed through North America, Asia, New Zealand and Europe.

A new subgenus, *Plicacesta*, is proposed for four plicately ribbed species of Asia. The living *Lima smithi* SOWERBY from Japan is designated the type species of *Plicacesta*.

ECA

Additions to a Catalogue of the Described Recent and Tertiary Species of *Acesta* and *Plicacesta*

by HAROLD E. VOKES. in: Tulane Studies in Geology, vol. 2; no. 1; pp. 18 to 20.

Additions to the author's previously published catalogue of these *Lima* subgenera (vol. 1, no. 2 of the same series) include considerations of one living and one Miocene species of *Acesta*, two doubtful Eocene species of *Acesta*, and one living and one Miocene species of *Plicacesta*.

ECA

Cenozoic Muricidae of the Western Atlantic Region Part I - *Murex sensu stricto*

by EMILY H. VOKES. in: Tulane Studies in Geology, vol. 1; pp. 93 to 123; pls. 1 to 4; tables 1, 2. 18 January 1963.

A systematic review of the marine gastropods of the Neogene subgenus *Murex sensu stricto* (type: *M. tribulus* LINNAEUS) reveals the occurrence of 19 fossil species and subspecies and 15 living species which can be assigned to

that taxon. Two subgroups are recognized: a "Western Atlantic" subgroup and an "Indo-Pacific" subgroup. Both are represented in modern Western Atlantic faunas, with the "Indo-Pacific" subgroup generally inhabiting water less than 50 fathoms deep, and the "Western Atlantic" subgroup ranging into slightly cooler and deeper water.

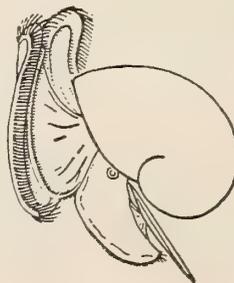
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The so-called *Patinopecten* of Japan

by KÔICHIRO MASUDA. in Palaeont. Soc. Japan, Trans. Proc., N. S., no. 52; pp. 145 to 153; pls. 22, 23 (in English with Japanese abstract). 10 December 1963

A critical review of fossil (Neogene) and modern scallops conventionally labeled *Patinopecten* reveals consistent differences between species from opposite sides of the North Pacific. The living eastern Pacific type species of *Patinopecten*, *Pecten caurinus* GOULD, with numerous western North American fossil species of *Patinopecten* and *Lituyapecten*, are characterized by well-developed auricular crurae with distal denticles and by squarish right valve ribs which are found on *P. caurinus*. A single Japanese species, the Pliocene *Pecten tokunagai* YOKOYAMA, exhibits both the *Patinopecten*-like form and distinct cardinal crura. That species is made the type species of a new monotypic genus, *Yabepecten*, by MASUDA. *Yabepecten* is grouped with the eastern Pacific *Patinopecten s. s.* and *Lituyapecten*, and with the restricted genus *Pecten* to form a newly constituted subfamily Pectiniinae. The many Japanese species formerly treated as *Patinopecten* are placed in a new genus, *Mizuhopecten*, with *Pecten yessoensis* JAY the type and sole living species. *Mizuhopecten* is grouped with previously segregated *Patinopecten*-like scallops (*Masudapecten* AKIYAMA, *Fortipecten* YABE & HATAI, *Kotorapecten* MASUDA, and *Nipponopecten* MASUDA) as a new subfamily, Fortipectiniinae.

ECA



THE VELIGER is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable. In the unlikely event that space considerations make limitations necessary, papers dealing with mollusks from the Pacific region will be given priority. However, in this case the term "Pacific region" is to be most liberally interpreted.

It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or lesser taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, will be published in the column "NOTES & NEWS"; in this column will also appear notices of meetings of the American Malacological Union, as well as news items which are deemed of interest to our subscribers in general. Articles on "METHODS & TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

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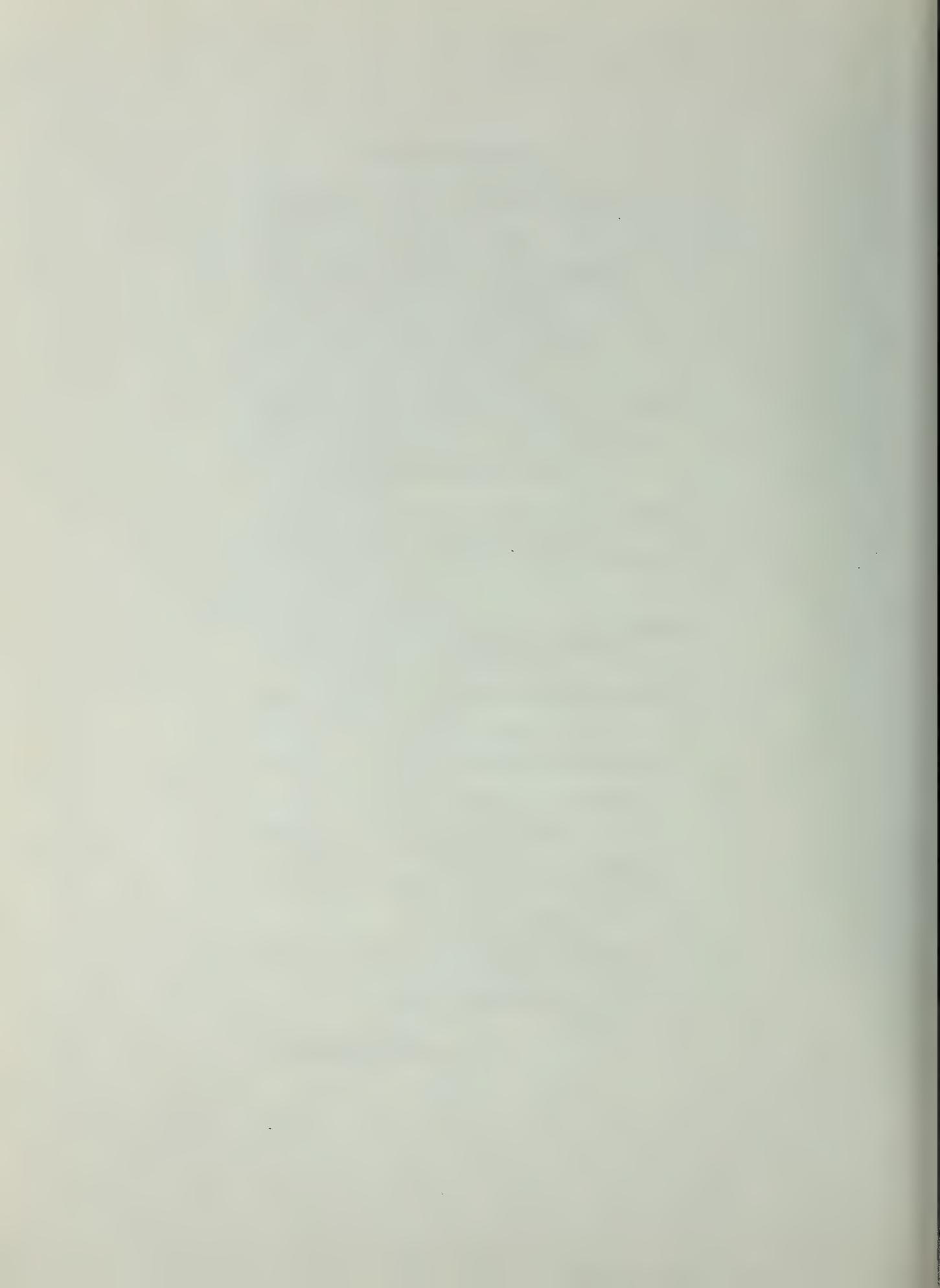
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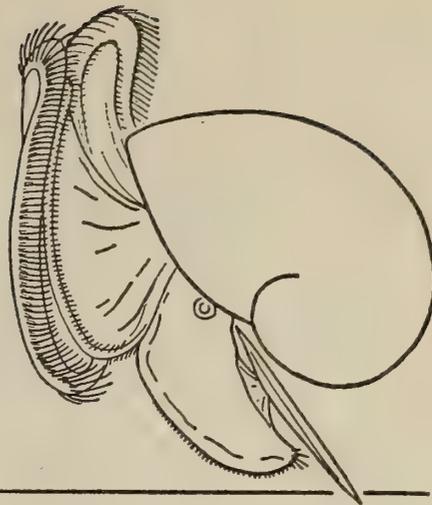
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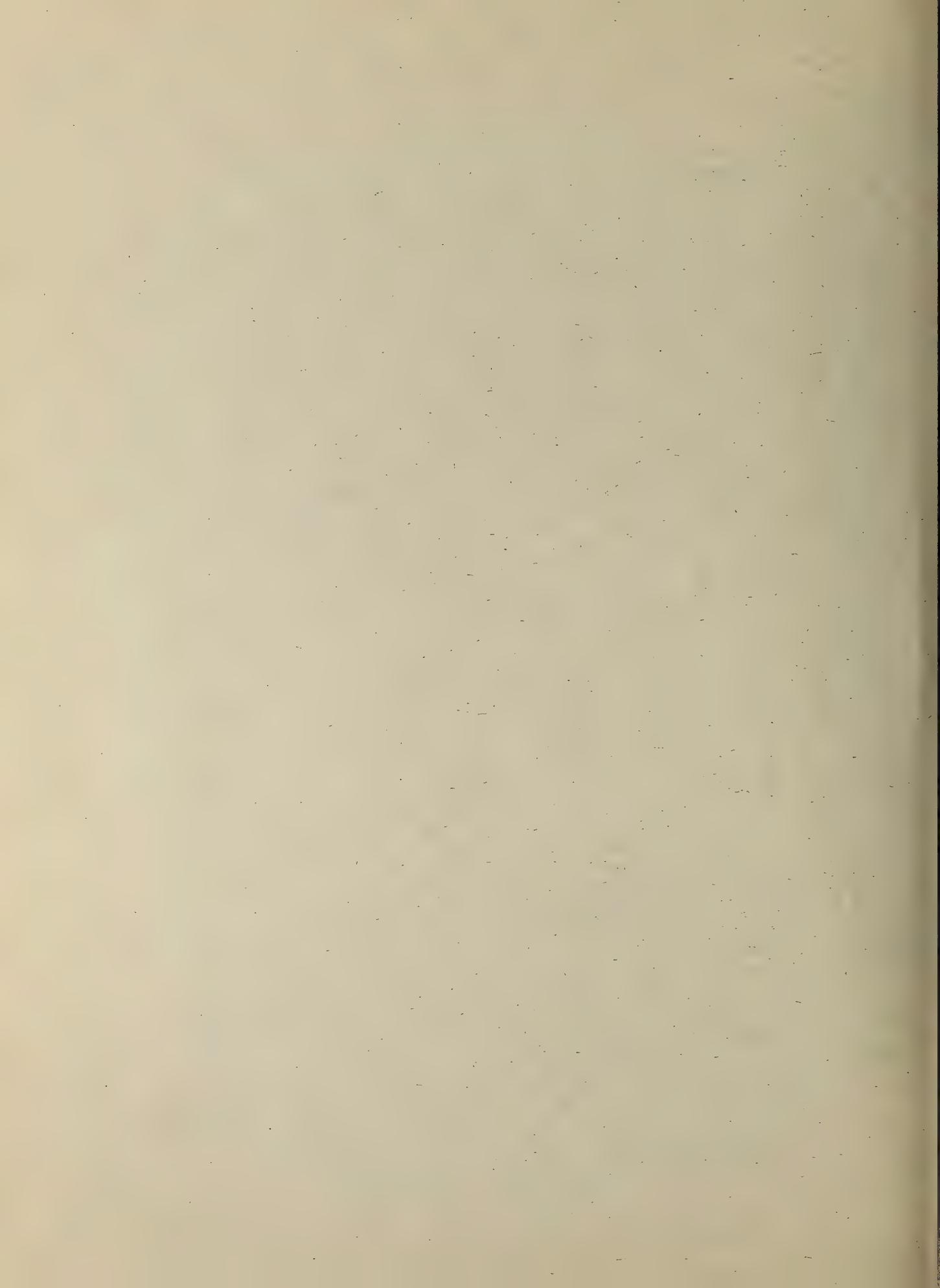
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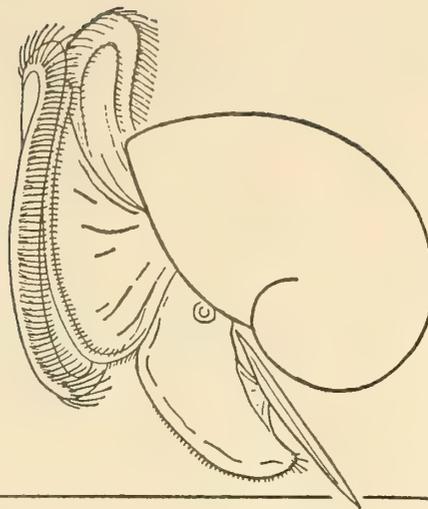
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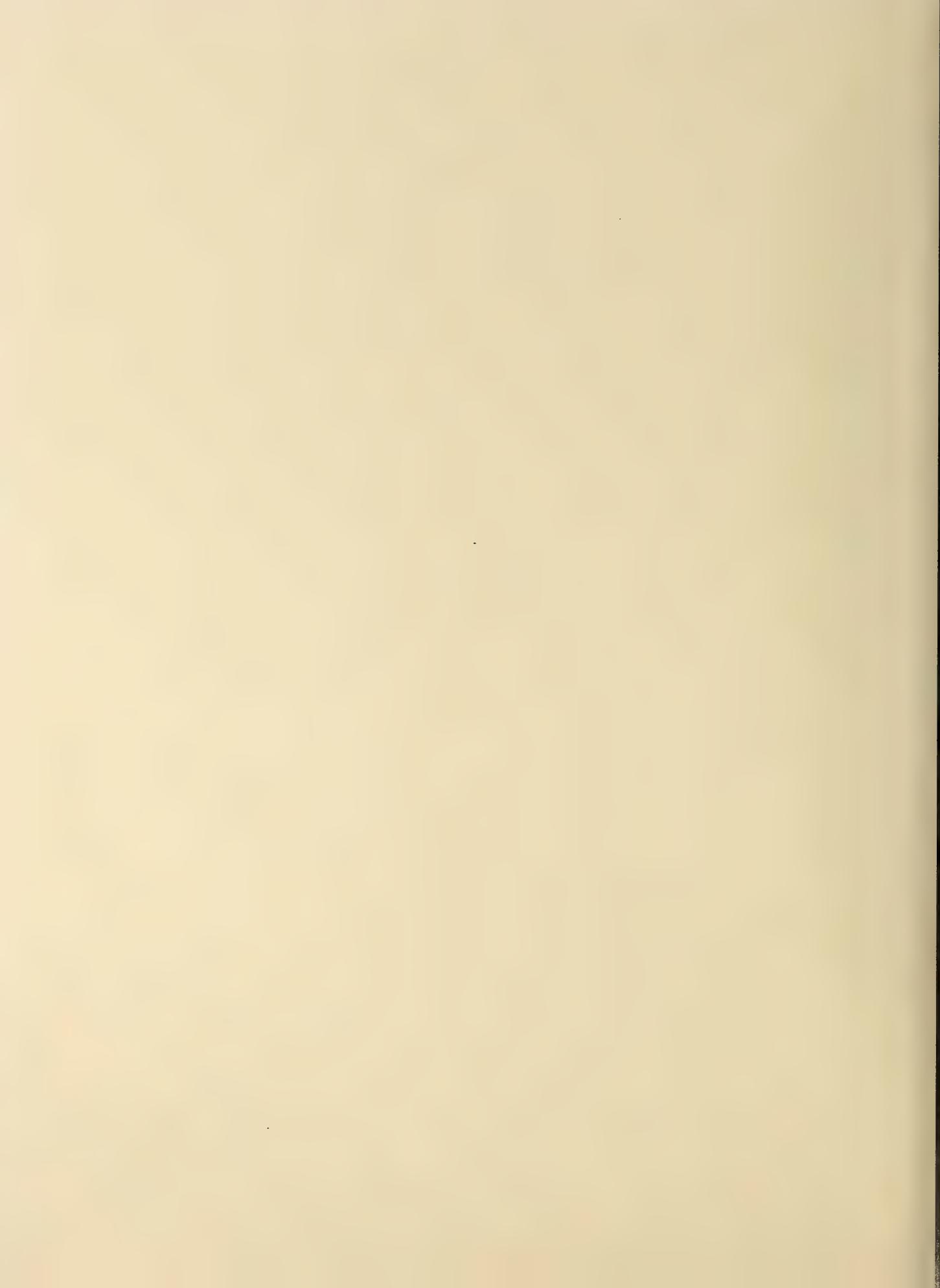


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Foreword

WHEN DR. DONALD P. ABBOTT of Stanford University's Hopkins Marine Station described to me the aims and methods of the course "Problems in Marine Biology" (see the article by Drs. Abbott, Blinks and Phillips below), I was impressed by the novel approach to the teaching of the subject. Since the Northern California Malacozoological Club, the publisher of the *Veliger* at that time, is a corporation devoted to all scientific and educational aspects pertaining to mollusks in any way whatever, I, as the Editor of the journal expressed my interest in the experiment. It is unnecessary to repeat here much of what is recorded in the introductory article as this may be regarded as "history." However, as will be seen in perusing the following papers, the various studies submitted by the students show remarkable results. But what was most gratifying was the fact that, although each paper was reviewed by at least two (in many cases four) outside referees only six papers were not accepted.

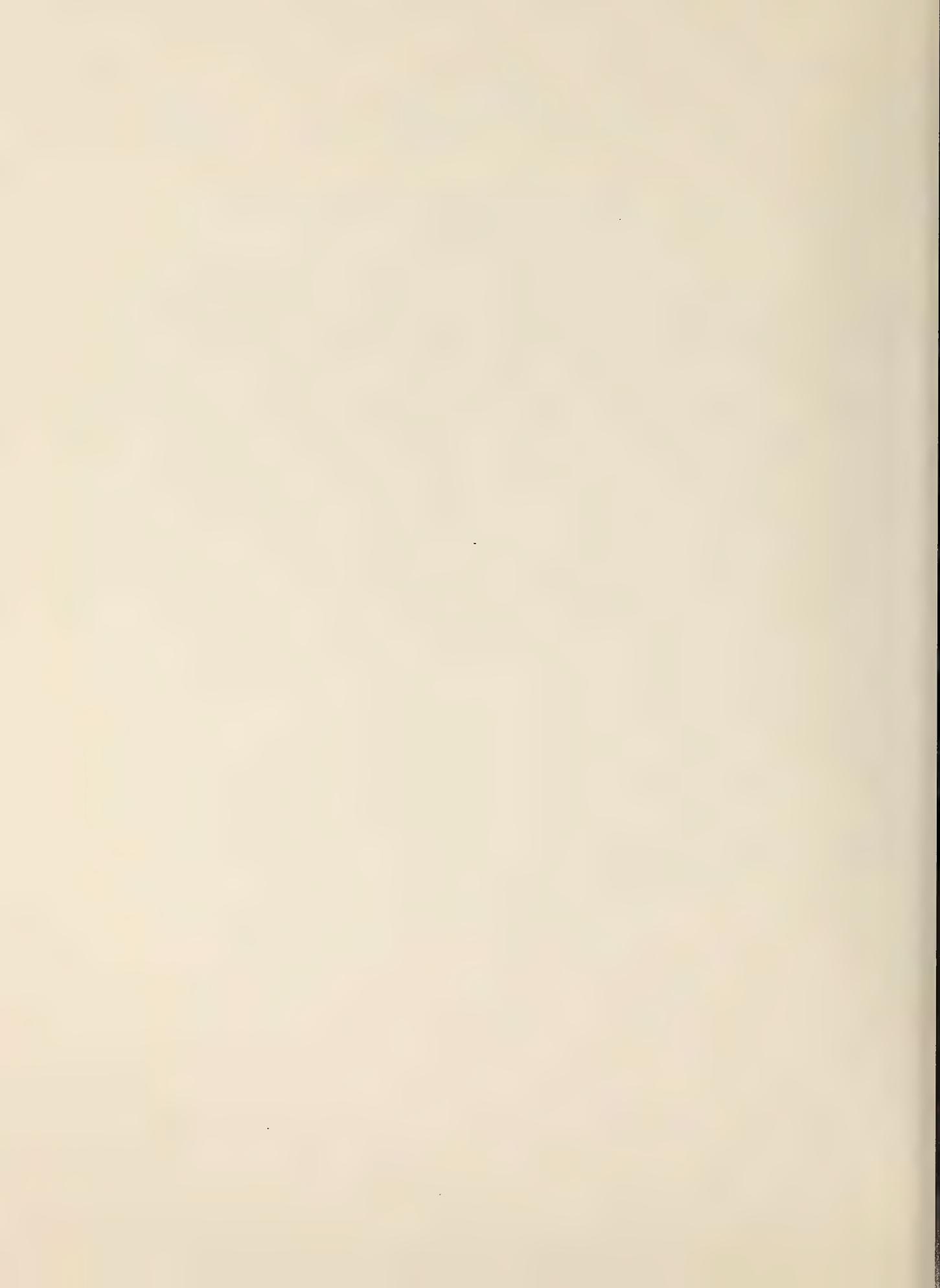
As all studies dealt with *Tegula funebris* (A. ADAMS, 1854), it seemed desirable to include other papers concerned with the same species, i. e. papers submitted by authors not connected with the course in any way whatever. It was deemed appropriate to do so because it would allow this symposium of papers to be more complete. Of course, it was also recognized that the inclusion of papers by more experienced authors would tend to throw the variability of the other papers into sharper relief. However, this was not considered detrimental. Certainly, it

is very evident that each relatively small project has uncovered research problems with great promise of yielding, eventually, important results.

The papers are presented to the critical eyes of the professional malacologists with the understanding that not all would have been submitted for publication by their respective authors in a context other than this particular one; nor would all have been accepted, perhaps, in their present form for publication had they been submitted as single, separate contributions. Since all together they throw light upon many diverse aspects of the biology of one molluscan species, they each contribute perhaps more to our understanding, not only of *Tegula funebris*, but of other gastropods as well, than they would if they were published only after each study had been brought to a much more mature conclusion — and then scattered through various specialized journals. Still more important, I think, is the fact that this symposium demonstrates a vital, exciting approach to the teaching of a very general subject through the utilization of a common, single species.

The *Veliger* has passed into the ownership of the California Malacozoological Society, Inc. The aims and purposes of this new corporation, in relation to The *Veliger*, are the same. Thus, the Society now presents this Supplement to Volume 6 of The *Veliger* as a record of an experiment in teaching marine biology.

R. Stohler, Editor.



An Experiment in Undergraduate Teaching and Research in the Biological Sciences

BY

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AND

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THE PAPERS which form the bulk of this supplement to *The Veliger* are the outcome of an experiment in undergraduate teaching, conducted at the Hopkins Marine Station during the spring of 1963. The class, a group of 25 Stanford University biology majors, spent the entire ten-week quarter at the Marine Station, enrolled in a new 15 unit course called "Problems in Marine Biology," which met all day, five days a week.

The course was planned and conducted by a three-man faculty which included an invertebrate zoologist (Abbott), a general and plant physiologist (Blinks), and an immunologist-biochemist (Phillips), aided by a teaching assistant with experience in invertebrate development (M. Hadfield). Our general objective was to give a limited group of undergraduates an opportunity to make concentrated studies and to engage in research on individual problems in the area of marine biology.

Fairly early in the planning stages it became clear that the faculty members were in essential agreement on certain features of the approach to be used:

(1) We would plan to start with a broad but brief survey of the marine intertidal zone. Thereafter we would concentrate our attention on a single species, which would be studied in detail in both cooperative and individual research projects. By investigating many different aspects of a single species we hoped to get broad views and insights as well as understanding in depth.

(2) We would make our initial approach as naturalists, looking first at nature in the field. As questions and problems arose we would try to combine the approach of the field observer with that of the experimentalist and laboratory biologist, making an effort to avoid any dichotomy between observation and experiment, or laboratory and field.

(3) We would try to be holistic in our approach, ignoring the fact that biology has been sliced up, for practical convenience, into a number of fields and levels of organization, and considering only that the biologist sees in nature a nearly endless supply of questions and problems, and that he has at his disposal a wide variety of concepts, methods, and tools which he may use in trying to answer or solve them.

(4) Finally, we hoped to plan and conduct the work in such a way that over the ten-week period the students would experience, on miniature scale, not only the activities but also the inner feelings of a scientist engaged in research: the stimulus that comes from realizing how little man really knows and understands, the struggle to formulate a clear problem and a line of attack, the excitement and joy of inquiry and discovery, the intense intellectual and emotional commitment of the scientist to his research, the difficulties and frustrations that may accompany the work, the pleasure of sharing results with colleagues working along similar lines, the struggle to express the results clearly and concisely on paper, and the profound satisfactions that come from even a modest creative achievement in science.

Our attempts to apply this approach and achieve these ends are chronicled below.

Out of 30 applicants for the course we chose 25, fifteen men and ten women. All had had the minimum prerequisite courses (a year of chemistry, and either introductory botany and zoology or a year of biology), and in addition the majority had studied organic chemistry, comparative anatomy, vertebrate embryology, and one or more advanced courses in the biological sciences. As finally selected, the class consisted of 2 sophomores, 14 juniors,

7 seniors, and 2 beginning graduate students. Their previous grade point averages ran from B plus to C.

Before the first day of work the faculty tabulated the student's past records, then split the class up into six teams, each with four or five students. An attempt was made to divide up the sexes, the talents, and the course-work backgrounds represented in the class into six fairly evenly matched working groups. Following this, the faculty went out to the Marine Station's shoreline and selected six different field stations or study areas, one for each of the student teams.

We started work during a week of good tides, with low water occurring in the late morning and early afternoon. On the first class day, after registration and orientation, the class was given an introductory lecture on marine plants. Each team was then provided with graph paper and some elementary surveying equipment (stout cord, a line level, a yardstick, and marking materials) and sent to one of the selected field stations with this assignment: survey a profile strip perpendicular to the shoreline in your study area, extending from the highest splash zone out as far as you can get with safety; along this profile, plot the distribution of the common species of intertidal plants present. The teams were told not to attempt to key out species in the field, but instead to collect all of the different kinds of plants present (insofar as these could be recognized by students in the field), to label each type with a number or letter, and to record their occurrence on the profile charts. The teams went to work without further specific instructions, but faculty members observed the field work, made suggestions where these seemed needed, and called attention to things which might be overlooked. In the afternoon, after the rising tide enforced retreat, the teams returned to the laboratory, identified their collections with faculty help, tabulated and compared results, and in class discussion tried to relate differences in the occurrence and abundance of species with differences in habitat.

The second day, after a lecture on common macroscopic intertidal invertebrates, each team worked its profile a second time, this time recording the occurrence and distribution of common benthic animals. The third day the profile exercise was repeated, the concern this time being the commoner microorganisms, both those in the water and those forming films on the surfaces of rock and weed.

This three day survey, though brief and superficial, allowed each student to become intimately familiar with the topography of one small area and allowed him to sample the more abundant species in each of the kingdoms of organisms present. During the survey everyone became familiar with the most conspicuous of the larger inter-

tidal gastropods, the black turban snail *Tegula funebris* (A. ADAMS, 1854), though the students were still unaware that we had selected this creature to be the hero of the course.

On the fourth day the students were given a lecture on the concepts of organism and environment, and were sent out on the ebbing tide with a different type of assignment. Each team was told to "describe the population of *Tegula funebris* in your profile area." No instructions as to what this involved or how one might go about doing it, were given. We stated only that there was no single "correct" approach or method of procedure; that each team should discuss the assignment, decide for itself what was essential to a "description of a population," formulate its own methods, and get busy for the rest of the day. The students were also told that after lunch on the following day, each team would be assigned a panel of the blackboard on which to plot what they considered to be the essence of their findings, and that each team should elect one member to report to the class on (1) *what* their team had done, (2) *why* they had done what they did, and (3) what they thought they had found out. The teams went to work. The instructors observed, but tried to avoid making suggestions on what to do and how to do it.

Morning on the fifth day passed with a lecture on the sea as an environment, and in student preparation for afternoon reports. These reports, each delivered for the whole class, were most interesting. No two teams had handled the assignment in quite the same way. For example, one team laid out a line of quadrats, counted and measured all *Tegula* present, then plotted numbers and mean sizes against intertidal elevation and distance from shore. Another team with a different orientation recorded *Tegula* distribution in a semi-quantitative manner along a broad strip, noted that the species population was grouped in discontinuous clusters, set up hypotheses which might account for this curious pattern of distribution, and spent the remaining time in designing and carrying out observations and simple experiments to test these hypotheses.

The student reports brought out numerous provocative observations, and raised many questions which the faculty either could not answer, could answer only in general terms, or could answer only in terms of predictions based on knowledge of other snail species. It became clear that to most of us, *Tegula funebris* was little more than a black shell; that we knew almost nothing in detail of its food, habits, responses, tolerance limits, enemies, growth rate, life span, reproduction, and a host of other matters. We began to tabulate categories of things we did not know about *Tegula*, and out of this came the program for the work of the next six class days.

During this period the tides were poor for field work, and the days were devoted primarily to intensive indoor studies of *Tegula*. Lectures were used to lay a foundation of concept and background information for the practical methods and exercises carried out in the laboratory on the same day. Faculty members alternated in charge of the work, but each attended his colleagues' lectures and observed their laboratory exercises, and each made a real effort to relate his topic of the day to material covered earlier. A brief outline of the program of this part of the course follows (Table 1).

It seems worthwhile here to underline a particularly significant difference in emphasis, separating the present course from the more conventional college biology courses oriented around "principles" of a selected "field," or around particular biological taxa. The organization and stress in these courses generally reflect the viewpoint of the scientist in his capacity as a *teacher*; his stress tends to be on imparting organized knowledge. In principles courses, a firm grasp of the principles is regarded as the important thing; specific examples are regarded as illustrative rather than of great importance for themselves. In courses dealing with specific taxa, imparting a knowledge of the group is the main desideratum. In both types the scientist, as a teacher, is trying to pass on that material within the scope of the course which is of *general* rather than merely specific significance; he is dealing in statements describing that part of the behavior of the cosmos or of its parts which seems orderly and consistent. In

the principles course, organization is around the principles, concepts, or laws. In the taxon-oriented course, while generalizations are sought, principles may or may not receive emphasis; nevertheless they are always assumed to form a constant part of the background. In courses of both types, the orientation and emphasis is usually that of the scientist-*teacher*, striving to impart organized knowledge and clearer understanding.

Our own treatment of principles and other subject matter in the present course differs from the above. And the difference in treatment reflects the difference in attitude between the scientist in his role as a teacher and the scientist in his role as a *researcher*. The dedicated researcher is not so concerned with the broad and balanced view, and with orderly generalization in matters peripheral to his research; for him the most important thing is the problem under investigation. In the researcher's mind and in his hands, principles, concepts, instruments, techniques, and all the rest of accumulated human knowledge and know-how, become mere tools to be brought to bear on the task of answering his question. All human experience and capability become means, to be applied in achieving his specific ends. The tools, in such a view, have no real value in themselves; those which are immediately useful are used, the others are laid aside.

And so it was in the present course. Our aim was *not* to pass on to the students a better grasp of biological principles as such, or a greater knowledge of marine snails

Table 1

Lecture	Laboratory
Basic molluscan morphology, torsion and its consequences, the early evolution of the gastropods, and the anatomy of the Trochacea.	Dissection of <i>Tegula</i> , to work out the gross anatomy.
Physical and chemical factors in the marine environment, tolerance limits of organisms, and the concept of limiting factors.	Observations of responses of <i>Tegula</i> to various physical stimuli; determination of tolerance limits for several physical factors.
Energy sources and nutritional types of organisms; biogeochemical cycles; enzyme action in proteases and carbohydrases; methods of determining enzyme action; digestion in <i>Tegula</i> .	Determination of food of <i>Tegula</i> from gut contents; assays to determine the categories of enzymes present in different segments of the gut in <i>Tegula</i> .
Obtaining energy; transport of O ₂ and CO ₂ ; the excretion of nitrogenous wastes.	Determination of myoglobin and lactic acid in muscles; determination of hemocyanin; determination of nitrogenous waste products in excretory organs.
Receptors, nervous system, and effectors of <i>Tegula</i> ; responses of <i>Tegula</i> and other snails to predators; responses of commensal species to the <i>Tegula</i> host.	Observing and measuring responses of <i>Tegula</i> to starfishes and predatory gastropods; measuring responses of <i>Crepidula adunca</i> and <i>Acmaea asmi</i> to <i>Tegula funebris</i> .
Photosynthesis in marine algae; concepts of standing crop and productivity; intertidal and oceanic productivity; methods of measuring productivity.	Survey of food plant supply for <i>Tegula</i> in the field; field determinations of photosynthetic rate using Winkler methods.

as a group, or an increased facility in the use of scientific apparatus, or even a better understanding of *Tegula funebris*. Our aim was to involve all of the students, intellectually and emotionally, in an intensive and comprehensive investigation of a common local species. We chose *T. funebris* to work with, but it could well have been another species of animal or plant. We looked at the animal and we asked questions. Then we selected those principles, concepts, methods, and instruments which were needed now in pursuing the answers to those questions; we introduced them, not as things of intrinsic interest or value, but as tools for effective inquiry. At this stage of the work, familiarity with the tool was all we expected; mastery could come later where, in particular cases, a given tool proved crucially important. But our attitude was this: the proper understanding and expert use of tools is not the prime objective of the researcher but only a necessary incidental to his work.

Discoveries new to both students and faculty were made each day. Moreover, the class was beginning to use its time and its tools more effectively in investigation. By the time the tides had again become favorable for field work, it is safe to say that the least informed student in the class knew more about *Tegula funebris* than had the best informed malacologist in the world only a few days before. Starting with a poorly studied species this result could hardly have been otherwise; nevertheless, the knowledge that they were breaking new ground provided a continuing source of stimulation to the class.

With the return of good tides, the students were given their next big field assignment. We posed these general questions: How does a typical *Tegula funebris* spend its time? What is the general activity pattern of the *T. funebris* population, (1) during a 24 hour cycle of day and night, and (2) over a nearly 25 hour cycle of tides?

To facilitate round-the-clock observations, the six original teams were combined to form three teams, each with eight or nine members, and only three of the original profile areas were selected for the proposed study. Each team was instructed to set up its own work shifts, and to plan its approach, methods, and program without faculty aid. Three days were allowed for the exercise.

The first day saw a flurry of activity which ranged from the testing of fluorescent paints and other materials calculated to facilitate night observation, to the laying up of food supplies for the night shifts. Excitement in the exercise ran high and continued high, despite rains, rough water, long hours, and the frustrating difficulties of trying to follow and record the activities of a partially submerged population of purplish black animals at night. This was at least partly because information new to both students and faculty was continually coming in. Up to this time, practically all of our field work had been carried out

during daytime periods of low tide, when the *Tegula* population is usually highly clustered and quite inactive. In the present exercise it quickly became apparent that the population was far more mobile and dynamic than suspected; animals dispersed, became clustered again, moved up and down, and otherwise shifted about in pronounced fashion along with changes in light, tidal level, and local current.

Much overtime went into completing this exercise, and when it was over we found the team oral reports absorbing, as much for the student attitude reflected as for the findings on *Tegula*. As one faculty member remarked to a colleague after the reports, "Excellent! Who would have thought you could get a group of 25 Stanford undergraduates so stirred up over the doings of a little black snail?" Reports were followed by a reassessment of the things we had found out about *Tegula*, and further, a listing of some of the questions, problems, and good leads that remained. The list was a long one.

Students were given the weekend and the first part of the following week to survey the list, do a bit of reading and perhaps a bit of pilot investigating, and to select for themselves individual problems which would occupy them for most of the remainder of the quarter. They were lectured on biological literature sources and the use of a research library, and instructed how to use the abstracting and indexing serials, such as Biological Abstracts, Chemical Abstracts, and the Zoological Record. Toward the end of the fourth week, each member of the class handed in a written prospectus for a research problem. This was gone over very carefully with a faculty member, revised, resubmitted, and often rewritten again. A real effort was made to get students to frame their problems in fairly concrete terms, to formulate them in terms of specific and answerable questions, and to limit them to such a degree that there was a reasonable hope that some answers could be obtained before the end of the quarter.

The fifth week of the class began with a talk from each student, covering what his problem was, and how he was planning to tackle it, or at least start on it. Some idea of the scope of the projects attempted may be gained from the following list of abbreviated project titles.

Distribution and movements of the *Tegula funebris* population.

Factors governing the upper and lower limits of distribution of the *Tegula funebris* population.

The activity pattern in *Tegula funebris*.

Orientation and dispersion of *Tegula funebris* with respect to current.

Responses of *Tegula funebris* to starfish and gastropod predators.

Interactions between populations of *Tegula funebris* and hermit crabs.

Photoreception and responses to light in *Tegula funebris*.

Chemoreception in *Tegula funebris*.

The anatomy of *Tegula funebris*.

Structure, growth, breakdown, and repair of the shell in *Tegula funebris*.

Algae on the shell of *Tegula funebris*, in relation to the distribution, food, and feeding of the commensal limpet *Acmaea asmi*.

Attraction of the larvae of *Acmaea asmi* to *Tegula funebris*.

Dispersal of the young of the commensal gastropod *Crepidula adunca* to new *Tegula funebris* hosts.

Reproduction and larval development in *Tegula funebris*.

Food preferences and feeding in *Tegula funebris*.

The carbohydrases in the gut of *Tegula funebris*.

The proteinases and lipases in the gut of *Tegula funebris*.

Yeasts living in the gut of *Tegula funebris*.

Diurnal fluctuations in the O₂ consumption of *Tegula funebris*.

Production and fate of lactic acid in the muscles of *Tegula funebris*.

Hemocyanin of *Tegula funebris*.

Excretory products of *Tegula funebris*.

In a few cases the projects above were handled by two students working in close collaboration, but the majority were carried out by individuals. Each student was assigned a faculty advisor who aided in finding references and equipment and in getting the project started. For a time there were real problems of space and equipment. Also, it very quickly became clear that no real class work schedule was possible, and that the laboratory would have to be open and available 24 hours a day, seven days a week. No formal lectures or labs were therefore held. Students were expected to report to their advisors periodically, but student independence and initiative were encouraged as much as possible. There was surprisingly little "goofing off."

By the middle of the seventh week, work had progressed to a point where the findings of one student were beginning to throw light on projects tackled by others. We therefore scheduled a series of small conferences, each attended by a few students working on interrelated problems and by one or two faculty advisors. Topics around which discussions were organized included the following:

Distribution of *Tegula funebris* and ecologically related species, and factors affecting that distribution.

Sensory reception.

Commensals and predators of *Tegula funebris*.

Food habits and feeding.

Digestion.

General physiology.

Structure, development and growth.

In most cases, an individual student was assigned to two different groups, so his findings could be considered from at least two different points of view. Students were asked to bring in their data in organized form, and to be prepared to present and discuss them with others.

We hoped the interchange in these discussion groups would in some ways compare with that experienced at small scientific meetings limited to investigators working on closely related problems. The results in most cases did not live up to our expectations, and in retrospect it is clear that those expectations were too high. A number of students were still struggling with methods, and discussions in some areas centered on these. Some students brought in quantities of undigested data. Only a minority presented findings effectively in the form of tables or graphs. Among the lessons learned was this: that unless problems and findings were presented in clear, concise, organized form, and illustrated graphically in some manner, the investigator failed to get much across to his audience, and discussions lagged or never got started, or were restricted to comments by the faculty advisors. Nevertheless, it appeared at this stage of the work that the findings of a majority of students included some small but original contributions to science, of particular interest to malacologists.

With this in mind, the faculty contacted Dr. Rudolf Stohler, editor of *The Veliger*, presented a brief outline of what the student group was doing, and inquired whether or not papers resulting from the course might be considered for publication in that journal. Dr. Stohler's response was immediate; the course sounded interesting, and any papers resulting from it would be considered for publication providing they passed editorial board inspection. There was no guarantee that all or any papers would be accepted, but if a sufficient number proved suitable, it might be possible to issue a sort of "Symposium on *Tegula*" as a supplement to *The Veliger*. Word of this response was passed to the students, and this provided an additional stimulus.

The eighth and ninth weeks of the course passed in research and in conferences between students and their advisors, and the lights in the laboratory burned very late. A deadline for turning in final drafts of papers to faculty advisors was set at the end of the ninth week, a full seven days before the end of the course, in order to allow time for rewriting. In a lecture on the subject of

writing and illustrating scientific papers, it was stressed that not only must a scientific paper have something to say, but it must say it in an organized fashion, concisely, and with unequivocal clarity; students were referred to current biological periodicals for specific examples.

Oral reports on research projects occupied three successive mornings of the final week of class. These talks were attended not only by all members of the class and faculty, but also by other graduate students and investigators in residence at the Marine Station at the time. An effort was made to hold the talks under circumstances approximating those of a regular small scientific meeting. Individual reports were limited to one-half hour each, and were accompanied by illustrations and graphs from student papers, projected by means of an opaque projector. The reports went very well. For the most part they were organized and had been rehearsed, and were

delivered in a manner comparing favorably with that of professional scientists at meetings. We were exceedingly proud of student performance here.

All of the remaining time during the last week went into criticism and revision of the written research reports. Despite instructions, most of the written reports resembled first drafts of undergraduate term papers rather than scientific manuscripts. The best were none too good, while the worst were longwinded, chatty, poorly organized, and frequently incoherent. The papers were gone over in student-advisor conferences, criticised in real detail, sentence by sentence, torn apart and reorganized, and sent back for rewriting. The rewritten version was also criticised, and often sent back for further revision. Those papers which passed the review of the faculty, and that of the editorial board of *The Veliger*, are presented in the following pages.

On Growth and Longevity in *Tegula funebris*

(Mollusca : Gastropoda)

BY

RICHARD L. DARBY

Department of Biology, University of Oregon, Eugene, Oregon

(Plate 1)

ALEX COMFORT (1957) has reviewed the literature on the life-spans of mollusks, and has gathered together the published longevity records for members of the phylum. Reference to his listing reveals that the more long-lived forms fall into two categories: (1) Bivalves, in which age can be estimated with fair confidence from annual growth rings on the shell, and (2) the more primitive marine gastropods, in which age determination by annuli has been generally unconvincing and is instead usually inferential from growth rate data and/or size-class groupings. It is the purpose of the present paper to offer evidence which suggests rather forcefully that the black turban snail, *Tegula funebris*, has a life-span greater than that recorded for any other gastropod, and that, unlike other members of the group, the ages of individuals of this species (at least in the population studied) may be approximately determined by counting growth lines.

During the 9-month period from October through June, 1959-60, a population of *Tegula funebris* was studied at Sunset Bay, Coos County, Oregon, in an attempt to determine the annual pattern of growth and mortality. The problem was suggested by Dr. Peter W. Frank of the University of Oregon, and the work was carried out under his guidance and with funds from the undergraduate research participation program of the National Science Foundation.

Unfortunately, the establishment of a long-range study program utilizing large sample sizes was frustrated through lack of a successful technique for marking and recapture. Two sorts of tagging methods were attempted on the 880 animals eventually released. Initially, numbered monel alloy tags (fig. 2) were attached near the lip of the shell by drilling small holes with a high-speed electric tool and dental bit. Subsequent observations on the 600 animals

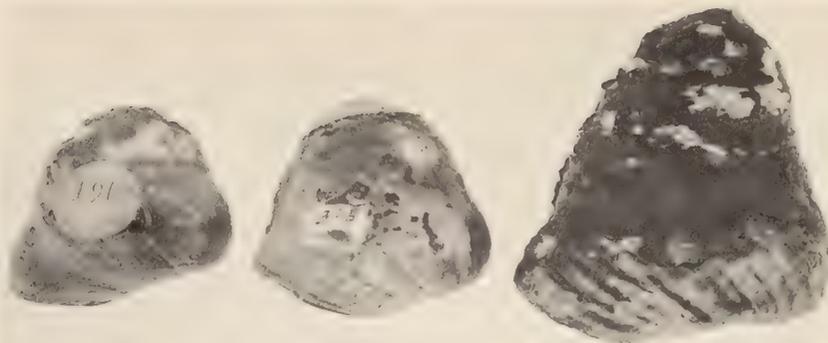


Figure 1



Figure 2



Figure 3

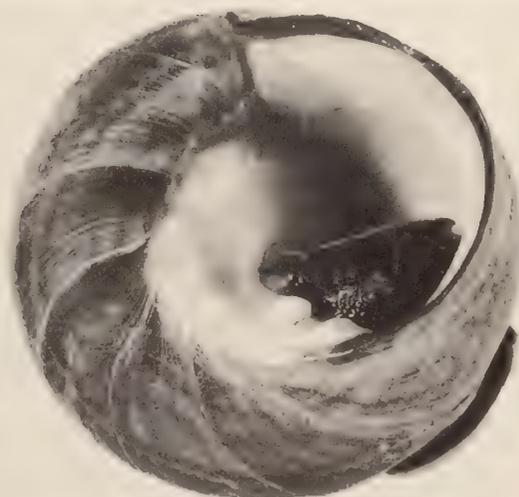
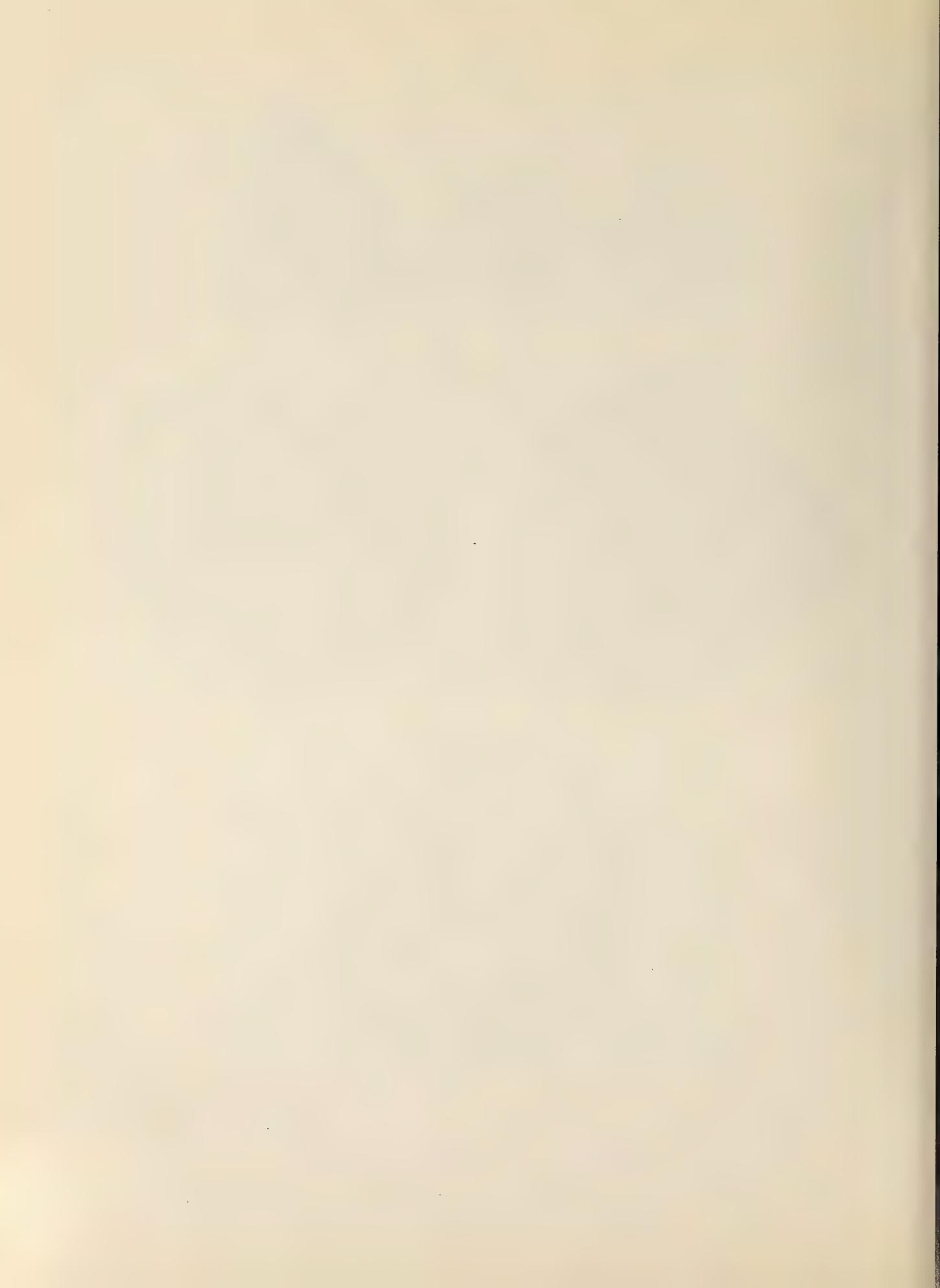


Figure 4

Three specimens of *Tegula funebralis* for demonstration of slow rate of growth and appearance of growth lines. Explanation in text.
Photographs by Bernard Freemesser.



so tagged suggested that mortality increased and growth was inhibited, and the method was discontinued. The second method used numbered squares of tape applied to the dried shell surface and painted over with a transparent plastic substance which hardened on exposure (fig. 1, center). These tags permitted growth but did not hold up well. With the failure to obtain a marking method which would assure recovery of sufficient numbers of individuals for studies of growth and mortality rates, the project was discontinued in the summer of 1960.

In August 1962, a single tagged individual was recovered from the original release area incidental to collecting snails for class work. This animal, marked with tape, showed very little shell accretion relative to its total size over the 27-month period since released (no. 364, Table 1). Six months later, in February 1963, another tagged animal was discovered by members of a class in ecology. This individual, bearing a metal tag (no. 190, figs. 1, 2, and 4), had nevertheless continued to grow and showed a pattern of shell accretion similar to that of the other recaptured snail. Several days later we systematically searched the study area and recovered 5 additional tagged animals showing subsequent growth. Data for the 7 snails are given in Table 1.

Table 1

Growth of seven marked individuals of *Tegula funebris* from Sunset Bay, Oregon.

Tag No.	Date		Diameter at ¹	
	released	recaptured	release	recapture
190 ²	11-29-59	2-23-63	23.0mm	23.8mm
435 ²	1-8-60	2-27-63	26.5	27.1
443 ²	1-8-60	3-3-63	27.7	29.3
A161 ²	3-26-60	2-27-63	26.3	27.3
364	5-15-60	8-9-62	19.9	21.8
375	5-15-60	2-27-63	25.1	25.6
387	5-15-60	2-27-63	22.9	24.3

¹ measurement of shell height is unworkable because of erosion at the apex.

² monel tag.

Reference to the photographs of tagged animals demonstrates quite clearly the relatively small annual increment of new shell produced by this species (the first prominent line distal to the tag corresponds to the shell margin at time of release). These figures also demonstrate that age can apparently be approximated by counting lines of growth—the more pronounced lines are apparently annual. These lines are most conspicuous when seen in umbilical view of the last body whorl (figs. 3, 4) — here

the shell surface is kept polished by movements of the animal. Age determination by counting such lines leads to the conclusion that the two tagged animals figured are at least 12 years old. For comparison, one of the largest individuals of the population was selected and its age estimated in the same way. This animal (fig. 1, right, and fig. 3) appears at least 30 years old. It can be seen that this larger individual has about 19 growth periods recorded on the largest body whorl (fig. 3), and that this last whorl represents growth since the animal was about the age of the two marked specimens.

DISCUSSION

ON THE BASIS of the rate of shell accretion shown over a 3-year period, the conclusion that *Tegula funebris* is a very slow-growing species, at least on the Oregon coast, seems inescapable. This slow growth rate is apparently coupled with a low adult mortality and, in the field, the presumably stable population is characterized by a relative accumulation of larger individuals.

The validity of the argument that age can be estimated rather closely by counting lines of growth has not been established rigorously as yet, but the evidence gathered so far supports such an idea quite graphically. It may be true, as MACGINITIE & MACGINITIE (1949) have stated, that some populations (presumably southern) show a continual slow increase in shell size rather than a seasonal suspension of growth as indicated here. Such latitudinal variation in growth rate has been demonstrated in the razor clam *Siliqua patula* (WEYMOUTH & McMILLIN, 1931). It is also conceivable that the local population experiences growth surges which are not strictly annual, and that 3 such periods occurred in the present case just by coincidence.

Frank has developed an improved method for marking of *Tegula*, and he and his students at Eugene are now engaged in a long-range study of this same population of snails as part of a larger study of the population ecology of a number of intertidal invertebrates.

LITERATURE CITED

- COMFORT, A.
1957. The duration of life in molluscs. Proc. Malacol. Soc. London 32: 219-241
- MACGINITIE, GEORGE, & NETTIE MACGINITIE
1949. Natural history of marine animals. 473 pp.; illus. McGraw-Hill, New York.
- WEYMOUTH, F. W. & H. C. McMILLIN
1931. The relative growth and mortality of the pacific razor clam (*Siliqua patula* DIXON) and their bearing on the commercial fishery. Bull. U. S. Bur. Fish. 46: 543-567

Some Properties of DNA from the Prosobranch Gastropod

Tegula funebris

BY

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AND

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THIS COMMUNICATION reports the isolation and partial characterization of deoxyribonucleic acid (DNA) from the testis of the marine prosobranch *Tegula funebris*. Estimates of the DNA nucleotide composition from chemical analysis, buoyant density (SCHILDKRAUT, MARMUR & DOTY, 1962), and thermal denaturation temperature (MARMUR & DOTY, 1962) are in good agreement. Of additional interest is the presence in digests of *Tegula* DNA of at least one unidentified chromatographic component, presumably an unusual nucleotide, which represents 3 to 6% of the total nucleotide content.

MATERIALS AND METHODS

Specimens of *Tegula (Chlorostoma) funebris* (A. ADAMS, 1854), collected from high tidepools in the intertidal area at Arroyo de los Frijoles in San Mateo County, California on February 16, 1963, were stored at 13° C. and dissected in the cold within 72 hours of collection. After the shells had been cracked in a vise, the testis of each male was dissected away from the closely adjacent hepatopancreas; minute portions of this organ were unavoidably included with the sample. Dissection of approximately fifty males yielded 7.1 grams of testicular tissue, which appeared on microscopic examination to consist largely of mature sperm.

From this tissue DNA was isolated by the method of KAY, SIMMONS & DOUNCE (1952), except that the product was at no time subjected to air drying. The final product was dissolved in 0.02M NaCl and stored at 4° C.

Deoxypentose was determined by the method of DISCHE (1930) and pentose by the method of MEJBAUM (1939). Protein estimation was carried out according to LOWRY *et al.* (1951), using purified bovine serum albumin as a standard.

To determine the nucleotide composition of the DNA a sample corresponding to 0.9 micromole of nucleotide phosphate was degraded completely to 5'—mononucleotides by sequential treatment with bovine pancreatic

DNase (Worthington Biochemical Corporation) and purified snake venom diesterase (KOERNER & SINSHEIMER, 1957). Following chromatography of the digest on Whatman No. 1 paper in an ammonium sulfate—sodium acetate—isopropanol solvent (MARKHAM & SMITH, 1952), spots corresponding to the nucleotide components were located with a UV lamp, cut out and eluted in 0.01M potassium phosphate buffer, pH 7. Using published extinction coefficients (BEAVEN, HOLIDAY & JOHNSON, 1955), the nucleotides were identified and quantitatively estimated from measurements of optical density at several wave lengths with a Zeiss spectrophotometer. Recovery of chromatographed material was between 80 and 93%.

For buoyant density determination, samples of *Tegula* DNA were centrifuged with a reference DNA of known density in concentrated solutions of cesium chloride for 16 to 20 hours at 44,770 rpm in a Spinco Model E analytical ultracentrifuge equipped with a UV optical system (MESELSON, STAHL & VINOGRAD, 1957; SCHILDKRAUT, MARMUR & DOTY, 1962). Buoyant density values were calculated from tracings made with a Joyce-Loebl double beam microdensitometer of UV photographs taken of the cells at equilibrium. As reference DNAs, the synthetic deoxyadenylate—deoxythymidylate copolymer (dAT, SCHACHMAN *et al.*, 1960; $\rho = 1.679 \text{ gm cm}^{-3}$) and N^{15} -labelled *Pseudomonas aeruginosa* DNA ($\rho = 1.742 \text{ gm cm}^{-3}$), kindly provided by Dr. Schildkraut, were used.

To determine the thermal denaturation temperature (MARMUR & DOTY, 1959) changes in optical density at 260 m μ of DNA solutions in stoppered quartz cuvettes were followed in a Zeiss PMQ spectrophotometer equipped to allow measurement of the cell temperature and regulation of the temperature to within a half degree. Determinations were carried out in a solution of 0.075M NaCl and 0.0075M Na citrate; corrections for ionic strength differences were made according to INMAN & BALDWIN (unpublished data) to facilitate comparison with values obtained at other salt concentrations.

RESULTS

Purity: Chemical analyses of the isolated *Tegula* DNA showed little contamination with protein or with RNA. Protein could be excluded to a level of less than 0.1% by weight; the ratio of purine pentose to deoxy-pentose was 0.003.

Chemical analysis of nucleotide composition: Whereas control analyses of calf thymus DNA gave only the four commonly occurring deoxyribonucleotides in amounts expected from published data (BEAVEN, HOLIDAY & JOHNSON, 1955), chromatograms of *Tegula* DNA digests consistently showed five distinct UV-absorbing spots. Four of these, in the order in which they chromatographed, could be identified as the 5'-deoxyribonucleotides of adenine (slowest moving), guanine, thymine and cytosine (Table I). The fifth component, which migrated ahead of deoxycytidylate, gave absorbency ratios which did not appear to correspond with published values for any of the "rare" nucleotides previously identified in DNA from other sources. Its chromatographic behavior and absorbency ratios suggested that it might be a deoxycytidylate derivative; however, authentic samples of 5'-5-methyl- and 5'-5-hydroxymethyl deoxycytidylate did not cochromatograph with the unknown component.

A sixth component, present in smaller amount and imperfectly resolved from deoxyadenylate was also observed

Table 1

UV Absorbancy Ratios and Quantitative Estimation of *Tegula* DNA Nucleotides

Nucleotide	Quantity Present μ Moles		
	Absorbancy Ratios 250 $m\mu$ /260 $m\mu$ 280 $m\mu$ /260 $m\mu$		
Experiment I			
dAMP	.75	.14	.19
dGMP	1.12	.68	.13
dTMP	.72	.75	.24
dCMP	.79	.98	.11
Unknown	.87	.67	.02-.04 ¹
Experiment II			
dAMP	.77	.07	.19
dGMP	1.12	.68	.14
dTMP	.62	.65	.31
dCMP	.79	.98	.13
Unknown	.81	.68	.02-.04 ¹

¹ Assuming a molar extinction coefficient at 260 $m\mu$ of 7500 to 15000.

on the chromatograms. The identity of these components remains undetermined.

Buoyant Density in Cesium Chloride: Equilibrium density gradient sedimentation of *Tegula* DNA in CsCl showed a major symmetrical band at a buoyant density of 1.697 gm. cm.⁻³. In runs using the N¹⁵ *Pseudomonas aeruginosa* DNA as a reference, a small "satellite" component, corresponding to approximately 1% of the total DNA, could also be detected at a density of 1.682 gm. cm.⁻³. Similar low density components have been described previously by SUEOKA (1961) in DNA from *Cancer irroratus* T. SAY, 1817 and *Cancer borealis* W. STIMPSON, 1859. They have been shown to consist almost entirely of deoxyadenylate and deoxythymidylate residues (SUEOKA & CHENG, 1962).

Thermal Denaturation Temperature: Measurement of optical density of a solution of *Tegula* DNA as a function of increasing temperature showed the sharp hyperchromic transition characteristic of native DNA (MARMUR & DOTY, 1959). The transition occurred over a range of approximately 14° C, with a midpoint (T_m) of 78.5° C. This figure corresponds to a value of 84° C at the ionic strength employed by MARMUR & DOTY (1962).

Table 2

Comparison of Estimations of *Tegula* DNA Nucleotide Composition

Method	Guanine + Cytosine Content
Chemical Analysis	38% ¹
Buoyant Density	38%
Thermal Denaturation Temperature	36%

¹ Assuming that the unknown component is a derivative of deoxycytidylate.

CONCLUSIONS

From the above determinations, the nucleotide composition of *Tegula* DNA can be estimated (Table II) using the established empirical relationships of guanine-cytosine (GC) content with buoyant density (SCHILDKRAUT, MARMUR & DOTY, 1962) and thermal denaturation temperature (MARMUR & DOTY, 1962). The values so obtained are in quite good agreement with the results obtained by chemical analysis. It may be concluded that the GC content of *Tegula* DNA is approximately 38%. This value is similar to that reported for *Anodonta sp.* (37%), *Chlamys (Pecten) islandica* (MÜLLER, 1776) (40%) and *Patella sp.* (36%) (ANTONOV & BELOZERSKII, 1961) and for *Mercenaria (Venus) mercenaria* (LINNAEUS, 1758) (37%)

(SUEOKA, 1961). All of these contrast with the value of 47% found by ANTONOV & BELOZERSKII (1961) for DNA from muscular tissue from *Buccinum undatum* LINNAEUS, 1761.

The apparent presence of unusual nucleotides, as well as a low density "satellite" component in the DNA from *Tegula funebris* makes it an interesting object for further study.

ACKNOWLEDGMENT

The work reported above was carried out as a laboratory exercise during a course in biochemistry at the Stanford University School of Medicine. Our thanks are due to the staff of the basic medical sciences laboratories and to members of the biochemistry department who very generously contributed equipment and special reagents. We are particularly grateful to Mr. William B. Wood of this department, who carried out the buoyant density determinations and assisted in preparation of the manuscript.

LITERATURE CITED

- ANTONOV, A. S. & A. N. BELOZERSKII
1961. Comparative study of the nucleotide composition of the deoxyribonucleic acids of certain vertebrates and invertebrates. Doklady, Akad. Nauk SSSR 138 (1/6): 113 - 115
- BEAVEN, G. H., E. R. HOLIDAY & E. A. JOHNSON
1955. Optical properties of nucleic acids and their components. Chapt. 14 in: The nucleic acids, vol. 1: 493 - 553. Chargaff & Davidson, ed.
- DISCHE, ZACHARIAS
1930. Über einige neue charakteristische Farbreaktionen der Thymonucleinsäure und eine Mikromethode zur Bestimmung derselben in tierischen Organen mit Hilfe dieser Reaktionen. Mikrochemie 8: 4 - 32
- KAY, ERNEST M., NORMAN S. SIMMONS & ALEXANDER DOUNCE
1952. An improved preparation of sodium desoxyribonucleate. Journ. Amer. Chem. Soc. 74 (7): 1724 - 1726
- KOERNER, JAMES F. & ROBERT L. SINSHEIMER
1957. A desoxyribonuclease from calf spleen. II. Mode of action. Journ. Biol. Chem. 228 (2): 1049 - 1062
- LOWRY, O. H., N. J. ROSEBROUGH, A. L. FARR & R. J. RANDALL
1951. Protein measurement with the Folin Phenol reagent. Journ. Biol. Chem. 193 (1): 265 - 275
- MARKHAM, R. & J. D. SMITH
1952. Structure of ribonucleic acids. I. Cyclic nucleotides produced by ribonuclease and alkaline hydrolysis. Biochem. Journ. 52 (4): 552 - 557
- MARMUR, JULIUS & PAUL DOTY
1959. Heterogeneity in deoxyribonucleic acids. I. Dependence on composition of the configurational stability of deoxyribonucleic acids. Nature 183: 1427 - 1429
1962. Determination of the base composition of desoxyribonucleic acid from its thermal denaturation temperature. Journ. Molec. Biol. 5 (1): 109 - 118
- MEJBAUM, WANDA
1939. Über die Bestimmung kleiner Pentosemengen, insbesondere in Derivaten der Adenylsäure. Hoppe-Seyler's Zeit. f. physiol. Chem. 258: 117 - 120
- MESELSON, M. F. W. STAHL & JEROME VINOGRAD
1957. Equilibrium sedimentation of macromolecules in density gradients. Proc. Nat. Acad. Sci., Wash. 43 (7): 581 - 588
- SCHACHMAN, H. K., J. ADLER, C. M. RADDING, I. R. LEHMAN & A. KORNBURG
1960. Enzymatic synthesis of deoxyribonucleic acid. VII. Synthesis of a polymer of deoxyadenylate and deoxythymidylate. Journ. Biol. Chem. 235 (11): 3242 - 3249
- SCHILDKRAUT, C. L., J. MARMUR & PAUL DOTY
1962. Determination of the base composition of deoxyribonucleic acid from its buoyant density in CsCl. Journ. Molec. Biol. 4 (6): 430 - 443
- SUEOKA, NOBORU
1961. Variation and heterogeneity of base composition of desoxyribonucleic acids: A compilation of new and old data. Journ. Molec. Biol. 3 (1): 31 - 40
- SUEOKA, NOBORU & TS'AI-YING CHENG
1962. Fractionation of nucleic acids with the methylated albumin column. Journ. Molec. Biol. 4 (3): 161 - 172



The Hemocyanins of *Tegula funebris* and *Tegula brunnea*

(Mollusca : Gastropoda)

BY

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(3 Text figures)

THE PURPOSE OF THIS STUDY was to develop a method of purification of hemocyanin and to compare some properties of this respiratory pigment in *Tegula funebris* (A. ADAMS, 1854) and *Tegula brunnea* (PHILIPPI, 1848).

METHODS AND MATERIALS

Animals were collected at Mussel Point and at Point Pinos, Pacific Grove, California. After one hour of anesthesia, in 0.01% (w/v) solution of "Sevin 50" (1-naphthyl-N-methyl carbamate) in filtered sea water, the foot of the animal, which becomes somewhat distended, was lanced and the blood collected in a small crucible. Care was taken in collecting the blood to prevent contamination with fluid from the mantle cavity. Contamination was minimized by shaking the animal in order to remove most of this fluid and by holding the foot of the animal between thumb and forefinger while lancing to prevent the animal from withdrawing into its shell and forcing the fluid out. The blood was centrifuged for 30 minutes to remove cells and other debris, and either analyzed immediately or frozen for study at a later time. Freezing produced no noticeable effect on the blood.

The oxygen dissociation data were obtained on 5 ml samples of blood placed in a Klett tube and covered with a vaccine cap. Different mixtures of air and nitrogen were regulated with two Gelman flowmeters (range 1 to 10 CFH) and allowed to pass over the sample of blood. The gas input and exhaust were equipped with 20-gauge hypodermic needles. In order to prevent excessive evaporation of the sample, the gas mixture was only passed over it for 10 minutes. The sample was then shaken to equilibrate it with the gas mixture in the sealed tube, and the density of color measured in a Klett-Summerson Photoelectric Colorimeter using a no. 54 green filter (520 to 580 m μ) against a blank of distilled water. The process was repeated until a constant reading was obtained for any gas mixture. Values were obtained for varying ratios of air to nitrogen starting with pure nitrogen in which

hemocyanin became completely reduced and ending with pure air in which the pigment became fully oxygenated. Values for reduced and oxygenated hemocyanin were obtained for various dilutions of the blood in filtered sea water adjusted to the same pH as the blood in order to establish a standard curve for concentration of oxidized *Tegula* hemocyanin.

Purification of the hemocyanin was accomplished by filtration of samples of blood through a 6 cc Sephadex G-200 column. Initial fractionation of 1 ml samples of blood into 1 ml aliquots was evaluated by observing the location of the blue color characteristic of hemocyanin and measurement of the protein by the method of LOWRY (1951) using a standard curve prepared with Armour Bovine Serum Albumin Fraction V. The void volume of

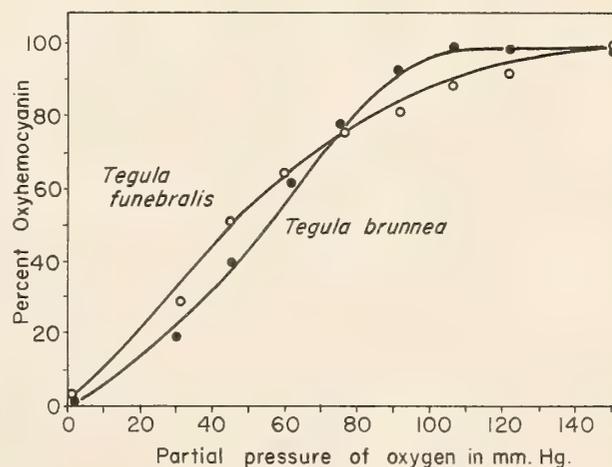


Figure 1: Oxygen dissociation curves for *Tegula funebris* and *Tegula brunnea*. pH for *T. funebris* is 7.2 and for *T. brunnea* is 7.8. Temperature for both species is 15° C. Values for *T. funebris* are represented by open circles and for *T. brunnea* by closed circles.

the column was established using 1 ml of a mixture of diluted india ink and phenol red dye. Samples of hemocyanin thus purified were used for further study.

The nitrogen content was determined by Nesslerization after digestion in H_2SO_4 , H_3PO_4 1 : 3 containing 0.55% $CuSO_4$. Dry weight was determined on samples after drying in an oven at $80^\circ C$ to constant weight.

The absorption spectrum was determined on a Beckman DKB spectrophotometer.

RESULTS

Oxygen equilibrium curves are shown in Figure 1. Both curves were corrected for the absorption and light scattering by the use of a completely reduced sample of blood. The pH of *Tegula funebris* blood was 7.2 and the temperature for gas equilibration was $15^\circ C$. The P_{50} for the sample, i. e., the partial pressure at which 50% saturation of the hemocyanin was reached, was 45 mm Hg. The pH of *T. brunnea* blood was 7.8 and equilibration carried out at the same temperature revealed a P_{50} of 55 mm Hg.



Figure 2: Fractionation of *Tegula brunnea* serum by Gel filtration through Sephadex G-200. Elution with 3% NaCl

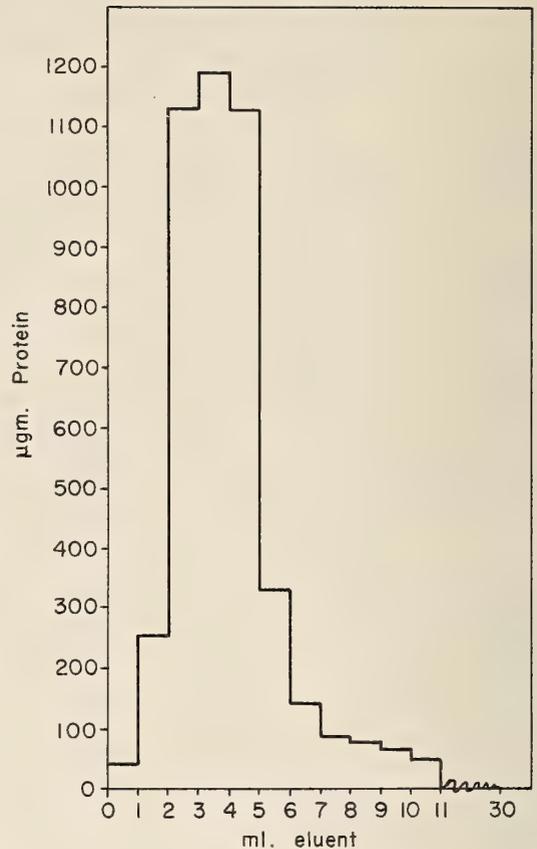


Figure 3: Fractionation of *Tegula funebris* serum by Gel filtration through Sephadex G-200. Elution with 3% NaCl.

In order to investigate the nature of interaction between prosthetic groups of the pigment, the Hill equation for respiratory pigments was used (MANWELL, 1960, p. 207). For *Tegula funebris* and *T. brunnea* at the pH used, the line obtained from plotting the Hill equation logarithmically is curved. Hence, interaction between prosthetic groups varies over the range of oxygen tensions.

Figures 2 and 3 show the results of fractionation of the blood of *Tegula funebris* and *T. brunnea* on a Sephadex G-200 column. The characteristic blue color of oxyhemocyanin could be detected in the third, fourth, and fifth ml of eluent for *T. funebris* and second, third, and fourth ml of eluent for *T. brunnea*. These were coincident with the elution pattern in terms of protein. The void volume of the column corresponded to the first two ml of eluent. The elution of the pigment, as was expected, indicates a

molecular size in excess of that corresponding to a molecular weight of 200000.

The nitrogen content of the purified hemocyanin corresponded to the expected amount in terms of the Lowry protein estimation. The nitrogen content in terms of per cent dry weight was approximately 15%. Therefore, the purified material was not contaminated with nitrogen-containing non-protein material nor with large molecular weight material lacking nitrogen.

The purified material gave the two peaks characteristic of hemocyanin. The broader minor peak had a maximum at 560 $m\mu$ and the sharper major peak at 371 $m\mu$.

DISCUSSION

Since the oxygen dissociation curves are based on the examination of only two samples, an interpretation of the small differences observed is not possible.

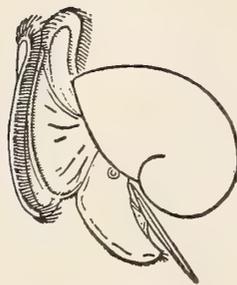
The use of Sephadex G-200 for purification of hemocyanin produces very clean samples of the pigment in any desired solution of electrolyte. Fractionation of the blood of *Tegula funebris* and *T. brunnea* indicates that the molecular size of these hemocyanins exceeds that of a molecule with a molecular weight of 200000. This agrees with the values listed in the literature (REDFIELD, 1950). It appears that there are no other smaller molecular weight proteins or polypeptides in the blood of these animals since only the one peak appears on elution.

SUMMARY

1. Hemocyanins from *Tegula funebris* and *T. brunnea* were compared with respect to oxygen equilibration.
2. Only slight differences between the hemocyanins for the two species were detected in the oxygen dissociation curves.
3. P_{50} values for *T. funebris* and *T. brunnea* were determined to be 45 and 55 mm Hg respectively.
4. For the pH used, prosthetic group interaction appeared to vary depending on the oxygen partial pressure.
5. A method for purification of hemocyanin was developed using Sephadex G-200.
6. It appears that no smaller molecular weight proteins or polypeptides are present in these sera.
7. The absorption spectrum for *T. funebris* blood gives the major peak at 371 $m\mu$ and the minor peak at 560 $m\mu$.

LITERATURE CITED

- LOWRY, O. H., *et al.*
1951. Protein measurement with the Folin Phenol reagent. *Journ. Biol. Chem.* **193**: 265 - 275
- MANWELL, C.
1960. Comparative physiology: Blood pigments. *Ann. Rev. Phys.* **22**: 191 - 244
- REDFIELD, A. C.
1950. Hemocyanin, in: Copper metabolism. McElroy and Glass (eds.). Baltimore; Johns Hopkins Press. pp. viii, 443.



Proteolytic Enzymes in the Gastropod *Tegula funebris*

BY

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(3 Text figures; 1 Table)

RELATIVELY LITTLE has been reported on invertebrate enzymes. In the black turban snail, *Tegula funebris* (A. ADAMS, 1854), commonly found in the rocky intertidal zone of the western coast of North America, various carbohydrases have recently been reported (GALLI & GIESE, 1959). Although these snails are primarily herbivorous, one might expect proteases and lipases to be present in their digestive system. The purpose of this study was to find and to characterize the proteases in *T. funebris*.

METHODS

Only fresh animals collected at China Point, Pacific Grove, California, were used in this experiment. The enzyme extract was a saline homogenate of the entire digestive tract, beginning with the tissue of the buccal cavity and the salivary glands and ending with the hind gut. This also included the digestive gland, spiral caecum, and a small, unavoidable section of gonad. The tissue from one animal was homogenized in 3.0 ml of distilled water or saline solution for about two minutes. This extract was centrifuged for one hour in the high speed Servel and filtered through Whatman No. 1 paper. When the extract at this stage of purification was used in the test system, the enzyme controls were undesirably high. This was caused by various low molecular weight polypeptides, which added to the color development process described below. Therefore, this extract was filtered through a Sephadex G-50 column, with a volume of about 10 ml, which crudely separated the protein material with respect to its molecular weight. Assuming the proteases to be among the larger molecules present, I collected the fourth through the seventh milliliters of filtrate as it came off the column. This was determined by filtering 2.5 ml of crude extract through the column with the continued addition of distilled water or saline solution and determining the amount of protein in each of the first twenty-four 1.0 ml aliquots (see Figure 1). The assay procedure is described below. These four milliliters of filtrate contained essentially all of the protease activity of the entire gut and were diluted with

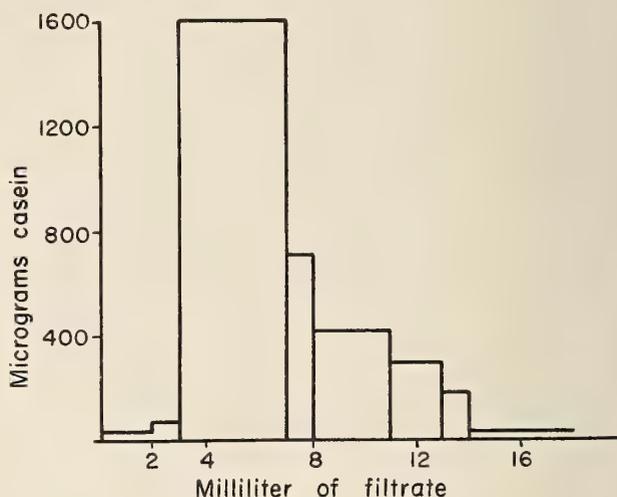


Figure 1: Filtration of 2.5 ml Tissue Extract on Sephadex G-50 Column.

water or saline solution to such a volume that the tissue weight/volume extract quotient was 0.03. Although the activity of this purified extract was not as high as that of the crude extract, the enzyme controls were reduced to a level corresponding to only 5% of the total activity. This was the extract used in the test system.

A modified version of the casein digestion method described by KUNITZ was employed (COLOWICK & KAPLAN, 1955, pp. 33 ff.). The substrate was a 1% solution of Difco sodium caseinate in distilled water. This solution was boiled for 15 minutes to assure complete dissolution and denaturation of the casein. To this were added a few drops of toluene to prevent the mass growth of bacteria in both the stock solution and also the test system. To 1.0 ml of substrate was added 2.5 ml of buffer, at twice the desired final concentration, and 1.0 ml of enzyme extract. The system was brought to 5.0 ml by the addition of 0.5 ml of distilled water. The tubes were incubated for 24 hours at 15° C; digestion was stopped

by the addition of 4.0 ml of trichloroacetic acid, and the tubes were allowed to stand overnight to provide ample time for the complete precipitation of TCA-insoluble materials. The hydrolyzed products were assayed using the Lowry adaptation of the Folin method (LOWRY, 1951).

RESULTS

It was necessary to determine the pH optima of the enzymes before further investigation; therefore, a series of buffers, a 0.05M citrate-phosphate buffer over the pH range 4.0 to 7.1, a 0.1M phosphate buffer over the range 7.2 to 7.8, a 0.05M veronal-HCl buffer over the range 7.6 to 8.9, and a 0.05M glycine-NaOH buffer over the range 8.6 to 12, were used. Three activity peaks resulted; one with a pH optimum of 5.0 in citrate-phosphate buffer, one with a pH optimum of 8.6 in veronal and glycine buffers, and the third with an optimum of 10.5 in glycine-NaOH buffer (see Figures 2 and 3). The phosphate buffer system yielded very low results; this was the first evidence of the necessity of a divalent metallic ion, which was removed from the system by the phosphate buffer. Since the citrate-phosphate buffer can also cause this removal occasionally, one must assume that any metallic ion which activates the acid enzyme is more firmly bound to the protein molecule.

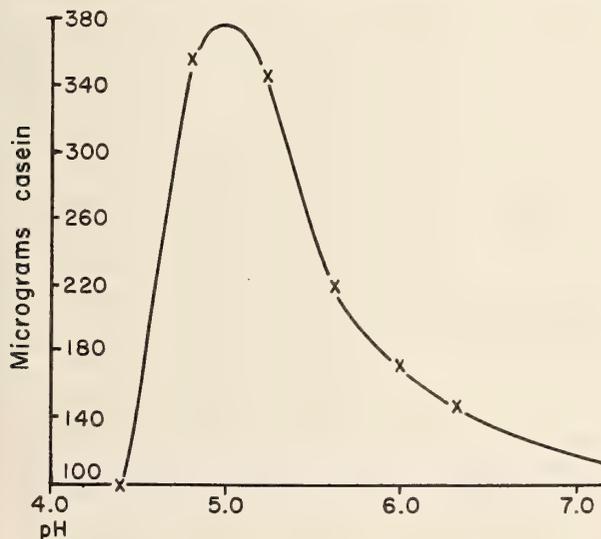


Figure 2: Activity in 0.05M Citrate-Phosphate Buffer.

The next problem was to determine the effects of various activators and inhibitors. To one system was added 0.5 ml of a 10% solution of sodium ethylene diamine tetraacetate (EDTA) as a strong chelating agent. Enzymatic activity at the two pH values tested was drastically reduced, showing the effect of the removal of divalent metallic ions from the test system. Various ions were

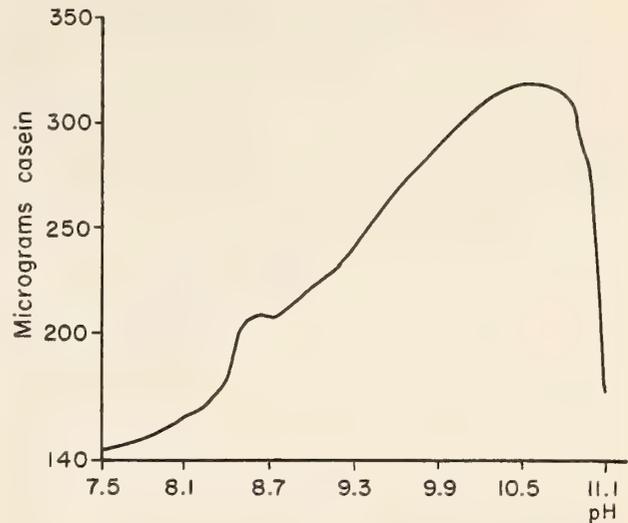


Figure 3: Activity in 0.05M Glycine-NaOH Buffer.

tested for activation or inhibition, and the results are given in Table 1. Since Mn^{2+} , Co^{2+} , and cysteine all react with reagent C and Phenol reagent to modify the color, the values represented in the table are the corrected differences between the total activity reading for each test system and the corresponding controls for the enzyme extract, substrate, and the particular activator or inhibitor. The activators and inhibitors were tested at a final concentration of 0.001 M.

Table 1
Effects of Various Agents on Enzyme Activity.

Agent	Effect	
	5.0 pH	8.3 pH
Normal	172	136
Calcium chloride	— 13	— 22
Cobalt sulfate	— 132	— 140
Magnesium chloride	— 9	— 9
Manganous chloride	+ 72	+ 59
Zinc sulfate	+ 10	— 98
Cysteine	+ 59	— 3
Mercuric chloride	— 120	— 32

+ = activated — = inhibited
values are micrograms casein hydrolyzed

DISCUSSION

Two proteolytic enzymes in *Tegula funebris* (pH optima at 5.0 and 8.6) are very similar to other proteases which have been found in related mollusks and marine animals (PROSSER, 1950). With respect to pH optima and

activators, these acid and slightly alkaline enzymes show many similarities to cathepsins and trypsin respectively (SUMNER & MYRBÄCK, 1950, pp. 857ff.). The acid enzyme and cathepsins are both inactivated upon oxidation as shown by the addition of HgCl_2 , and conversely, they are activated by reduction, as shown by the addition of cysteine. The question of intra- or extra-cellular digestion still remains unanswered.

The activity of the slightly alkaline enzyme is less than that of the acid one. It resembles a trypsin of some type with respect to its pH optimum and differs from some other molluscan enzymes in that it is not inhibited by cysteine. Activity is also increased by the manganous ion, as in the case of the acid enzyme, and is significantly inhibited by the presence of the zinc ion.

Various proteinases with very alkaline pH optima have been reported in the literature (POWNING, 1951 and SHINODA, 1930). This enzyme in *Tegula* is completely uncharacterized. It was tested for dipeptidase activity using a glycyl-glycine substrate; however, no activity was observed in the assay system used. Further experiments on the enzyme's specificity are now underway.

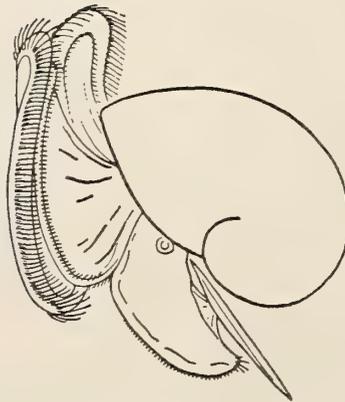
Preliminary studies indicate that the acid enzyme is concentrated in the midgut region, i. e. the stomach and the digestive gland.

SUMMARY

Three proteolytic enzymes were found in the digestive tract of *Tegula funebris*, which had pH optima of 5.0, 8.6, and 10.5. The enzyme extract was a saline homogenate of the entire digestive tract which had been centrifuged, filtered, and then filtered through a Sephadex G-50 column. The substrate used was sodium caseinate. Activators include Mn^{++} , and cysteine; inhibitors include Co^{++} , Zn^{++} , and Hg^{++} .

LITERATURE CITED

- COLOWICK, SIDNEY P. & NATHAN O. KAPLAN
1955. Methods in enzymology, vol. II. New York, Acad. Press Inc. xx + 987 pp.
- GALLI, D. P. & ARTHUR C. GIESE
1959. Carbohydrate digestion in a herbivorous snail, *Tegula funebris*. Journ. Exp. Zool. 140: 415-440
- LOWRY, O. H. *et al.*
1951. Protein measurements with the Folin Phenol reagent. Journ. Biol. Chem. 193: 265-275
- PROSSER, C. LADD (ed.)
1950. Comparative animal physiology. W. B. Saunders. ix + 888 pp.; illust.
- SUMNER, JAMES & KARL MYRBÄCK
1950. The enzymes, vol. I, part II. Acad. Press Inc. New York. 1361 pp.; illust.



Chemoreception by *Tegula funebris*

(Mollusca : Gastropoda)

BY

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(3 Text figures)

OBSERVATIONS IN THE FIELD and in the laboratory showed that escape responses are elicited in *Tegula funebris* (A. ADAMS, 1854) by the immediate presence of starfish. Since contact with the starfish is not essential to effect the response, I proposed to determine the location of possible chemoreceptive sites.

MATERIALS AND METHODS

Species used in the tests were *Tegula funebris* and *Pisaster ochraceus* (BRANDT, 1835). All test animals were taken from the intertidal region at China Point, Hopkins Marine Station, Pacific Grove, California.

The *Tegula funebris* were anesthetized in an isotonic solution of Mg Cl₂. Twenty animals were kept as controls following anesthesia; from some of the remaining animals various structures were removed (head tentacles, epipodial structures, epipodial fringe, osphradium) and others had either the bottom or the side of the foot scraped. The operated animals were then observed in order to determine any deviation from the behavior of the control snails.

Pisaster ochraceus was selected from among the various species of starfish because of its abundance and its highly effective stimulation of *Tegula funebris* (YARNALL, 1964).

Three types of tests were performed.

1) Snails were arranged around the sides in the bottom of a plastic bucket to which a *Pisaster ochraceus* was then added. The sea water level was maintained at 6 cm (approximately 4½ liters). The number of snails out of the water after a specified time was scored.

2) Detached starfish tube feet were touched against *Tegula funebris* which had been placed on a water table over which ran a continuous supply of sea water. Responses observed were those described by FEDER (1956). They were classified as strong, moderate, and slight (strong = immediate and marked escape reaction

to one stimulation by the detached tube foot; moderate = noticeable avoidance after being stimulated once - but without the rapidity or the sharpness in turning of a strong response; slight = several stimulations necessary to elicit a reaction as noticeable as a moderate response). 3) A homogenate of starfish tube feet (4 g wet weight of tube feet to 8 cc of sea water) was made. The supernatant resulting after centrifugation was diluted to several different concentrations. For tests 1 ml supernatant was added to 200 cc sea water in a small dish. The number of snails out of the water after a specified time was scored. Since the potency of individual extracts of tube feet varied, a new control group was required for each preparation.

RESULTS AND DISCUSSION

The results are shown in the form of bar graphs in Figures 1 to 3.

The results in Figure 1 demonstrate that scraping of much of the epithelial layer of the side or bottom of the foot does not impair sensitivity to chemical stimulation by starfish secretions. This same modification of the snail does not remove its ability to be stimulated by contact with tube feet as is indicated in Figure 2. Also, while it is not indicated in the figures, excising of the border of the sides and bottom of the foot does not cause noticeable change in the chemoreceptive ability of the snail.

Normal snails exhibit escape responses when any side of the foot is stimulated by a detached tube foot. These responses are specific only for detached tube feet; human hands, bare probes, and probes with detached *Tegula funebris* feet will not elicit any escape response.

The necessity for touch as a stimulus for these sites may be demonstrated by placing the left or right side of a snail without epipodial structures against a starfish arm. Such a modified snail will become excited and

show faster random motion. Detached tube feet held near the surface of the side of the foot do not cause a reaction.

The head tentacles appear to be primarily tactile receptors. Normal responses are elicited after their extirpation (Figures 1 to 3). But chemoreception on physical contact is assuredly another of the tentacles' properties, for responses of the tentacles to detached tube feet are definite and specific.

The main function of the head tentacles is apparently to help localize the source of stimulation, so that in this case the snail might be better able to steer away from the starfish. When stimulated by detached tube feet, animals

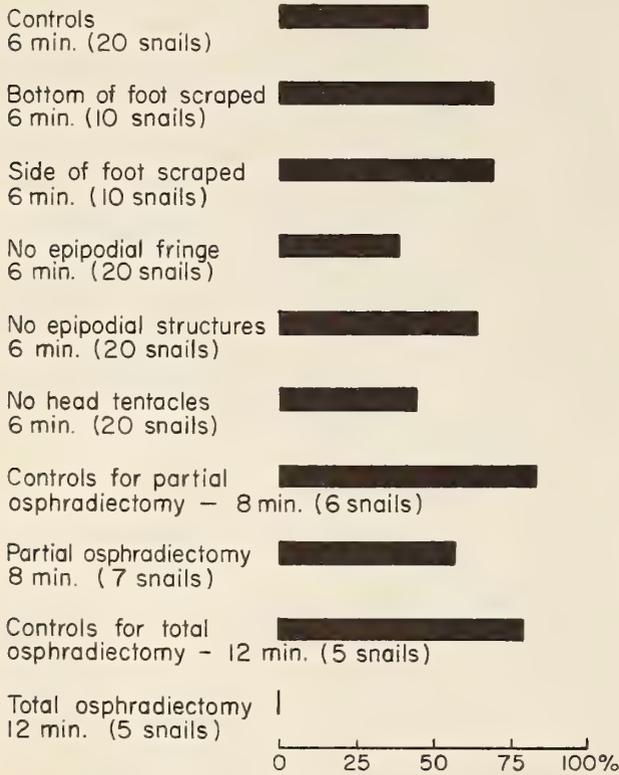


Figure 1:

Escape of *Tegula funebris* from *Pisaster ochraceus*
Abcissae represent percent of snails out of water.

deprived of tentacles did not give responses oriented as much away from the tube foot as the control animals did, i. e., the operated animals usually turned less than 90°, as opposed to the controls.

Likewise, the chief function of the epipodial structures seems to be that of tactile receptors. Their extirpation makes little difference in *Tegula funebris*'s reactions to tube feet or tube feet extract (Figures 1 to 3). Also, like the head tentacles, epipodial structures do have chemo-

receptive properties on physical contact. Their reactions to tube feet are specific, although not as marked as those of the head tentacles.

The epipodial structures also appear to function as stimulus localizers. Epipodialectomized animals, when stimulated on the side of the foot by tube feet, do not veer away from the tube feet in as directed a manner as control animals. They usually turn at an angle of 45° or less to the opposite side from which they were stimulated.

The osphradium, a bipectinate structure located at the base of the mantle and in close association with the ctenidium, is in this herbivorous species quite small and difficult to remove. Because of the severity of the operation for removal of the osphradium, a group of special control animals was prepared. These control animals were subjected to all steps in the operation, including cracking of the shell, except that their osphradia were left intact. Two groups of test animals, those partially osphradiectomized and without part of their shell and a group that was totally osphradiectomized and with shell pieces fitted back together, were used. In the partially osphradiectomized animals the osphradial nerve was cut distal to the left parietal ganglion, and that portion of the osphradium growing along the edge of the ctenidium on

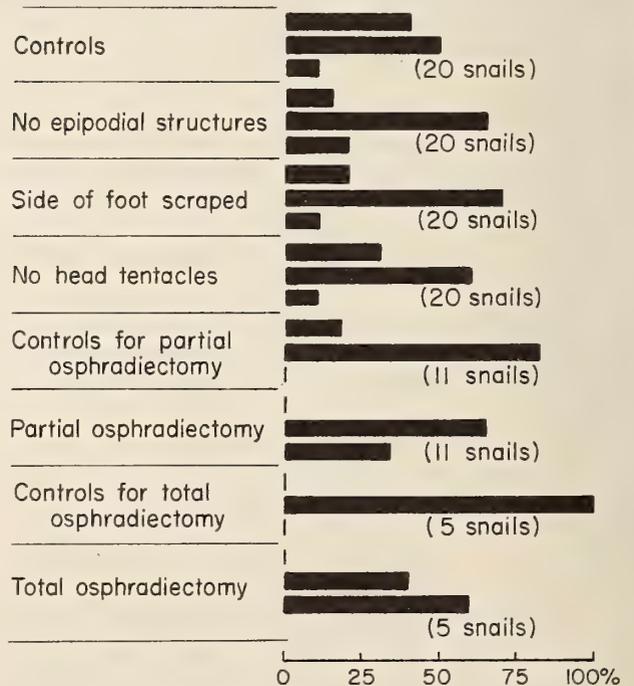


Figure 2: Response of *Tegula funebris* to tube feet of *Pisaster ochraceus*. In each group the top line represents strong response, the middle line moderate response, and the bottom line slight response (see text).

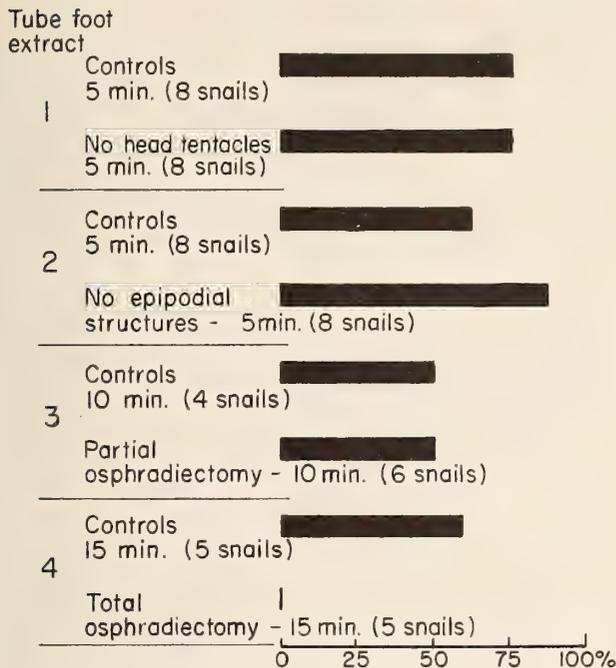


Figure 3: Detection of *Pisaster ochraceus* extract by *Tegula funebralis*. (Extract contained 1.04×10^{-4} parts by wet weight of tube feet.) Abscissae represent percent of snails out of the extract.

the ventral side was removed. The mass of the osphradium, located under the ganglion, could not be reached by this technique, which resulted in partially osphradiectomized animals. Total osphradiectomy involved removal of the remaining osphradial mass.

There is no appreciable difference in the behavior of the partially osphradiectomized animals and their controls (Figures 1 to 3). Obviously, most of the osphradium, or at least the yellow mass in close connection with the parietal ganglion, must be removed before olfactory properties are eliminated.

Osphradiectomized animals show no more movement of the tentacles or general excitement in the presence of tube foot extract or in a bucket with a starfish than they do in ordinary sea water. These animals do withdraw their head tentacles slightly from detached tube feet, but the reactions are not at all as strong as those given by any of the other test animals. After 15 minutes of exposure to starfish one osphradiectomized animal crawled out of the water, but it returned 30 seconds later.

Those sites found to be chemoreceptive in a gustatory sense, that is requiring physical contact, are the sides of the foot, the head tentacles, and the epipodial structures.

The osphradium functions as an olfactory sense organ, being chemoreceptive without physical contact.

The chemoreceptive sites of *Tegula funebralis* are extremely sensitive. While not indicated by figures a straight-line correspondence between the concentration of *Pisaster ochraceus* tube foot extract (expressed logarithmically) and the probability of eliciting an escape response in *T. funebralis* could be demonstrated. The 50% threshold effect lies about midway between the 1/64 and the 1/32 dilutions of an extract 33% by wet weight of tube feet, 1 ml of which is added to 200 cc sea water; i. e., *T. funebralis* will escape 50% of the time within 5 minutes from a solution that is 2.6 to 5.2×10^{-5} parts by wet weight of tube feet. Decreasing the dilution results in gradually increasing activity by the test animals.

The movement resulting from the presence of the starfish or of its secretion appears to be random. *Tegula funebralis* have been observed to run into a starfish up to four times before finally climbing out of the bucket. The snail appears to test the concentration of starfish secretion and orients and moves randomly. It eventually reaches an area of lower concentration of the chemical stimulus. However, in the immediate proximity of a starfish contained in a bucket in a small volume of water (about $4\frac{1}{2}$ liters) there is not likely to be much of a concentration gradient, and the only available area of lower concentration is out of water.

Tegula funebralis can and do often adapt themselves to the presence of *Pisaster ochraceus* (see FEDER, 1956). This adaptation is not due to breakdown of the tube foot substance, but rather fatigue of the chemoreceptive sites. Snails added to a pan from which they were prevented from escaping by a wire screen and in which a starfish has immediately beforehand resided show marked activity for about 15 minutes, after which time they become quiescent. New *T. funebralis* then added also show increased activity for about 15 minutes, while the "fatigue" of the original snails is still manifested. Neither the subsequent reintroduction of the starfish nor the removal of the wire screen caused any of the twenty "fatigued" animals to move out of the bucket within 15 minutes.

SUMMARY

Tegula funebralis has both gustatory and olfactory sense sites. The side of the foot, the head tentacles, and the epipodial structures serve as contact chemoreceptive sites. Extirpation or scraping of these structures does not alter the overall sensitivity to *Pisaster ochraceus*. Scraping the bottom of the foot, cutting of the border between the side and the bottom of the foot, removal of the epipodial fringe (on the left side of the foot), removal of up to

half of the ctenidium do not noticeably alter chemoreception. The osphradium functions as an olfactory organ and is capable of detecting the presence of an extract containing 2.6×10^{-3} parts by wet weight of tube feet from *Pisaster ochraceus*. The osphradium, when stimulated, seems to cause the animals to be more sensitive to stimulations of the head tentacles and epipodial structures. Removal of part of the osphradium does not

result in appreciable change of chemoreceptive abilities of *T. funebris*.

LITERATURE CITED

- FEDER, H.
1956. Natural history of *Pisaster ochraceus*. Doctoral diss., Stanford Univ.

Identification and Location of Carbohydrases in the Intestinal Tract of *Tegula funebris*

(Mollusca : Gastropoda)

BY

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(6 Tables)

SINCE *Tegula funebris* (A. ADAMS, 1854) is an herbivorous marine animal, it is quite evident that it must have an efficient and well developed carbohydrate digestive mechanism. Although this subject has been explored to some degree already (GALLI, 1956), there still seemed much to be investigated. We limited our efforts to the study of five carbohydrates present in the environment of the animal: starch, laminarin, alginate, fucoidin, and cellobiose. Using these materials we hoped to localize the points of enzyme production within the alimentary canal and sites of carbohydrate digestion. The extent to which intracellular and extracellular digestion is involved in the foregut and hindgut was also studied.

The substrates were: starch (Baker and Adamson, reagent grade), alginate (Kelco Co., commercial grade), cellobiose (Pfanstiehl Chemical Co., C. P. grade). Laminarin and fucoidin were isolated from *Fucus* by the method of BLACK, DEWAR, & WOODWARD (1951 - 1952).

The alimentary canal was divided into eight anatomical

parts: buccal cavity, salivary glands, esophagus, stomach and digestive gland (since it was impossible to separate the stomach from the digestive gland), digestive gland (portions freed from the stomach), spiral caecum, thin hindgut, and thick hindgut.

The purpose of the first experiment was to determine the site of enzyme production. The gut segments were excised from snails fresh from the field. These tissues were refrigerated so as to retard any loss of enzyme activity due to denaturation or autolysis. Pools of tissue from five animals were washed, weighed, and extracted in a tissue grinder equipped with a Teflon pestle (Van Waters and Rogers Inc., Catalogue no. 48652) with either a citrate-phosphate buffer, pH 5.8, or a phosphate buffer, pH 7.4. These buffers were chosen since they approximate the extremes of hydrogen ion concentration occurring in the digestive tract. Enzyme activity was determined by incubating an appropriate aliquot of tissue extract with one of the substrates and assaying for reducing sugar by

the Somogyi reaction as modified by GALLI (1956). Enzyme and substrate controls were incubated simultaneously. Incubation was at 15° C for 24 hours.

The results are recorded in Tables 1, 2, and 3. It appears that throughout the entire length of the digestive tract there is widespread production of large concentrations of amylase and cellobiase. On the other hand, there was only a small and localized production of enzymes that split the 1,4- β -D-mannuronic acid linkage of alginic acid, the 1,2- α -L-fucose-4-sulfate linkage of fucoidin, and the 1,3- β -D-glucose linkage of laminarin. The results would further indicate that the salivary glands do not play an important role in enzyme production with the exception of cellobiase. It is also evident from Table 3 that some of the enzymes show different pH optima.

Table 1

Substrate Controls

Substrates, 0.1%; citrate-phosphate buffer, 0.5M, pH 5.8; phosphate buffer, 0.1M, pH 7.4; incubation at 15° C for 24 hours.

Substrate	μ g Reducing Sugar ¹
pH 5.8	
starch	0
laminarin	0
alginate	0
fucoidin	0
cellobiose	312.0
pH 7.4	
starch	0
laminarin	0
alginate	0
fucoidin	0
cellobiose	474.0

¹ μ g reducing sugar present in 1 ml substrate

The second experiment was conducted to investigate the site of enzyme action. The snails were starved until the digestive tract was cleared of material. A period of about ten days was required. Ligatures were used to isolate the previously mentioned parts of the digestive tract.

The salivary glands were cut away since they could not be excluded by ligatures. It was impossible to make any type of ligation between the stomach and digestive gland. Ligatures were of nylon thread. Substrate was injected through the wall into the ligated part with the aid of a 26-gauge needle. The substrate was injected into the

Table 2

Enzyme Controls

Tissue extracts (w/v): buccal cavity, 0.42%; salivary glands, 0.03%; esophagus, 0.06%; stomach and digestive gland, 0.21%; digestive gland, 0.04%; spiral caecum, 0.05%; thin hindgut, 0.06%; thick hindgut, 0.07%; citrate-phosphate buffer, 0.05M, pH 5.8; phosphate buffer, 0.1M, pH 7.4; incubated at 15° C for 24 hours.

Tissue	μ g Reducing Sugar ²
pH 5.8	
buccal cavity	19.0
salivary gland	0
esophagus	92.3
stomach and digestive gland	19.5
digestive gland	4.5
spiral caecum	18.0
thin hindgut	0
thick hindgut	82.0
pH 7.4	
buccal cavity	48.5
salivary gland	0
esophagus	0
stomach and digestive gland	70.4
digestive gland	21.0
spiral caecum	0
thin hindgut	0
thick hindgut	0

² reducing sugar present in 1 mg dry weight of tissue.

buccal cavity through the mouth, and into the thick hindgut through the anus. The ligated snails were held at 15° C for 24 hours submerged in Millipore filtered sea water. The snails survived this period of incubation. At the end of the incubation period, the ligated areas were excised, homogenized, and assayed for reducing sugar.

A duplicate experiment was performed in which a mixture of antibiotics was incorporated with the substrate in order to assess the role played by intestinal bacteria in carbohydrate hydrolysis. The antibiotic mixture contained: 50 units/ml penicillin, 25 μ g/ml streptomycin, 25 μ g/ml terramycin, 5 μ g/ml polymixin.

The results of these experiments are shown in Tables 4 and 5. A comparison of Tables 3 and 4 reveals some further points of interest. The salivary glands and esophagus contain a large amount of cellobiase; yet the absence of cellobiose hydrolysis in the esophagus suggests that the enzymes do not act upon the glucose- β -1,4-glucose

Table 3
 Reducing Sugar Released by Enzyme Action
 Substrates, 0.1%; citrate-phosphate buffer, 0.05M,
 pH 5.8; phosphate buffer, 0.1M, pH 7.4; incubation at
 15° C for 24 hours.

Anatomical Region	Substrates				
	Starch	Laminarin	Alginate	Fuoidin	Cellobiose
	μg Reducing Sugar ^a				
pH 5.8					
buccal cavity	52.5	136.6	53.1	119.0	0
salivary gland	0	0	0	0	1988.0
esophagus	49.5	422.7	207.7	872.7	1008.5
stomach and digestive gland	322.5	38.5	0	341.0	0
digestive gland	1195.5	0	0	131.5	0
spiral caecum	1206.0	105.0	0	0	2310.7
thin hindgut	406.0	0	0	0	1888.0
thick hindgut	1698.0	63.4	46.5	61.0	1953.0
pH 7.4					
buccal cavity	430.5	161.4	183.3	212.5	0
salivary gland	0	0	0	0	746.0
esophagus	107.6	0	0	0	293.7
stomach and digestive gland	525.6	0	0	529.6	0
digestive gland	2164.9	0	113.0	0	0
spiral caecum	834.0	0	0	0	2142.0
thin hindgut	710.0	0	0	0	1504.0
thick hindgut	689.4	0	0	0	434.8

^a μg reducing sugar released by enzyme extracted from 1 mg dry weight of tissue. The values in the table have been corrected by subtraction of substrate and enzyme controls (see tables 1 and 2).

linkages in this portion of the digestive tract. A comparison of Tables 4 and 5 shows that antibiotics decrease carbohydrate hydrolysis and suggests that microorganisms are, in part, involved in the breakdown of carbohydrates in all parts of the digestive tract. Hydrolysis of starch and cellobiose was most markedly affected by antibiotics.

Bacteria were cultured from the foregut and hindgut. The medium used contained: 1% agar, 0.001% aqueous extract of snail, 0.001% yeast extract, 0.01% Difco peptone, and 0.05% of one of the carbohydrate substrates and was buffered at one of the two different pH's — 5.8 or 7.4. A variety of colonial types developed. Hydrolysis of starch by the organisms was detected by loss of a reaction with iodine. The presence of reducing sugars could be demonstrated in the other cultures by Tollen's Reagent. Splitting of cellobiose could not be determined by these methods.

The purpose of the final set of experiments was to determine whether carbohydrate hydrolysis was occurring

in the lumen or in the wall of the foregut and hindgut. Carbohydrates were again injected into the various segments after ligation, and the snails were incubated for 24 hours. The areas were excised, opened, and washed with distilled water. Both the washings and a homogenate of the tissue were then tested for reducing sugar.

The results presented in Table 6 suggest that the majority of cellobiose hydrolysis in the hindgut occurred in the wall. Such a simple interpretation is not possible. The test procedure only determined the amounts of reducing sugar present in lumen and tissue. Cellobiose is a reducing sugar itself. An adequate correction for the reducing activity of the substrate when it is possibly divided between tissue and lumen is not possible. Since hydrolysis of this disaccharide does not result in a great change in molecular size, no marked difference in the absorption of the substrate and products of its hydrolysis might be expected. No distinction between intracellular digestion and absorption of the products of digestion can be made

Table 4
Reducing Sugars Released *in Situ*
Substrates, 0.1%; incubation at 15°C for 24 hours

Anatomical Region	Substrates				
	Starch	Laminarin	Alginate	Furoidin	Cellobiose
	μg Reducing Sugar ⁴				
buccal cavity & salivary gland	240.0	220.3	321.5	193.5	1965.0
buccal cavity	155.5	113.5	249.5	170.0	0
esophagus	105.5	103.4	65.7	182.3	0
stomach and digestive gland	873.6	282.6	521.6	1032.6	0
spiral caecum	1113.0	849.3	296.0	289.2	2680.0
thin hindgut	416.0	132.0	152.7	172.1	1772.8
thick hindgut	1660.0	63.9	0	0	1594.7

⁴ μg reducing sugar corrected by subtraction of appropriate tissue and substrate controls.

Table 5
Reducing sugar released *in Situ* in the Presence of
an Antibiotic
Substrates, 0.1%; incubation at 15°C for 24 hours.

Anatomical Region	Substrates				
	Starch	Laminarin	Alginate	Furoidin	Cellobiose
	μg Reducing Sugar ⁵				
buccal cavity & salivary gland	180.6	190.0	253.7	0	1760.4
buccal cavity	107.5	87.5	145.0	0	0
esophagus	0	0	0	169.3	0
stomach and digestive gland	132.6	0	155.8	184.6	0
spiral caecum	208.5	228.5	135.6	242.0	466.0
thin hindgut	307.0	112.2	120.8	154.0	430.7
thick hindgut	0	63.9	0	0	1413.0

⁵ μg reducing sugar corrected by subtraction of appropriate tissue and substrate controls.

in the case of this small molecular weight substrate. The results with starch, on the other hand, do indicate appreciable intracellular digestion in the hindgut tissue.

DISCUSSION

The observed enzymatic activity of the hindgut has not been previously reported. Both a cellobiase and an amylase are present here. Specific enzymes capable of hydrolyzing the other substrates tested also appear to be present in this part of the gut. However, it appears likely that the other enzymes are produced in the foregut or midgut

and are then carried to the hindgut in an active form. GALLI (1956), evidently, did not expect the hindgut to be important in digestion since he ignored this organ in his studies. Yet the activity of the hindgut was clearly demonstrated in our experiments. Also, when GALLI studied the foregut, he excluded the esophagus and concentrated on the buccal cavity and salivary glands. This was unfortunate since our results showed a reasonably wide range of activity here. All the carbohydrates tested underwent some decomposition in the esophagus, also Table 3 indicates that some of the enzymes may be produced here.

Table 6

Distribution of Reducing Sugar Formed *in Situ*
 Substrates: starch, laminarin, alginate, fucoïdin, 0.1%
 cellobiose, 0.15%; incubation at 15° C for 24 hours.

µg Reducing Sugar Present in Lumen

Anatomical Region	Substrates				
	Starch	Laminarin	Alginate	Fucoïdin	Cellobiose
	µg Reducing Sugar ^a				
foregut	172.3	87.4	0	256.9	321.7
hindgut	324.0	0	0	13.1	68.6

µg Reducing Sugar Present in Wall

Anatomical Region	Substrates				
	Starch	Laminarin	Alginate	Fucoïdin	Cellobiose
	µg Reducing Sugar ^a				
foregut	0	0	0	0	0.3
hindgut	152.8	0	0	0	684.5

^a corrected by subtraction of substrate control.

⁷ corrected by subtraction of tissue control.

SUMMARY

Carbohydrate digestion in the snail *Tegula funebris* (A. ADAMS, 1854), was studied. The intestinal sites of hydrolysis of certain carbohydrates and the location of production of their respective enzymes were studied. The presence of an amylase, laminarase, alginase, fucoïdase, and cellobiase was demonstrated. The major tissue sources of the above enzymes were: buccal cavity, stomach, digestive gland, spiral caecum, thin and thick hindgut for amylase; buccal cavity and esophagus for laminarase and alginase; buccal cavity, esophagus, stomach and digestive gland for fucoïdase; salivary glands, spiral caecum, thin and thick hindgut for cellobiase. Some of the carbohydrate hydrolysis appears to be due to bacterial action. Intracellular digestion of starch in the wall of the hindgut is indicated.

LITERATURE CITED

- BLACK, W. A. P., W. J. CORNHILL, E. T. DEWAR & F. N. WOODWARD
 1951. Manufacture of algal chemicals: Laboratory-scale isolation of Laminarin from brown marine algae. *Journ. appl. Chem.* 1: 505-517
- BLACK, W. A. P., E. T. DEWAR & F. N. WOODWARD
 1952. Manufacture of algal chemicals: Laboratory-scale isolation of Fucoïdin from brown marine algae. *Journ. Sci. of Food and Agricult.* 3: 122-129
- GALLI, DONALD RICHARD
 1956. Carbohydrate digestion in a herbivorous marine snail, *Tegula funebris*. Master of Arts Thes., Stanford Univ.; 153 pages



A New Pigment from *Tegula funebris*

(Mollusca : Gastropoda)

BY

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(1 Text figure; 3 Tables)

IN THE TROCHACEAN SPECIES *Tegula funebris* (A. ADAMS, 1854) and *T. brunnea* (PHILIPPI, 1848) which are abundant in the intertidal zone of the Pacific coast, the female gonad is bright green. In both species, the pigment is found in droplets evenly dispersed throughout the yolk. An extraction of the pigment in *T. funebris* was made. The crude green pigment was partitioned into a group of yellow carotenoids and an unknown green pigment. This is a study of these colored materials.

PREPARATION

The pigment was initially extracted from eggs carefully stripped from 200 gonads. The eggs were blended in a Waring blender with absolute methanol for five minutes. The methanol was changed, and extraction was repeated until the suspension was white. The crude green pigment was then dried and redissolved in methanol. This re-extraction was repeated three times. Ether and water partition of the pigment separated the material into a yellow epiphase and a green hypophase. Repeated partitioning was used to purify the materials.

RESULTS

The yellow material, dried and dissolved in petroleum ether (Bp. 40° 60° C) was placed on an Al₂O₃ column. The column was developed with a gradient of acetone in petroleum ether. The four bands observed were collected, and a tentative identification of zeaxanthin, lutein and alpha carotene was made from the data in Table I (P. KARRER & E. JUCKER, 1950).

The green pigment could not be identified. Some of its properties are briefly stated in Table II. In addition, in aqueous solution it freely passed through sephadex G-75 which indicates a molecular size larger than that corresponding to a molecular weight of 40,000. In aqueous solution, it may be warmed to 100° C without obvious

change. Prolonged heating at 100° C resulted in a brown discoloration, and is assumed to be due to decomposition. It is photosensitive, and becomes yellow with prolonged exposure to light. When reduced with hydrosulfite, a yellow color appears, but reoxidation to green can be achieved by autoxidation or treatment with H₂O₂. In methanol, a green fluorescence was observed in the oxidized form.

The large molecular size suggested a protein complex. The unknown was, therefore, placed in aqueous solution and an equal amount of CHCl₃ with .1 volume amylalcohol added. This was vigorously shaken and centrifuged for 10 minutes. A blue protein appeared between the phases of green aqueous solution and colorless CHCl₃. The aqueous phase was re-treated until the blue zone no longer appeared. The solubilities and spectrum of the un-

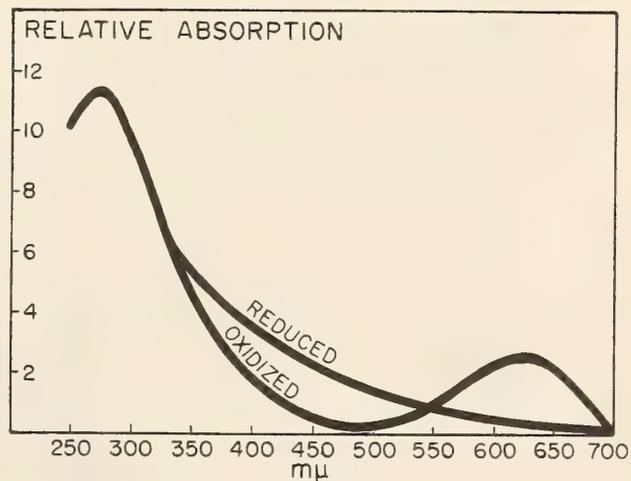


Figure 1: The absorption maxima of the unknown green pigment in H₂O. The oxidized state peaks at 640 and 273, while the reduced state peaks at 273μ.

Table 1
PROPERTIES OF YELLOW PIGMENTS

BAND	ABSORPTION		REMARKS	CAROTENOID*
	MAXIMA	in CS ₂		
I	517 482 450		hypophasic in petroleum ether and 90% MeOH	zeaxanthin
II	510 470 442		distributed in both phases of pet. ether and 90% MeOH	
III	508 475 445		hypophasic in petroleum ether and 90% MeOH	lutein
IV	509 477		epiphasic in petroleum ether and 90% MeOH	α - carotene

* Tentative identification on the basis of the absorption spectra and solubility properties.

Table 2
PROPERTIES OF GREEN PIGMENT

PIGMENT	SOLUBILITY	ABSORPTION MAXIMA $m\mu$		COLORATION	
		oxidized	reduced	oxidized	reduced
1. Native	s. H ₂ O, MeOH, EtOH, acet. i. eth., CHCl ₃ pet. eth., CS ₂	H ₂ O 640 273 MeOH 640 370*(s)	H ₂ O ... 273	neutral-green acid-yellow alkaline-yellow with ppt.	neutral-yellow acid-yellow alkaline-yellow
2. Deproteinized	same as 1.	same as 1	same as 1	same as 1 except alkaline-yellow with no ppt.	same as 1
3. Allagochrome (Habermann, 1960)	s. H ₂ O	H ₂ O 630 320 260	H ₂ O 320 260	neutral-green acid-red alkaline-brown	neutral-yellow-orange acid-? alkaline-?

* (s) = shoulder.

s. = soluble
i. = insoluble
eth. = ether
pet. eth. = petroleum ether
acet. = acetone

Table 3

Results of mass spectral analysis of crude green pigment in percent by weight

ELEMENT	PERCENT	ELEMENT	PERCENT
Al	0.005	Na	1.0
Ca	0.10	Pb	0.01
Cu	0.005	Si	0.005
Fe	0.01	Sn	0.01
Mg	0.03	Zn	trace
Mn	trace		

known without protein appear in Table II. It should be noted that the absorption spectrum of the oxidized form was not changed.

In preliminary observations of the development of the closely related *Tegula brunnea* the green pigment present in the eggs was observed to concentrate in the ciliated cells of the trochophore. The amount appeared to increase as the velum formed.

DISCUSSION

The unknown pigment resembles Allagochrome (HABERMANN, 1960; GARRICK & HABERMANN, 1962) in its absorption spectrum and oxidation-reduction activities. A comparison of the two pigments' properties can be seen in Table II. Allagochrome is present in a variety of higher plants and its function is hypothesized to be respiratory due to the ease with which oxidation and reduction can be induced.

The peak at 273 $m\mu$ also is suspiciously near the characteristic peak, 275 $m\mu$ of the coenzyme Q, a lipid soluble quinone (CRANE, 1959). There is a broad distribution of the five known forms of coenzyme Q in aerobic tissues. It has been found in all vertebrates, higher plants, aerobic bacteria, invertebrates and red and green algæ. The view

is that coenzyme Q is necessary for respiratory electron transfer occurring in the mitochondria and equivalent structures. While several quinones of biological origin have been described, their actual involvement in electron transport has seldom been demonstrated. If a respiratory function for the unknown pigment is postulated, the observed migration of the pigment to the ciliated cells of the velum of the trochophore and veliger larvæ may be of significance. These cells would be expected to have a high metabolic activity.

SUMMARY

The pigments of the eggs of *Tegula funebris* were extracted in methanol. This crude green pigment contained three yellow materials with spectral properties resembling the carotenoids: zeaxanthin, lutein and alpha carotene, and an unknown green pigment. The green pigment was found to have an attached protein, absorption maxima in H₂O at 640, 273 $m\mu$ in the oxidized form and 273 $m\mu$ in the reduced state, and a marked resemblance to known quinones that have been suggested to act as respiratory pigments.

LITERATURE CITED

- CRANE, F. L.
1959. Internal distribution of Coenzyme Q in higher plants. *Plant Physiol.* 34: 128 - 131
- GARRICK, L. S. & H. M. HABERMANN
1962. Distribution of allagochrome in vascular plants. *Amer. Journ. Bot.* 49: 1078 - 1088
- HABERMANN, H. M.
1960. A new leaf pigment (pp. 73 - 82 in:) *Comp. Biochem. of photoreactive systems*; Acad. Press, New York and London. xii + 437 pp.
- KARRER, P. & E. JUCKER
1950. *Caretonoids*. Elsevier Publ. Co., Inc. New York etc. x + 384 pp.



Excretory Products of *Tegula funebris* and *Tegula brunnea*

(Mollusca : Gastropoda)

BY

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(1 Table)

INTRODUCTION

QUESTIONS CONCERNING the excretory products of *Tegula funebris* (A. ADAMS, 1854) arose when some rather casual qualitative tests were performed on the kidneys of the snail. The right kidney appeared to contain a high concentration of uric acid while the left kidney had none. This is a quantitative study of the excretory products of this snail and the related species, *T. brunnea* (PHILIPPI, 1848).

METHODS

The snails, both *Tegula funebris* and *Tegula brunnea*, used in these experiments were taken from the same area near the Hopkins Marine Station in Pacific Grove, California. They were collected at low tide; all except two groups were immediately killed and the tissues to be investigated were prepared as protein-free filtrates. Two groups were kept in a tank in the laboratory for a week before they were examined; they were not fed during this period. The *Tegula funebris* used were approximately 2 - 2.5 cm. in diameter. The *Tegula brunnea* were slightly smaller, 1.8 - 2.0 cm. in diameter. It was necessary to use large snails in order to obtain samples free of other contaminating tissues. A few *Tegula montereyi* (KIENER, 1850), 2.5 - 3.0 cm. in diameter, were used; these came from kelp beds forty feet under surface.

The tissues examined were the ctenidium, digestive gland, and the two kidneys. The latter (which could be more accurately called coelomoducts) are very different morphologically. The left kidney is known as the papillary sac because of the many villi on its internal surface. Each villus has a hemocoelic space in its center. The right kidney has two lobes; the anterior one runs parallel to the left kidney, and the posterior one is behind the pericardial cavity. The left kidney is white; in both *Tegula funebris* and *Tegula brunnea* the right kidney is green in males and yellow in females. The posterior lobe of the right

kidney was used since it could be more readily dissected free of other tissue.

All four tissues from each group of ten snails were removed, blotted on a piece of filter paper, and weighed on a Mettler balance. A tungstic acid filtrate prepared by Haden's modification of Folin's method (TODD, SANFORD & STILWELL, 1948, p. 352) was used to remove protein from a tissue homogenate. The four filtrates from the tissues of each group were stored between tests in a freezer.

In order to interpret the results of the tests for excretory products, it was necessary to determine the total non-protein nitrogen in the various tissues. This was done by the method of Folin and Wu (TODD, SANFORD & STILWELL, 1948, pp. 353-354) which was modified by decreasing all the constituents in proportion so that the final volume after the addition of Nessler's solution would be 10 ml.

Ammonia was determined by adding 1 ml of Nessler's solution to a solution of 1 ml of protein-free filtrate and 8 ml. of distilled water. Urea was determined by the modified method of Hawk-Andes (LEVINSON & MACFATE, 1952, pp. 370-371); the volume of all the reagents was reduced proportionally to give a final volume after Nesslerization of 10 ml. Twelve drops of a five per cent urease solution made from Arlington tablets and purified with permutit powder were used. Benedict's method for the quantitative determination of uric acid (TODD, SANFORD & STILWELL, 1948, pp. 361-362) was used without modification.

RESULTS

URIC ACID was found in significant quantities in the right kidneys of both *Tegula funebris* and *Tegula brunnea*, but no trace of this compound was found in the left kidneys of these snails. In *Tegula montereyi* there was no detectable uric acid present in any of the tissues tested. Slight traces of free ammonia were found in the digestive

Table 1

Group	Tissue	Non-protein N mg/g wet wt.	Uric acid mg/g wet wt.	Uric acid N Non-protein N	× 100
<i>Tegula funebris</i>					
1 ¹	Right kidney	3.58	1.27	11.8	
	Left kidney	0.907	0		
	Digestive gland	1.55	0		
	Ctenidium	0.796	0		
2	Right kidney	1.55	1.89	40.7	
	Left kidney	1.66	0		
	Digestive gland	2.81	0		
	Ctenidium	1.70	0		
3	Right kidney	1.86	1.36	24.4	
	Left kidney	1.54	0		
	Digestive gland	1.00	0		
	Ctenidium	1.45	0		
<i>Tegula brunnea</i>					
1 ¹	Right kidney	6.86	4.0	22	
	Left kidney	1.79	0		
	Digestive gland	2.15	0		
	Ctenidium	1.73	0		
2	Right kidney	4.82	5.03	34.8	
	Left kidney	3.08	0		
	Digestive gland	2.66	0		
	Ctenidium	2.98	0		
3	Right kidney	2.20	4.48	76.6	
	Left kidney	2.50	0		
	Digestive gland	1.80	0		
	Ctenidium	3.06	0		

¹ maintained in the laboratory for one week without added food.

gland of both *Tegula funebris* and *Tegula brunnea*. There was no detectable urea in any of the tissues examined. These results are presented in Table I.

DISCUSSION

A comparison of the uric acid production of *Tegula funebris* and *T. brunnea* with that of *T. montereyi* seems to support Needham's theory concerning the adaptive significance of uric acid formation (NEEDHAM, 1935). Since *T. montereyi* are constantly in the water, any ammonia formed can be continuously diffused into the sea, and so there is no need for them to expend the extra energy

necessary to convert their wastes into uric acid. *Tegula funebris* and *T. brunnea*, which both live in the intertidal zone, are exposed to the air a good deal of the time and so tend to convert their wastes into the non-toxic and conveniently stored uric acid.

The left kidney does not appear to have any excretory function and perhaps serves as an organ of reabsorption as does the left kidney of *Haliotis* (HARRISON, 1961). Reabsorption would enable the animal to conserve many valuable nutrients that would otherwise be lost in the urine. This function of the left kidney seems quite probable when one considers both the increase in surface area

provided by the papillae and the highly vascularized nature of these papillae.

SUMMARY

1. Tests were performed on the snails, *Tegula funebris* and *T. brunnea*, to determine the nature and quantity of their excretory products and the organs of excretion.

2. Standard colorimetric assays were used on homogenates prepared from the ctenidium, digestive gland, right and left kidneys. Total non-protein nitrogen, ammonia, urea, and uric acid were determined.

3. Uric acid was observed to be the major excretory product of these snails. It accounted for 11.8% to 76.6% of the total non-protein nitrogen in the right kidneys, the only organs where this waste product was detectable. Only slight traces of ammonia were found in the digestive gland, and no urea was present in the tissues tested.

LITERATURE CITED

- HARRISON, F. M.
1961. Some excretory processes in the abalone *Haliotis rufescens*. Journ. Exp. Biol. 39 179-192
- LEVINSON & MACFATE
1951. Clinical laboratory diagnosis. 4th ed.; pp. 1-1146. Lea & Febiger, Philadelphia
- NEEDHAM, J.
1935. Problems of nitrogen catabolism in invertebrates. II. Correlations between uricotelic metabolism and habitat in the phylum Mollusca. Biochem. Journ. 29: 238-251
- PICKEN, L. E. R.
1937. The mechanism of urine formation in invertebrates. II. The excretory mechanism of certain Mollusca. Journ. Exp. Biol. 14: 20-34
- TODD, SANFORD & STILWELL
1948. Clinical diagnosis by laboratory methods. 11th ed. W. B. Saunders Co.; i-xi + 954 pp.

The Distribution and Movement of *Tegula funebris* in the Intertidal Region of Monterey Bay, California

(Mollusca : Gastropoda)

BY

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(9 Text figures)

INTRODUCTION

Tegula funebris (A. ADAMS, 1854) is very common along the west coast of California, although little work has been done on its intertidal distribution. Hewatt (1934) describes its distribution as between the plus one and plus five foot level above mean lower low water. Ricketts and Calvin (1962, pp. 352-355) put the population center at the three foot tide level. Neither reference describes the distribution extent along the intertidal region. We inves-

tigated *Tegula funebris*' intertidal distribution and movement patterns in relation to certain biological and physical environmental factors. Before investigating movement patterns, we wanted an accurate, correlatable distribution analysis for several areas along Mussel Point, Pacific Grove, California. To do this, we collected information pertaining to numbers and size classes of this snail along with environmental data of the areas, such as vertical level of collection, algal covering, area configuration, substratum, and wave and current action. Factors that seem to

affect the distribution were then checked by exposing marked populations to these various conditions and observing the movements of the snails.

METHODOLOGY

We selected five areas along Mussel Point, each, as described below, representing a different environmental condition. In each area we marked the exact water level at low tide on a very calm day to give correlatable marks, whose height was then determined by use of existing benchmarks. At low tide a transect two meters wide was extended from shore to the minus two foot tide level in each area, and every *Tegula funebris* within the transect was counted and measured for the largest basal diameter of the shell from the lip to the edge of the opposite side.

In order to investigate the movement patterns of *Tegula funebris*, we put marked populations into areas which best represented the factor being tested and compared their movements with the movements of control groups in areas where the factor did not exist. A periodic position plot of the individuals within the population over time

resulted in an overall movement pattern which, when compared with that of other populations, gave information on the effectiveness of certain factors in influencing population distribution.

POPULATION DISTRIBUTION

Area A is a rocky, open coastline with a heavy algal covering. It has no current movement though the outer rocks facing seawards receive heavy wave action.

Area B is a rocky, open coastline without an algal covering. It has no current movement though the entire profile receives the heaviest wave action of all five areas. Mussels and barnacles almost entirely cover the rock surfaces below the plus three foot tidal level, and all *Tegula funebris* are found among these animals.

Area C is a semi-protected area with a heavy algal covering. The area has a light current flowing through it with a moderate wave surge.

Area D is a semi-protected area with a heavy algal covering. There is usually a moderate current flowing through it with a moderate wave surge, although the inner third

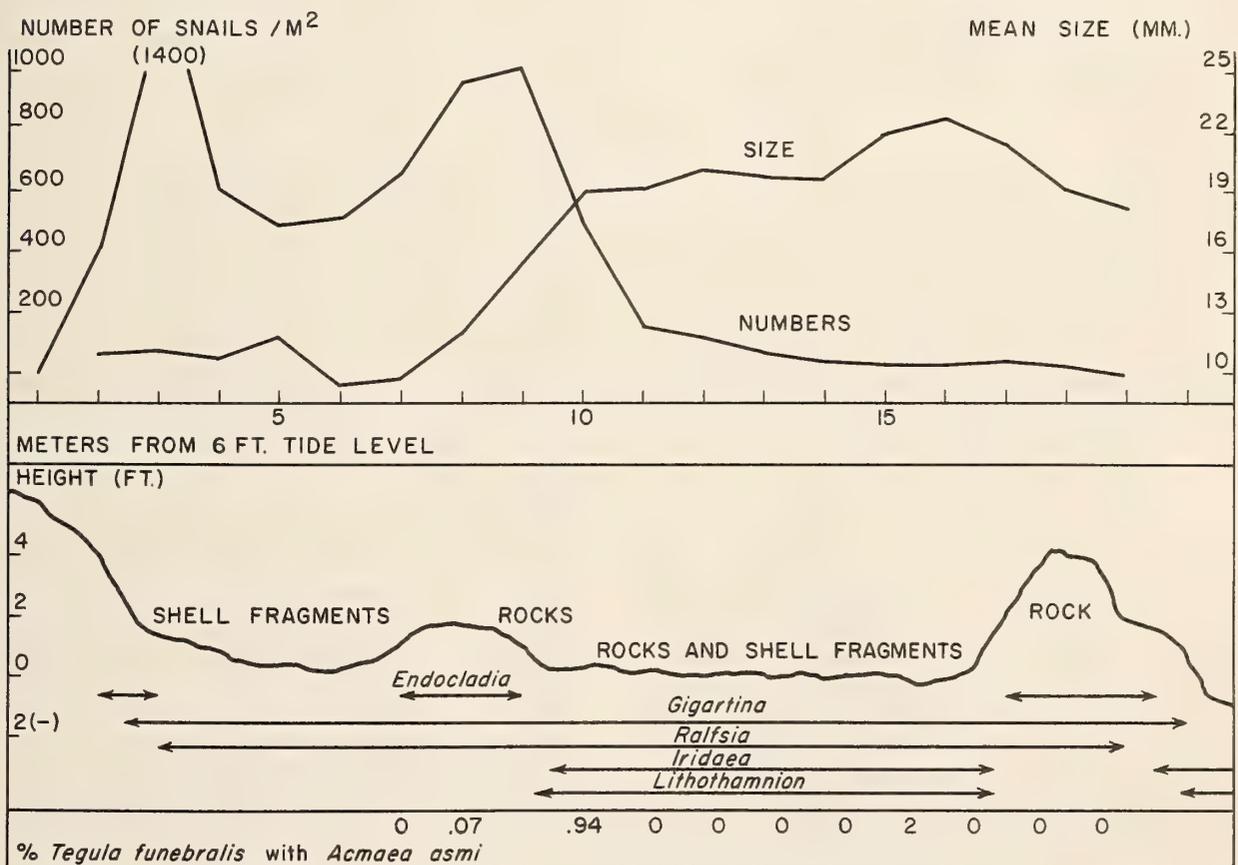


Figure 1: Distribution in numbers and size classes of *Tegula funebris* in Area A

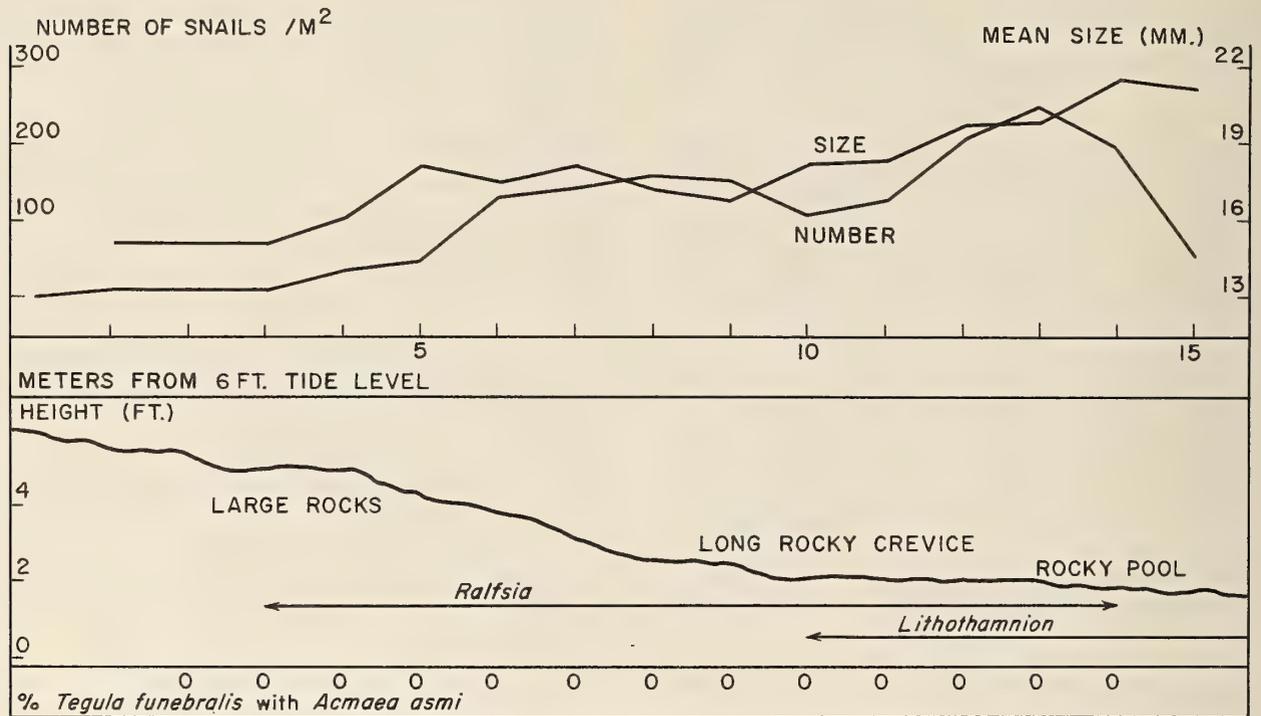


Figure 2: Distribution in numbers and size classes of *Tegula funebris* in Area B

of this profile has relatively quiet water.

Area E is a protected area with a sparse algal covering. It has no current movement and little wave surge. Pools in this area are very crowded at low tide and some of the *Tegula funebris* move about on the fine sand bottom of the pools. Only in these pools were the snails found to be grazing on dead algae, periodically cast up at high tide.

In all five areas *Tegula* tends to be clumped in places that have a sparse algal covering and usually is dispersed in areas of dense coverage.

DISCUSSION AND CONCLUSIONS

(Distribution)

THE COLLECTING of *Tegula funebris* was done at low tide; small irregularities in population numbers due to substrate irregularities smooth out at high tide when the snails disperse from their clumps in the crevices. In plotting their distribution in relation to certain environmental factors, we found relationships which indicate that certain biological and physical factors may control population distribution.

The population density decreases as the amount of algal covering increases, indicating that population density de-

pends to some extent on the amount of open rock surface available. Rocky areas which have little algal covering have a larger number of snails on them than a heavily covered rocky area. The reason for this distribution may be that rock surfaces provide the main food source for their grazing. Two notable exceptions are found, one in Area C at the twenty-eight meter mark (Fig. 3) where outer rocks are washed by heavy surge, reducing the density of snails in this area, and the other in Area D at the fifteen meter mark (Fig. 5) where a shell fragment substrate decreases the population density.

The mean size of the animals increases with the degree of algal covering. The larger snails are found in the heavy algal covering more often than in protected crevices.

Moderate current does not affect the *Tegula funebris* distribution, as the higher densities found along rock faces bordering the channel in Area D at thirty-eight meters are similar to the densities found shoreward at four meters in quiet water (Fig. 5).

Population densities are reduced in areas of heavy water turbulence. Area B with its heavy surf is relatively barren of *Tegula funebris* (Fig. 2). The outer rocks in Area C which receive heavy wave action are also sparsely

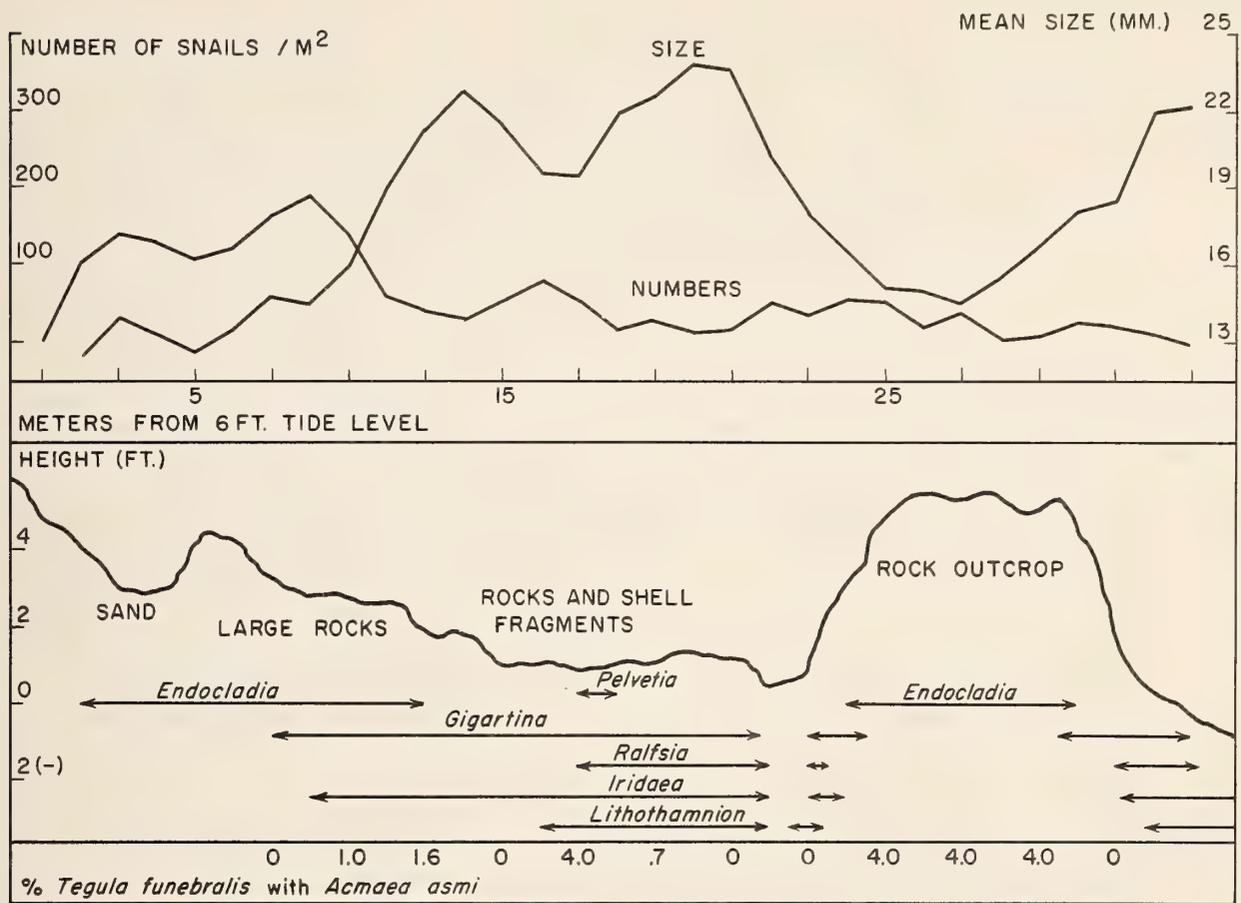


Figure 3: Distribution in numbers and size classes of *Tegula funebris* in Area C

populated, while similar areas closer to shore in calmer water have higher densities of snails (Fig. 3).

Vertical height clearly affects the population density quite aside from the maximum height of zero feet and plus six feet (Fig. 8). Between these limits similar heights in different places show different numbers of individuals as found in Area A between seven and sixteen meters from shore (Fig. 1), in Area C between eleven and twenty-five meters (Fig. 3), and in Area D (Fig. 5). Different vertical heights having similar population densities are found in Area C twelve and twenty-seven meters from shore, in area D between forty-two and fifty-four meters, and in Area D between forty-two and fifty-four meters, and in Area E between five and nine meters (Fig. 4). The greatest population density is at the plus two to four foot tidal level (Fig. 8). The mean size of animals

decreases with increase in the vertical height along the transects with the largest snails rarely found at the seaward edge of the transect (Fig. 7).

POPULATION MOVEMENTS

Population I (marked in the size classes 0-15 mm, 15-20 mm, and over 20 mm), was placed in Area D on outer rocks at the plus two foot tidal level. Water at high tide was turbulent with little current movement. This population was plotted for fifteen days (Fig. 9).

Population II (marked as in Population I), was placed in Area D on inner rocks at the plus three foot tidal level. Water at high tide was calm without current movement. This population was plotted for 19 days (Fig. 9).

Population III was placed in Area D at the plus three foot tidal level on an outer rock face bordering the current

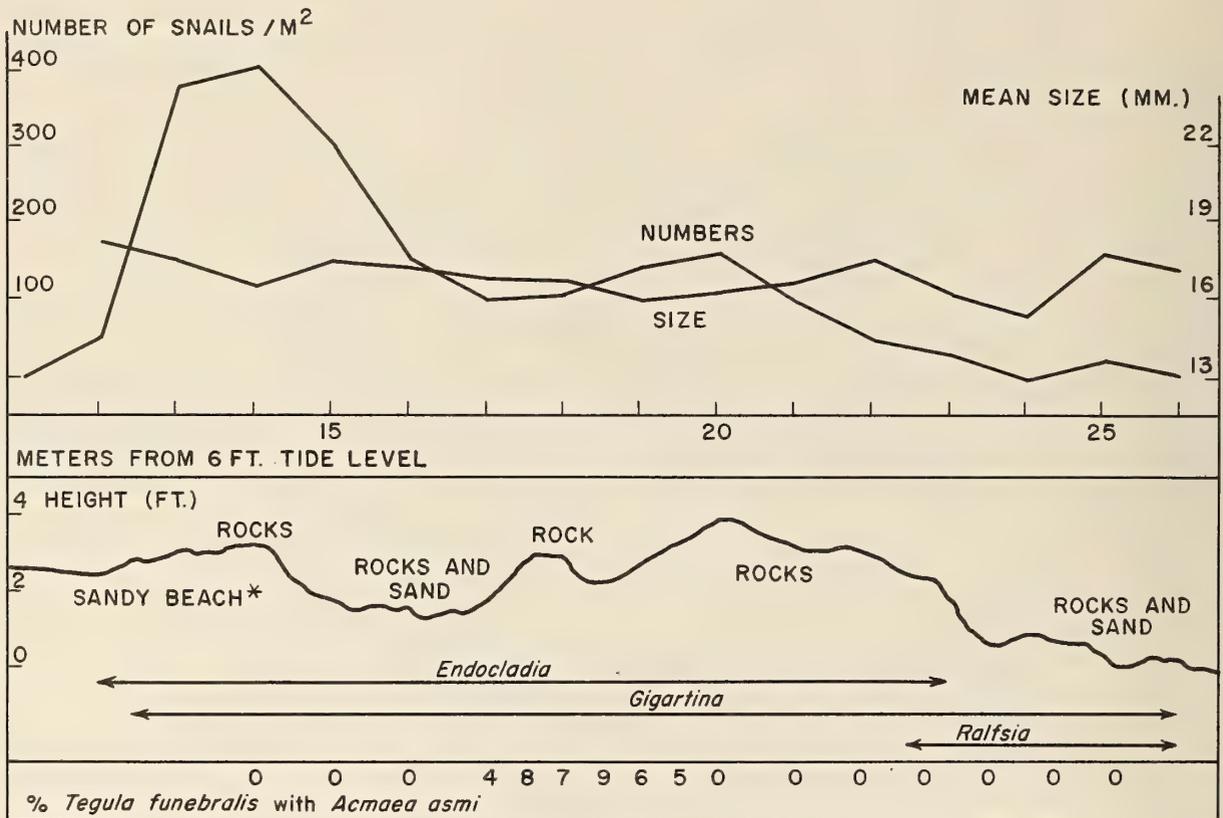


Figure 4: Distribution in numbers and size classes of *Tegula funebris* in Area E

(*sandy beach extends shoreward eleven meters to the plus six foot level)

channel. At high tide a moderate current runs through this channel. This population was plotted for fourteen days. After the first fourteen day study was completed, Population III was placed in the current channel at the minus one foot tidal level, directly out from the point of its original placement and was found after five days to have dispersed much as on the fifth day of the first period (Fig. 9).

Population IV, clustered under three rocks at the plus four foot tidal level, was marked and its vertical movement was followed during rising and falling tides over periods of 24 hours. During daylight hours at high tide, the population remained beneath the rocks with individuals rarely on rock tops. At night during high tides the population moved to the rock tops in large numbers. They moved up as soon after twilight as the tide permitted, in numbers dependent on the intensity of the moonlight. On bright moonlit nights the density on rock tops was half that found during dark overcast nights. During the low tide periods at night about four-fifths of the snails

moved down; all snails moved down at the first light of dawn. On nights of heavy wave surge the numbers on the rock tops were one tenth those normally found on the rocks for dark nights. This vertical movement was noted at many places along Mussel Point.

Population V (two groups, one taken from the zero to plus one foot level and the other from the plus four to five foot level) was marked and placed at the plus two foot level in a crevice of a rock outcrop. The rocks extend from a sandy substrate at zero feet to plus seven feet. The two groups, plotted for fourteen days, showed no vertical or horizontal separation. However, sixteen individuals were found beyond four meters down current and only nine beyond this distance up current.

DISCUSSION AND CONCLUSIONS (Movement)

Tegula funebris moves up to rock tops during the night high tide, but not during the daylight high tides. The

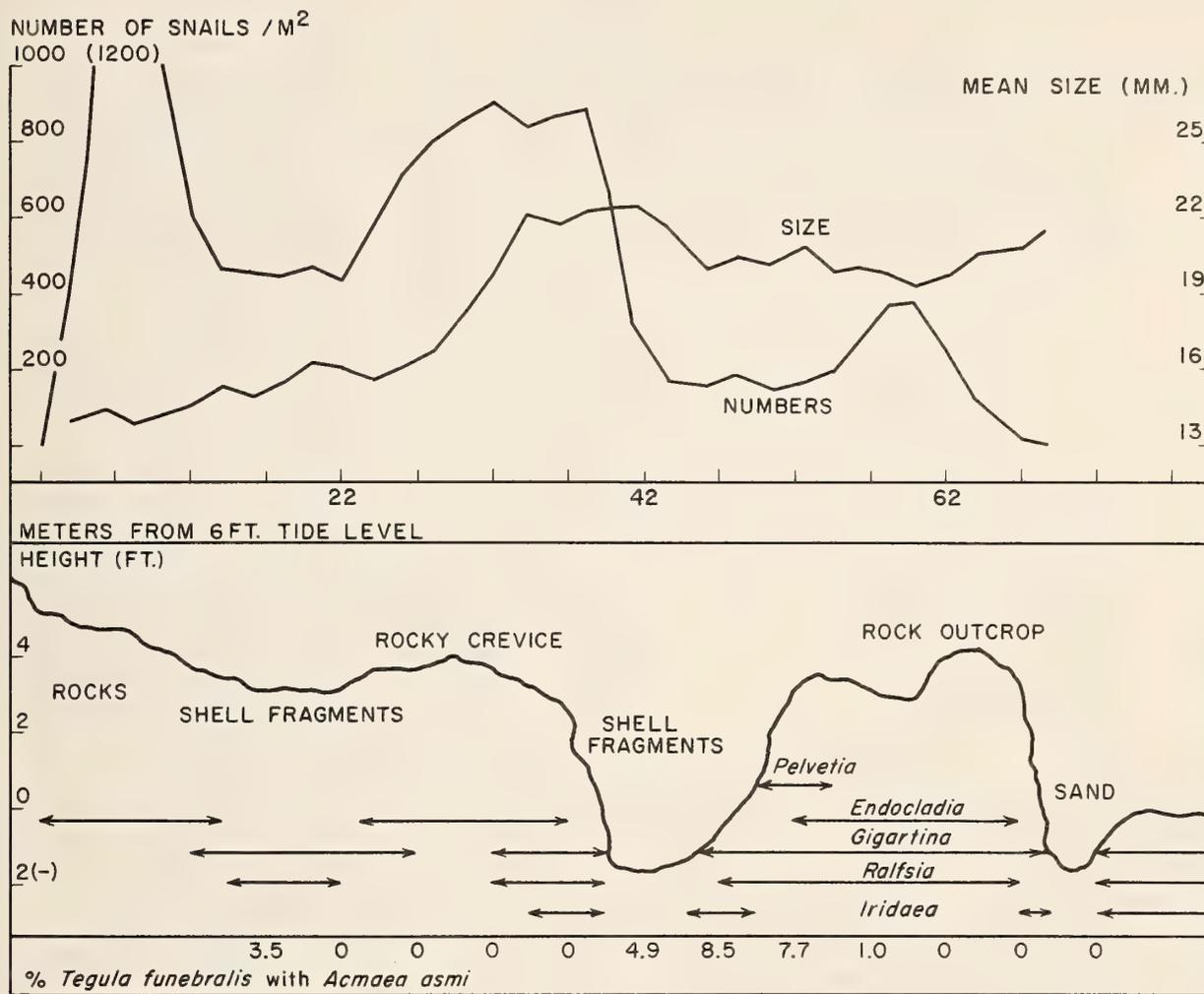


Figure 5: Distribution in numbers and size classes of *Tegula funebris* in Area D

upward movement seems to be light-dependent with the threshold level inhibiting this movement at the light intensity of the full moon.

Tegula funebris movements seem to be directed by water current to some extent, as slightly more of the individuals in Populations III and V were found down current than up current.

As shown by the movement of Population V, there seems to be no vertical specificity for *Tegula funebris* but a random dispersal.

The movements of *Tegula funebris* do not appear to differ with size; the three size classes were intermixed throughout the dispersal of Populations I and II.

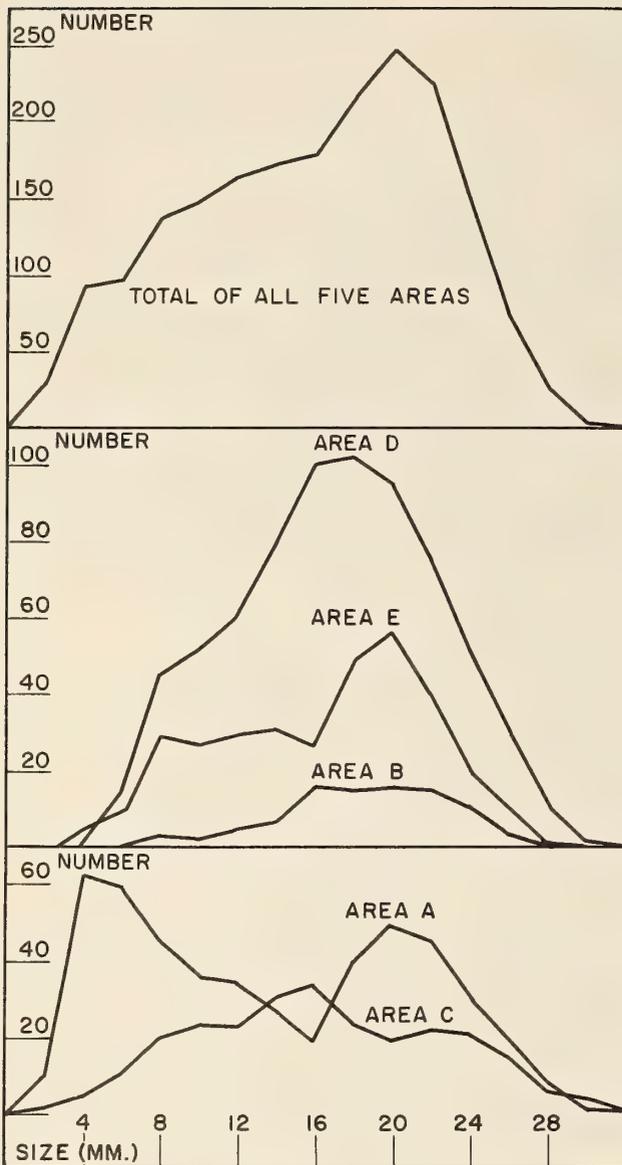


Figure 6: The relationship between numbers of animals and size classes for each of the five areas plus a total for all five areas

LITERATURE CITED

HEWATT, W. G.

1934. Ecological studies on selected marine intertidal communities of Monterey Bay. unpubl. Ph. D. Thesis, Stanford Univ. Stanford, California.

RICKETTS, EDWARD F., & JACK CALVIN

1962. Between Pacific tides. 3rd. Ed. Stanford Univ. Press, xi + 518 pp.; Stanford, Calif.

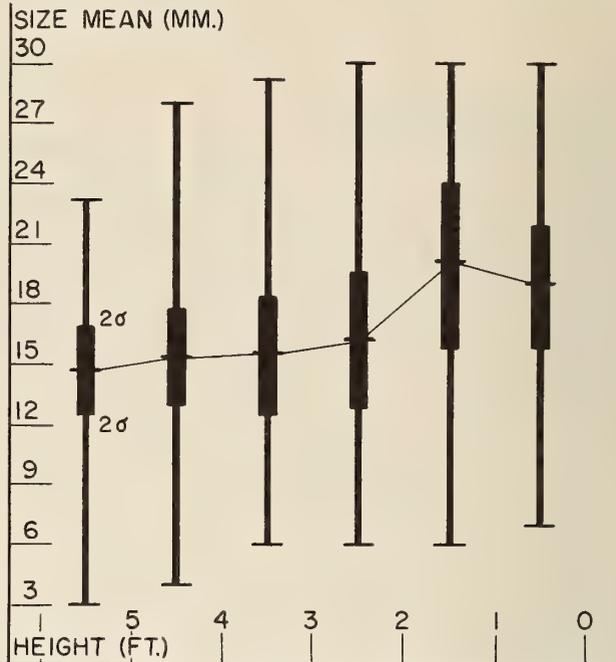


Figure 7: The range, standard deviation, and mean of *Tegula funebris* shell size. At each depth the vertical line indicates the total range; the broad portion of the line indicates that ninety-five percent of the individuals fall within this range (2σ); the crossbar indicates the mean

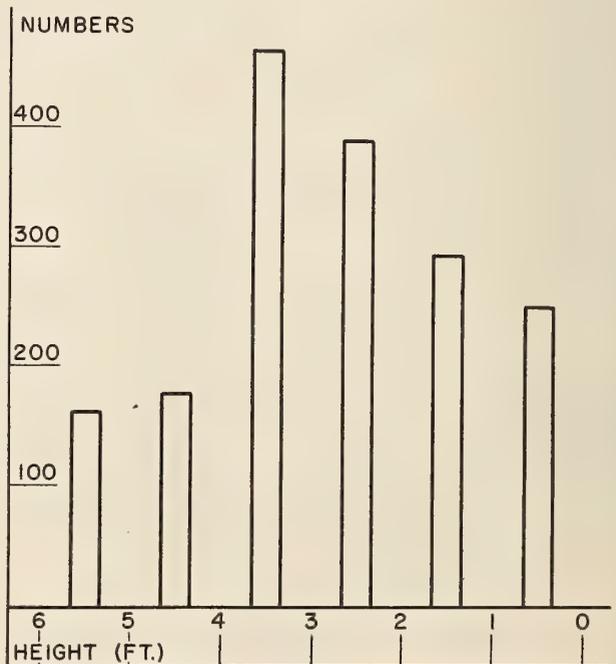


Figure 8: The number of *Tegula funebris* per square meter found at each vertical height level above mean lower low water

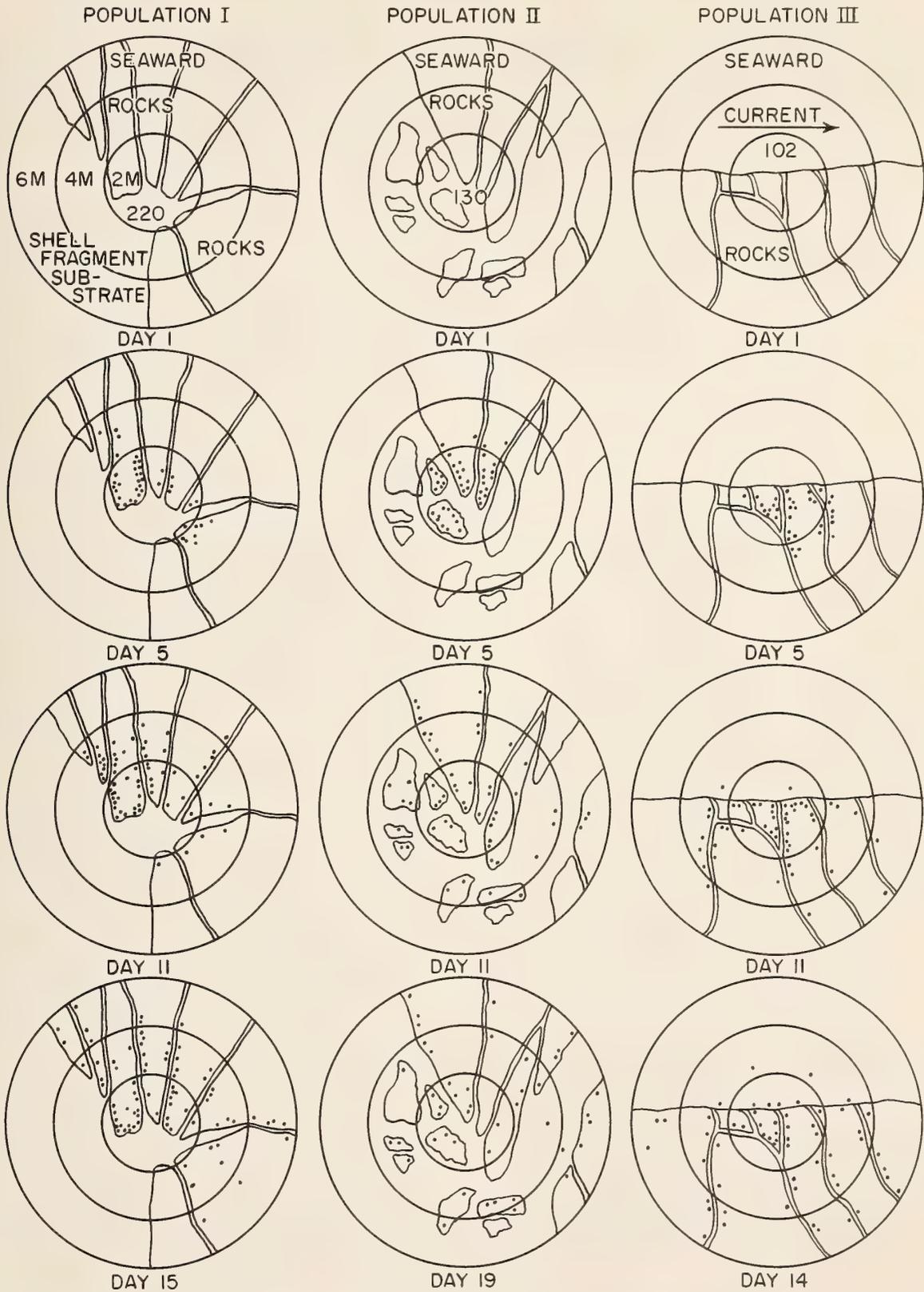


Figure 9: The redistribution of *Tegula funebralis* populations over various time periods. At Day 1 populations were placed in the center of the concentric circles

Orientation and Response of *Tegula funebris* to Tidal Current and Turbulence

(Mollusca : Gastropoda)

BY

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(4 Text figures)

Tegula funebris (A. ADAMS, 1854) is a creature of the intertidal zone, and subject to the currents and turbulence caused by the incoming and outgoing waves. Because of the prevalence of these factors in its life, it seemed desirable to test the snail's behavioural response to them.

METHODS

A. Current: Two types of experiments were performed.

(1) Individual *Tegula* were placed in a glass tube 76 cm long with an internal diameter of 2.15 cm, then subjected to a given current of sea water. Flow was uniform (flow characteristics were checked by the occasional addition of a little milk to the incoming water). Current was about 260 cm per minute; slope and light were controlled. Orientation of the snails was checked immediately before the current was started, and one minute after. (2) A number of *Tegula* was placed in a 2-liter Erlenmeyer flask half full of sea water, which then was placed on a magnetic stirrer. This produced a steady, uniform, horizontal current of about 450 cm per minute. This method introduces a vertical freedom of motion. As in all cases presented in this paper, day experiments were conducted in diffuse room light, night experiments in red light — 10 watt ruby bulb two feet away (shadow reaction tests showed the snails to be insensitive to this light).

Results: In the horizontal tube, with $N = 255$, 64.4% went against the current, 32.1% went with it, and 3.5% sideways. No diurnal or tidal difference was found (all snails were freshly collected; snails were placed in the tube five minutes before starting the experiment). Previous orientation did have an effect: Of those originally oriented away from the current 61% turned into it; only 19% of those oriented into it turned away (Figures 1a, 1b).

Thus the snails were much more likely to go into the current than away from it.

In the magnetic mixer experiments, with $N = 140$, 72% were oriented into the current after 30 minutes; only 14% were oriented away. The other 14% were either grouped, moving up the flask, oriented sideways, or not moving at all. Therefore, of those moving with respect to flow, 84% were moving against the current. Heating effects of the stirrer limited tests to about one hour — no more than a 3.5° C rise was allowed. One experiment was run for more than one hour, temperature being kept constant by running sea water. Figure 2 shows that the snails tend increasingly to go with the current after the first 3½ hours. This may be the result of fatigue.

Current also has an effect on vertical distribution. For measuring this, the flasks were divided into three zones: A - the bottom quarter; B - the middle two quarters; C - the top quarter. Current tends to keep snails down, while controls go up (see Figures 3a, 3b). The only exception was the group, with control, run at sunrise. Other than this, no diurnal effect was noticed.

B. Turbulence: Two types of experiments were run.

(1) Air was bubbled rather violently into 2-liter Erlenmeyer flasks full of sea water, containing a number of *Tegula* (usually 15). The amount of air entering was about 15 liters per minute. As in A (1) above, the flasks were divided into vertical zones A, B, and C. (2) This consisted of taking qualitative observations on the behavior and position of about 200 *Tegula* in an aquarium before and after heavy turbulence was produced with air. **Results:** In the flasks *Tegula* clusters very heavily around the air nozzle (at the bottom) by day; by night they cluster in the neck in the foam. Again, the controls

go up (Figures 4a, 4b). In aquaria turbulence produces great activity, and the snails tend to become randomly dispersed (at all other times they tend to clump: up at night, down at day). This result is more marked if the water level has been raised or lowered over a number of days. At sunrise and sunset there was greater activity, also.

Two preliminary experiments attempted to combine the effects of turbulence and current — this being a more natural field condition. (1) A small motor-driven propeller in an aquarium was pointed at a rock with *Tegula* on it. The orientation and position of each *Tegula* being noted, the propeller was run for one minute; the velocity of water approximated a medium-sized surge in the ocean on a quiet day. Orientation and position were again noted, both immediately and five minutes later. The results were consistent: the snails clamp hard, slowly orienting into the current. After it is stopped they rapidly move off, stopping when they reach a niche or crevice. (2) A *Tegula* was squirted with sea water direct from a tube; the stream had a velocity of 30m/minute. Results were again consistent: the snail clamps, leaves quickly when squirting ceases. The snail tends to go forward if squirted from behind, away if squirted from the front or side.

DISCUSSION

There is evidence that *Tegula* found the glass tube a "difficult" surface — probably due to its strong curvature

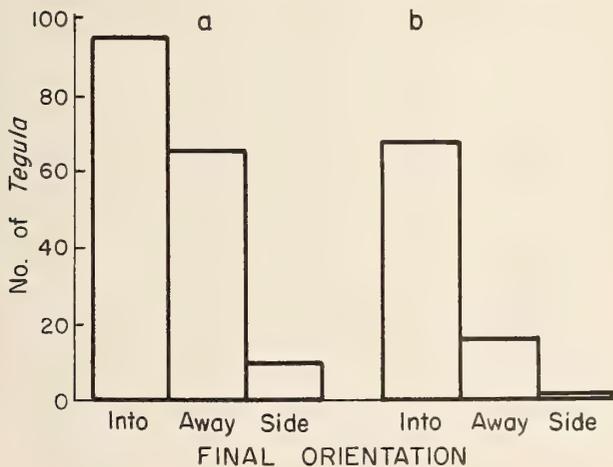


Figure 1: Orientation of *Tegula funebralis* with respect to current direction in a horizontal tube. Current of 260 centimeters per minute.
 a - Original orientation away from current
 b - Original orientation into current

(they would seldom encounter such a concave surface in nature). Many snails were washed off, even in weak currents; also, many of those oriented away made attempts to turn, but apparently could not (Note, in Figures 1a and 1b, that 10 of the 11 snails with a sideways final orientation were originally oriented away).

After a short while the behavior tended to become random (hence I used one minute as my marking point).

A possible source of error in the flask experiments was the magnetic stirrer: many snails were struck by it (whereupon they would promptly turn away), and since it was always spinning in the same direction.

In the bubbling flask experiments, there is evidence that air, and not turbulence, caused the observed effects. The snails always clustered around the air, whether down or up; evidently light caused the diurnal difference (KOSIN, 1964). If air bubbles were not present, a more intense light than that employed is needed to make them move down. HOLZ (1963) found that snails deprived of oxygen would revive faster in air than in water (even when heavily oxygenated), provided they are damp. Further, SNYDER (1964) found that respiration was greater at periods of low tide, while there was a lactic acid buildup at times of high tide: thus the presence of free air does seem to favor the respiratory activities of *Tegula funebralis*.

The question arises as to what sense organs are important in the current and turbulence behaviour of *Tegula funebralis*. Four large snails were deprived of epipodial tentacles and run in the magnetic stirrer flask: The results, though inconclusive, indicated a possible importance of these organs. Removal of head tentacles was not tried, but should be. Another possibility is the presence of some receptor sensitive to pressure applied to the shell. A suspended empty *Tegula* shell (aperture plugged with plasticene) which is free to turn will always orient forward when placed into a current, indicating less resistance; there is apparently a "resistance differential" for different orientations of the shell to oncoming current.

CONCLUSIONS

Tegula funebralis is activated when subjected to current and/or air turbulence; this behavior agrees with CLOUDSLEY-THOMPSON's remark (1961, p. 45) that many sea-shore animals are activated by waves. Further, current causes *Tegula* to orient into the flow, and also keeps them down near the bottom; if the current is sufficiently strong, however, they will often turn and head for shelter at the first respire. Preliminary tests in a vertical tube (250 cm/minute flow) indicate that snails tend to

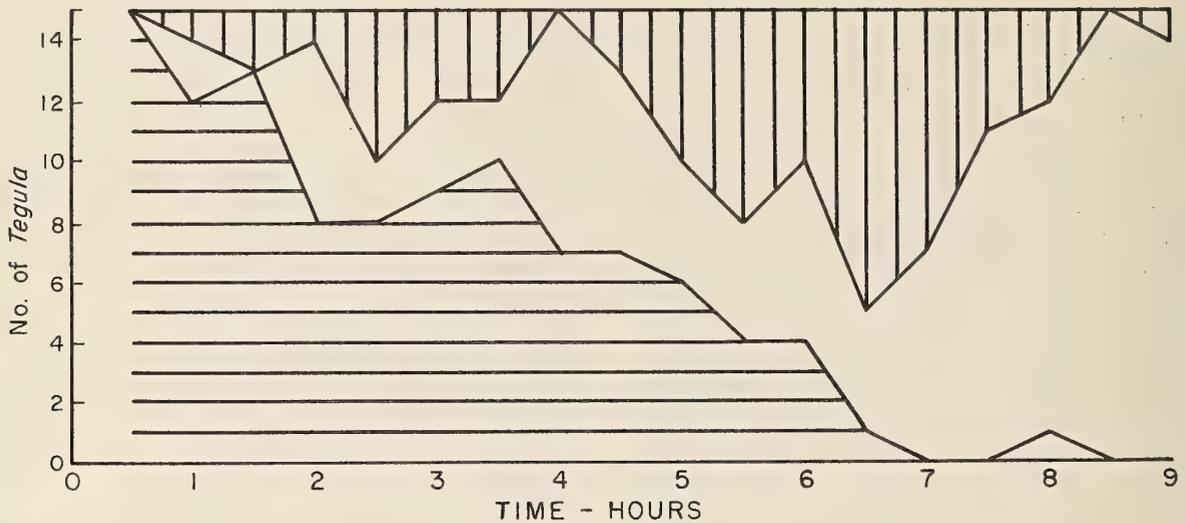


Figure 2: Change in the current orientation of *Tegula funebralis* with respect to time. Current of 450 centimeters per minute.
 Horizontal lines = into current
 Clear = away from current
 Vertical lines = other orientation

go down regardless of current direction: evidently current stimulation, and not direction, causes *Tegula* to go down. It was shown that *Tegula* change their orientation to current after a few hours: this may be a set pattern of response, or perhaps the snails became fatigued. Gradation of current needs to be tried in all these cases. Finally, there is a definite response to air jets: the snails would clump in regions of greatest turbulence. This turbulence seemed to enhance the effect of light (the snails going down in light, up in dark). It is possible, however, that these results were due to the entering air rather than to the turbulence: further tests are definitely necessary.

Hypotheses: Perhaps an advantage of *Tegula funebralis*'s orientation into the current is increased chemo-receptive ability, important in the detection of food and predators; also, wastes may be carried away. As MORTON (1960, p. 149) notes: "The forward-facing mantle cavity in prosobranchs becomes the centre of all those functions depending on the passage of a water current: respiration, olfaction, detection and removal of sediment, and in a few cases feeding as well."

My results tend to explain two occurrences noted in the field: (1) *Tegula* congregates in turbulent areas — tops of rocks at night, swirling areas during day. (2) *Tegula* frequently does not make a large net movement

away from an original low-tide position after a complete tidal cycle. The first, (1), is expected because of the bubbling flask results; (2) is perhaps explained by the reversal in orientation to current noted in the long magnetic stirrer experiment.

ACKNOWLEDGMENT

The author is happy to acknowledge the advice of Professor L. R. Blinks.

LITERATURE CITED

- CLOUDSLEY-THOMPSON, J. L.
 1961. Rhythmic activity in animal physiology and behaviour. New York and London, Acad. Press; 236 pp.; 33 text figs.
- HOLZ, WALTER
 1963. Unpublished class report. Hopkins Marine Station
- KOSIN, DOROTHEA F.
 1964. Light responses of *Tegula funebralis*. *The Veliger* 6; Supplement: 46-50; 7 text figs.
- MORTON, J. E.
 1958. Molluscs: An introduction to their form and functions. New York, Harper Bros. 232 pp.; 23 text figs.
- SNYDER, JANNA M.
 1963. Diurnal and tidal rhythm in the oxygen consumption of the gastropod *Tegula funebralis*. Unpublished student report, Hopkins Marine Station of Stanford University.

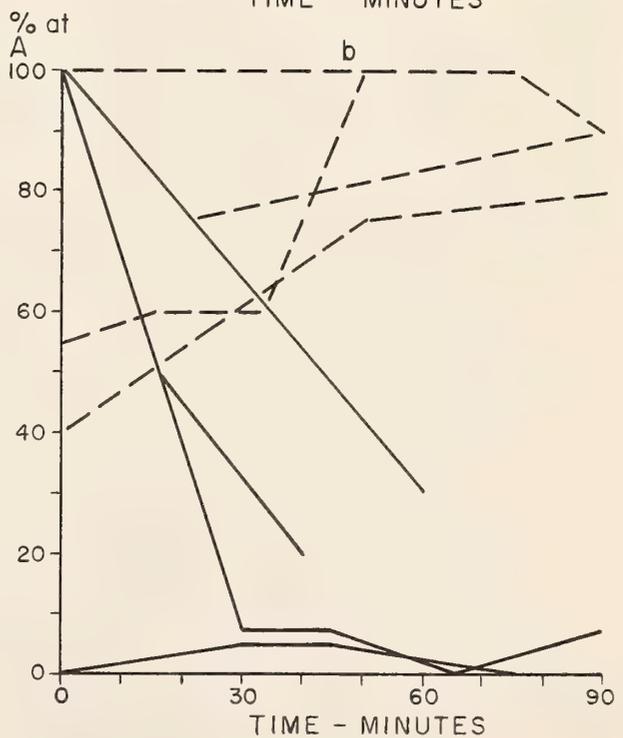
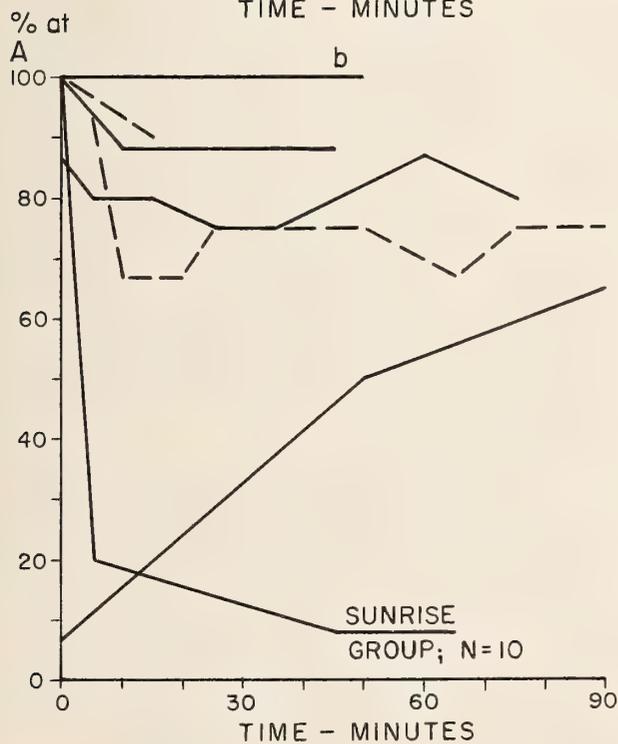
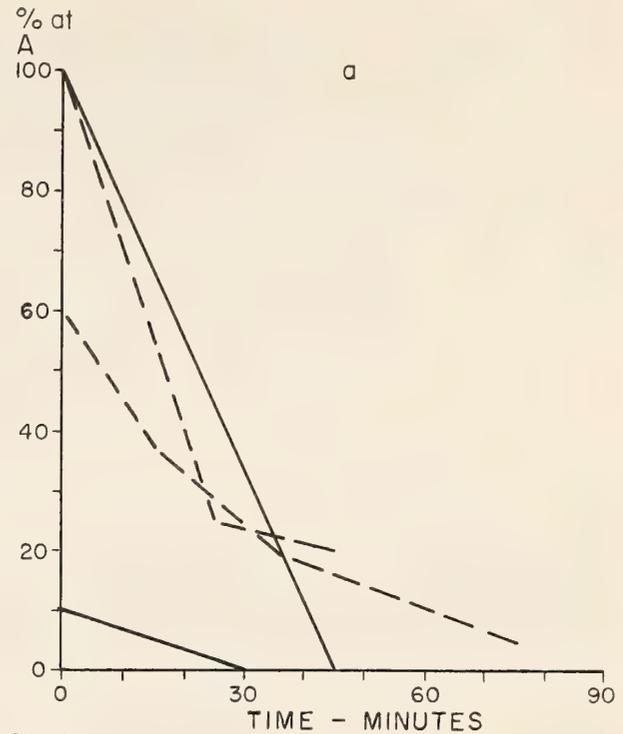
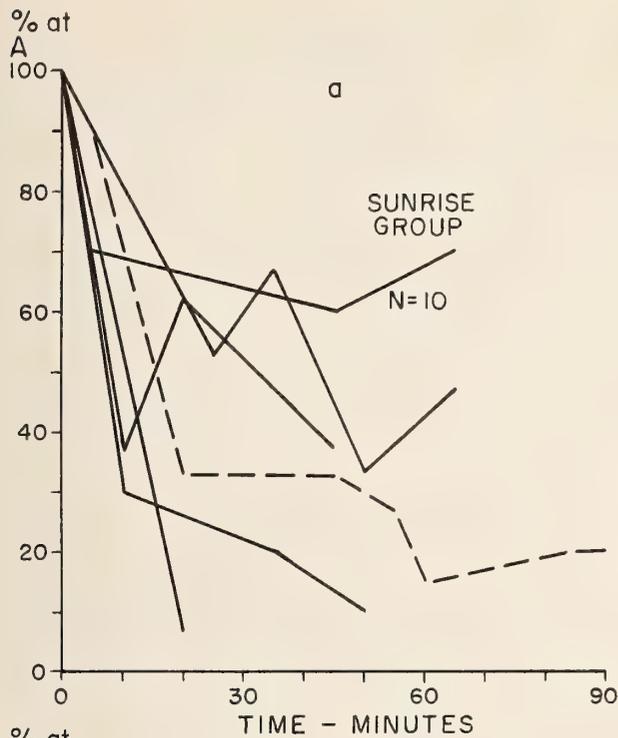


Figure 3: Current effect on vertical distribution of *Tegula funebris*. Current of 450 cm/min.

a. Controls

Solid line: Night - N = 48 (5 groups)
 Broken line: Day - N = 25 (2 groups)

b. Tests

Solid line: Night - N = 65 (5 groups)
 Broken line: Day - N = 25 (2 groups)

Figure 4: Turbulence effect on the vertical distribution of *Tegula funebris* (in flask)

a. Controls (quiet)

Solid line: Night - N = 40 (2 groups)
 Broken line: Day - N = 35 (2 groups)

b. Tests (turbulent)

Solid line: Night - N = 70 (4 groups)
 Broken line: Day - N = 69 (4 groups)

Feeding Activities of *Tegula funebris*

(Mollusca : Gastropoda)

BY

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(1 Text figure; 3 Tables)

INTRODUCTION

THE INTERTIDAL REGIONS at China Point, Pacific Grove, California, provide an abundance of marine plants for a dense population of the primarily herbivorous gastropod *Tegula funebris* (A. ADAMS, 1854). With the variety of plant foods available, *T. funebris* could be expected to display preferences. Feeding activity of the large snail population (400/m²) could certainly affect the algal crop within the *T. funebris* zone. LEIGHTON (in press) has established food preferences for several sublittoral benthic grazers and his extensive field observations have shown the profound effect of grazing activities on the standing algal crop.

The possible food sources of *Tegula funebris* fall into three categories: rock encrusting algæ, macroscopic plant forms, and organic detritus (see Fox, 1957, pp. 383-390) on the predominantly granite surfaces. In addition to the

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food sources, preferences, and the animal's effect on the littoral algal crop, a quantitative estimate of the food consumed by the snail under laboratory conditions was obtained. Light was investigated as a possible factor.

METHODS AND DATA

1. Food source determination: One to 3 grams of an alga (or stones covered with an encrusting form) were placed in plastic dishes containing 2 animals (5 to 10 grams each, wet weight, with shell). The dishes, located in a greenhouse, were continuously supplied with running seawater at 14° C. Any ingestion of the food was noted after 24 hours. Significant weight loss of the alga, fragmentation, evidence of radular rasping, or identification of the food in the gut or fecal material was used to determine whether or not ingestion had occurred. All animals and foods used were taken fresh from the field. The

plants listed in Table I were ingested in varying amounts and are therefore considered food sources.

A simplification of the organic carbon determination in the Manual of Seawater Analysis (STRICKLAND & PARSONS, 1960, pp. 117-121) was used to measure the organic detritus, or leptopel, on the granite surfaces, and therefore the availability of leptopel as a food source. Samples were collected by placing a plastic cylinder upright against the granite surfaces, sealed at the base with plasticene modeling clay. Five ml of 1.0 N. NaOH and 3 to 5 ml distilled water washings were successively poured into the sampling cylinder. This was accompanied by light scratching on the rock surface with a glass rod to simulate the rasping of *Tegula funebris*. One ml of 70% phosphoric acid was added to the sample and heated for 30 minutes in a boiling water bath, followed by 10 ml of potassium dichromate in sulfuric acid solution and 60 minutes of additional heating. After making up to 50 ml volume with distilled water, the sample was read on the Klett colorimeter, supplied with a blue filter. The result is given in µg of carbon, taken from a standard curve of glucose carbon. The samples were taken from barren rocks, 3 to 4 feet above MLLW.

Using the same technique, the organic carbon content of a sandstone sample (surface scrapings down to 2 mm) was found. The stone was taken from the intertidal area on the north side of Punta Banda near Ensenada, Baja California, and is probably a food source for the local *Tegula gallina* (FORBES, 1850) population. This warm water region has an almost exclusively sandstone substrate with a few patches of brown filamentous algæ. Examination of the fecal material from several *T. gallina* showed approximately 80% sandstone by volume. The remaining 20% contained fragments of the filamentous algæ.

The organic content of four granite surface samples averaged 57 µg C/cm², ranging from 22 to 67 µg C/cm².

Table 1

Plant foods ingested by *Tegula funebris*

<i>Cladophora</i> sp.	<i>Macrocystis integrifolia</i>
<i>Corallina</i> sp.	<i>Nereocystis Luetkeana</i>
<i>Egregia Menziesii</i>	<i>Pelvetia fastigiata</i>
<i>Chaetomorpha</i> sp.	<i>Peyssonnelia pacifica</i> ¹
<i>Endocladia muricata</i>	<i>Phyllospadix Scouleri</i>
<i>Gastroclonium Coulteri</i>	<i>Prionitis lanceolata</i>
<i>Gelidium</i> sp.	<i>Ralfsia pacifica</i> ¹
<i>Gigartina Aghardii</i>	<i>Rhodoglossum affine</i>
<i>Gigartina canaliculata</i>	<i>Ulva</i> sp.
<i>Iridaea flaccidum</i>	Unidentified unicellular green
<i>Lithothamnion</i> sp. ¹	alga growing on rocks ¹
	Diatoms

¹ Encrusting alga

Authorities for these names are given in SMITH (1944)

The four sandstone samples averaged 2110 μ g C/gm, with a 2000 to 2240 μ g C/gm range.

2. **Food preference determination:** Preference experiments were restricted to the macroscopic algæ. Plastic dishes were again used in the greenhouse. Three sets of algæ were offered on alternate days to the same animals, which had been collected one day before starting the series of tests. The four species of algæ in each set were placed, in combinations of three, in the dishes with either 10 small animals (range 1 to 4 grams), or 5 larger (range 6 to 12 grams). Wet weight differences of the algæ to the nearest 0.1 gram were taken after 24 hours. Control dishes showed no appreciable change in wet weight of any alga (maximum of 0.03 grams). Results are shown in Table 2.

3. **Feeding rates:** *Macrocystis integrifolia* blades were selected for the feeding rate determination because of the accessibility of its large blade area and its apparent appeal to *Tegula funebris*. Animals collected in the field were fed *M. integrifolia* for 36 hours before beginning. The wet weight of the alga consumed was measured 6 times at intervals of 8 to 25 hours for a total of 82 hours. Two size ranges of the snail were again selected (3 to 5 and

Table 2

Food preferences of *Tegula funebris*
(Grams of plant consumed in 24 hours)

Experiment	1				2				3			
Number of animals	A	B	C	D	E	F	G	H	I	J	K	L
10	0.3	0.2	x	0.0	2.0	0.1	x	0.0	2.5	0.1	x	0.1
10	0.5	x	0.1	0.0	x	0.1	0.1	0.1	x	0.0	0.0	0.0
10	0.5	0.2	0.2	x	2.1	0.0	0.0	x	2.5	0.2	0.0	x
10	x	0.3	0.1	0.1	2.1	x	0.0	0.0	2.6	x	0.0	0.1
Total eaten	1.3	0.7	0.4	0.1	6.2	0.2	0.1	0.1	7.6	0.3	0.0	0.2
Number of animals												
5	0.2	0.1	x	0.0	2.2	0.1	x	0.0	3.0	0.1	x	0.0
5	0.7	x	0.1	0.1	x	0.0	0.2	0.0	x	0.1	0.1	0.0
5	0.5	0.2	0.1	x	2.7	0.1	0.0	x	2.7	0.0	0.0	x
5	x	0.3	0.1	0.0	2.2	x	0.0	0.0	2.6	x	0.0	0.0
Total eaten	1.4	0.6	0.3	0.1	7.1	0.2	0.2	0.0	8.3	0.2	0.1	0.0

A *Gigartina canaliculata*B *Rhodoglossum affine*C *Endocladia muricata*D *Iridaea flaccidum*E *Macrocystis integrifolia*F *Corallina* sp.G *Pelvetia fastigiata*H *Gigartina Aghardii*I *Nereocystis Luetkeana*J *Cladophora* sp.K *Phyllospadix Scouleri*L *Prionitis* sp.

x = plant omitted from set

7 to 9 grams) with four animals in each dish. Results are converted to grams of the alga consumed per day per gram wet weight (with shell) of *T. funebris* (Table 3). The control algæ showed a maximum wet weight change of 0.02 grams.

4. Effect of grazing on the littoral algal crop. For this short period study (17 days), wire mesh cages, 50 x 50 x 20 cm, were fastened over the substrate with the bases flush to the rocks. Four cages were placed adjacently (2 in each of 2 areas). *Tegula funebris* was excluded from one cage and 200 to 300 animals were enclosed in the adjacent cage of each area. At the end of the study, the only appreciable changes that occurred were: a) noticeable grazing on *Rhodoglossum affine*, *Gelidium sp.*, and *Iridaea flaccidum*; b) the appearance of *Ulva sp.* in one of the cages without animals (the alga was found nowhere else within a radius of over 3 meters).

DISCUSSION

Though *Tegula funebris* will ingest almost any common alga, it displays definite preferences among the macroscopic forms, i.e. *Macrocystis integrifolia*, *Nereocystis Luetkeana*, *Rhodoglossum affine*, and *Gigartina canaliculata*. In each case, the preferred alga is a "fleshy" form. It is non-calcareous, nonfilamentous, and has a

tender thallus contrasted to the leathery texture of *Gigartina Aghardii* and *Pelvetia fastigiata*. The preferences are consistent in the two size groups of *T. funebris*.

Since the highly preferred giant brown algæ are normally available to the snail population only as drift material, the food sources of the animals include plants growing outside the *Tegula funebris* zone. This is supported by a field situation at a site of organic detritus sampling. The *T. funebris* population at this location dwells on extremely barren rocks and is apparently nourished by the considerable quantities of drift seaweeds that accumulate.

The encrusting algæ, particularly the abundant green alga and *Ralfsia pacifica*, are undoubtedly important in the diet of the animal. As Figure 1 illustrates, the width of the rasping pattern on a glass plate thinly coated with diatoms greatly exceeds that found on a thick *Macrocystis integrifolia* blade showing an efficient mechanism for covering a large surface area when necessary. This may also be important in keeping larger algae free of diatom growth.

Organic detritus on granite surfaces is probably only an incidental food source at best. The detritus does contain digestible compounds, however (see NIGRELLI, 1963, pp. 9-11). *Tegula gallina* undoubtedly utilizes the organic content of its sandstone substrate in a manner similar to

Table 3

Feeding rates of *Tegula funebris*

animal weight		Sunlight							amount consumed		
gms *		hours in test periods							total	gms day	gms gm* day
total	range	8.3	25.5	11.5	12.6	12.5	11.5				
33.1	7-9	0.18	0.14	0.35	0.16	0.18	0.12	1.13	0.33	0.010	
34.9	7-9	0.08	0.28	0.64	0.13	0.12	0.05	1.30	0.38	0.011	
15.5	3-5	0.06	0.25	0.38	0.00	0.11	0.10	0.90	0.26	0.017	
14.9	3-5	0.17	0.20	0.10	0.12	0.12	0.07	0.78	0.23	0.015	
		Constant Darkness									
32.1	7-9	0.03	0.26	0.45	0.02	0.01	0.30	1.07	0.31	0.010	
33.7	7-9	0.14	0.00	0.00	0.20	0.01	0.12	0.47	0.14	0.004	
15.1	3-5	0.00	0.19	0.25	0.11	0.07	0.07	0.69	0.20	0.013	
16.3	3-5	0.05	0.38	0.02	0.06	0.28	0.13	0.92	0.27	0.017	

Numbers represent the grams of *Macrocystis integrifolia* consumed in the given time period. Horizontal rows give data for 4 animals, with total weights and individual ranges (3 to 5 gms or 7 to 9 gms.)

*(in wet weight of animals, with shell)

Littorina planaxis (PHILIPPI, 1847) and *L. scutulata* (GOULD, 1849) as shown by NORTH, 1954. In earlier work, NORTH (unpublished data) measured the erosive activities of *T. funebris* on sandstone. He collected 1.1093 gms of eroded (ingested) sandstone from the fecal material of 11 snails (total weight 58.4 grams) in 24 hours. Organic detritus, as found in sandstone, may therefore be included as a food source of *T. funebris* as well as *T. gallina*, though sandstone is not found in the China Point area.

Table III clearly shows that the larger snails have a lower feeding rate (in grams consumed per gram of animal) than the smaller snails. The overall difference of 17% in feeding rate found between sunlight and constant darkness is too small to suggest a photokinetic response in feeding activity. The mean feeding rate in light (0.012 gm/gm of animal/day) probably represents the maximum found in the field, since the food was available in excess and shown to be highly preferred.

The condition of the algae in the cages at the end of the 17 day period (in experiment 4) verifies the preferences determined in the laboratory. Each of the species of algae

affected (except possibly *Ulva*) could be called a "fleshy" form. A definite relationship between the *Tegula funebris* population and the marine plants in its environment is certainly indicated.

SUMMARY

- 1) *Tegula funebris* will ingest nearly any alga growing in or out of the littoral zone. Both macroscopic and encrusting forms constitute important food sources; the granite surfaces contain a negligible amount of organic detritus and contribute little to the diet of the animal. Earlier work on *T. funebris* and observations of *T. gallina* show that the animals will ingest organic detritus when it is available.
- 2) The snail prefers a "fleshy" alga among macroscopic forms (e.g. *Macrocystis integrifolia*, *Nereocystis Luetkeana*, and *Gigartina canaliculata*).
- 6 114
- 3) Feeding rates per gram are greater in the smaller animals and are apparently not affected by lack of sunlight.
- 4) A short field study suggests the importance of the feeding activities of *Tegula funebris* on the local algal crops.

LITERATURE CITED

- FOX, DENIS L.
1957. Particulate organic detritus, pp. 383-390 in: HELG-PETH, JOEL W. (ed.), Treatise on marine ecology and paleoecology. New York, Waverly Press: viii + 1296 pp.
- LEIGHTON, DAVID L.
(in press) The effects of discharged wastes on kelp. Final report, Sacramento, California. Calif. State Water Pollut. Brd.
- NIGRELLI, R. F.
1963. Metabolites of the sea (Biol. Sci. Curricul. Study Pamphlet), Bristol, Conn., Hildreth Press; 35 pp.
- NORTH, W. J.
1954. Size distribution, erosive activities, and gross metabolic efficiency of the marine intertidal snails, *Littorina planaxis* and *L. scutulata*. Biol. Bull. 106 (2): 185-197
- SMITH, G. M.
1944. Marine algae of the Monterey Peninsula. Stanford Univ. Press; ix + 622 pp.
- STRICKLAND, J. D. H. & T. R. PARSONS
1960. A manual of seawater analysis (with special reference to the more common micronutrients and to particulate organic material) Ottawa, Canada; Fish. Res. Brd. of Canada Bull. 125: vi + 185

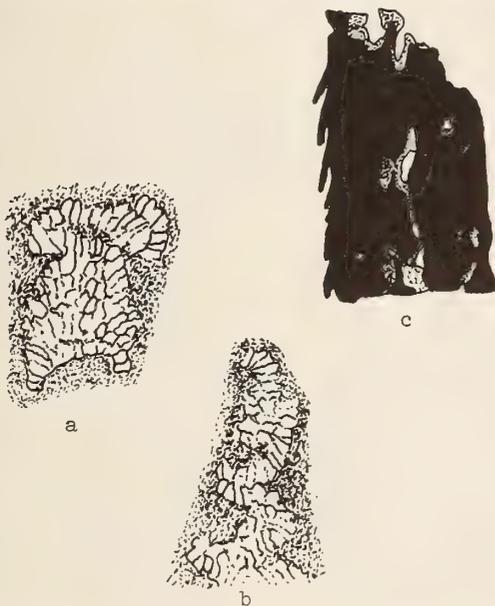


Figure 1: Rasping patterns produced by *Tegula funebris*.
a, b: on glass plate, thinly coated with diatoms;
c: on blade of *Macrocyctis integrifolia*. (all x $\frac{4}{5}$)

The Light Responses of *Tegula funebris*

(Mollusca : Gastropoda)

BY

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(7 Text figures)

THE BEHAVIOR OF *Tegula funebris* (A. ADAMS, 1854) on the shore is complex. The snails are found clustered in cracks and crevices of rocks on both sunny and foggy days when the tide is low. Their movements in tidepools are inconsistent; sometimes all snails are gathered on the shady side, at others they are scattered throughout the pool. They are subjected to the action of waves and currents, as well as tidal exposure and submersion, at different light conditions over the tidal cycle. To establish the role of each factor (such as light) would be difficult in nature, but in the laboratory most of the other factors can be controlled and light varied.

METHODS

Tegula funebris were tested for reactions to light in several manners: (1) Three aquaria, as much alike in contents as possible (rocks, shell fragments, algæ, number of snails) were set up under different light conditions and the snail movements noted. (2) Groups of snails were subjected to different intensities and spectral regions of visible light, and their reactions observed and timed. (3) Individuals were allowed to move in directional light. (4) Eyes and other appendages were removed and the response of such operated snails compared with the normal. Such operations were not generally harmful: all operated animals survived for at least two weeks and no infections were obvious. (Before operation, the snails were anesthetized by slow addition of an equal volume of isotonic $MgCl_2$ solution to sea water in which a number of snails were lying upside down. A temperature of $30^\circ C$ also served to keep the snails extended out of their shells.)

RESULTS

(1) The experiments with 3 aquaria in different light conditions indicate that *Tegula funebris* avoid light. Fig. 1 shows the number of snails at or near the surface of the water (all others being on or near the bottom). The day-

night exposure shows great migration downwards during full daylight; the snails gather in the shadiest parts under algæ, behind rocks, on the shady side of the aquarium. In darkness (with only a dim ruby light for occasional observation), the snails all remained at water level all the time. Snails kept at a constant low light intensity (about 70 foot candles) tended to stay at the top, though somewhat less than those in complete darkness.

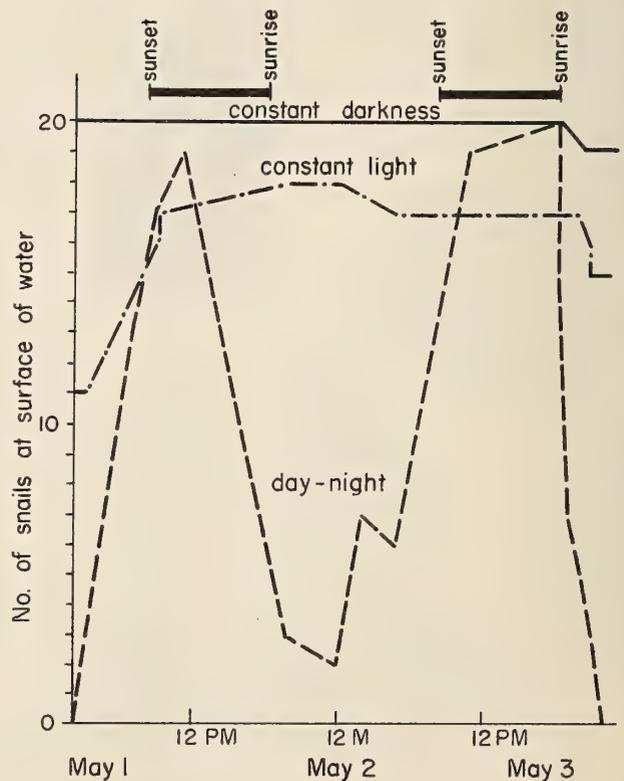


Figure 1: Distribution of 20 *Tegula funebris* in each of three similar aquaria under different light conditions: normal day and night; constant illumination at 70 foot candles; and darkness.

In constant conditions the distribution of *Tegula funebris* remains constant. When light conditions are alternated between light and dark the distribution alternates correspondingly up and down. (Fig. 2) The alternating light was presented out of phase with the day-night cycle and was conducted with snails which had been in the dark for two weeks. The response to the change of light conditions starts immediately, and the new distribution is reached within approximately one hour.

(2) Another method for measuring the light response was exposing groups of snails to beams of different intensities

Note: The following abbreviations are used where appropriate in all figures in this article.

- | | |
|----------------------|------------------|
| a shell aperture | ht head tentacle |
| an anus | k kidney |
| cm columellar muscle | mc mantle cavity |
| ct ctenidium | op operculum |
| e eye | os osphradium |
| f foot | r rectum |
| g gonad | s shell |
| h heart | sc spiral caecum |
| st stomach | |

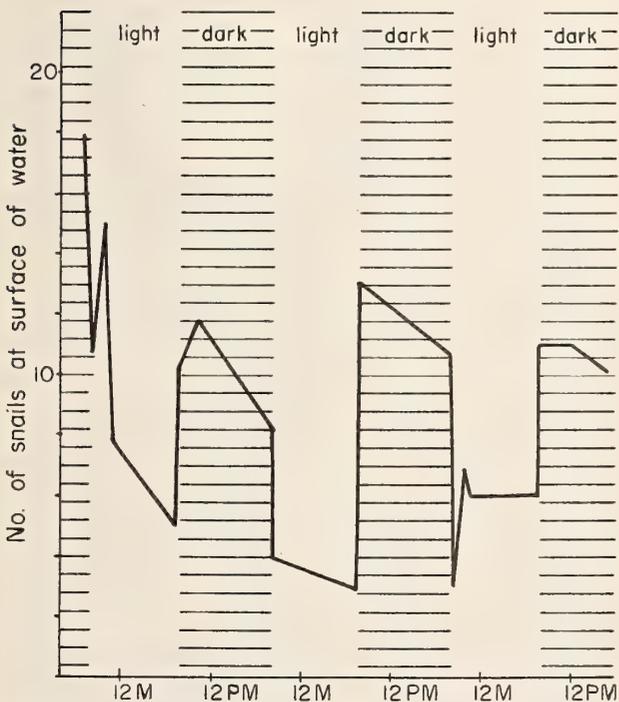


Figure 2: Effect of alternating light (70 foot candles) and darkness on 20 snails that had previously been in darkness for two weeks. The cycle is opposite to that of actual day and night.

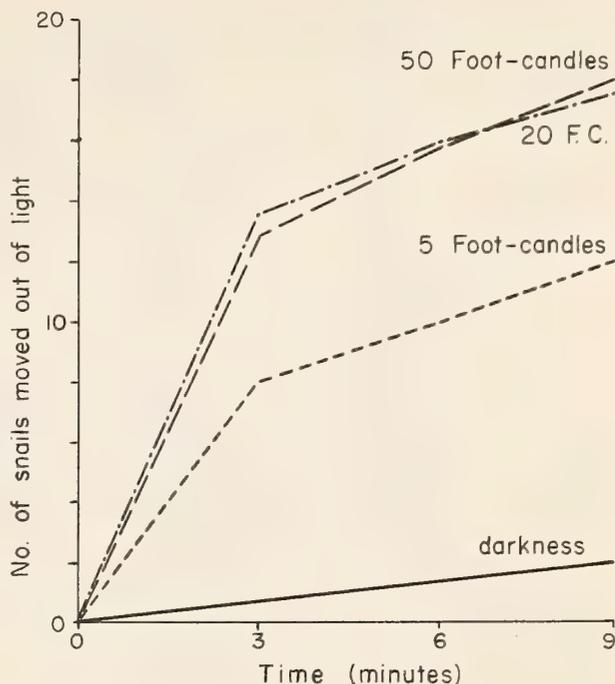


Figure 3: Rate of movement of snails out of a beam of light at three different intensities (5, 20, 50 f.c.). The rate in darkness is compared.

sities of light, and observing their rate of exit from the lighted area. As soon as the snails were placed in a circle of light, they began turning and pushing each other around in their attempt to move out of the light. They move to the darkest areas available, and rest only when they reach a crack or maximum darkness. The same number of snails left in the same area, but without light, disperse much more slowly. (Fig. 3). Snails previously adapted to different light intensities were also tested in this manner (Fig. 4). Those previously exposed to full sunlight (6000 F.C.) scarcely responded at all.

(3) Both operated and normal snails give a "shadow reaction," which is best observed if the snail is lying on its back, with foot partly extended. (If it is not extended far enough, it will withdraw into the shell when shadowed. If it is extended too far, the snail turns over and will not react at all. When the snail is attached to a surface by its foot, shading causes it to pull back its head, and to remain in that position for some time,— e. g. up to 5 minutes).

But when it is upside down, its normal reaction to a shadow is a slight contraction and pulling back of the foot, followed by a short period of quiet, and then a relaxation or extension of part or all of the foot. There is great variation in the amount of contraction, even in the same

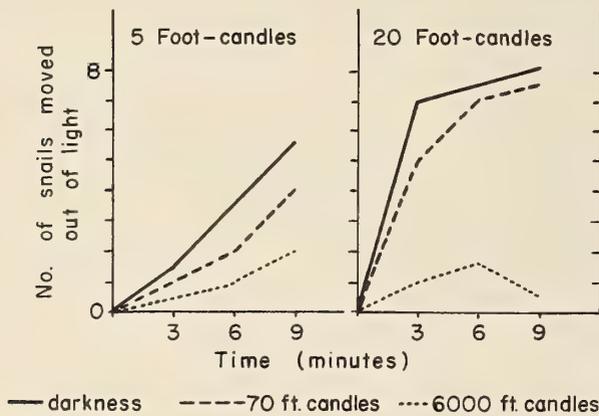


Figure 4: Rate of movement of snails out of a beam of light (5 and 20 foot candles), after previous adaptation to darkness, 70 foot candles and full daylight (6000 f.c.).

snail. The *duration* also varies, but not necessarily with the visible degree of contraction. A snail may contract deeply but shortly, or only slightly, but remain still for some time. Fig. 5 indicates the duration of contractions caused by 19 successive shadowings of 3 different snails; the average is 3 to 4 seconds. (The light was a microscope lamp about 30 cm above the snail, with some 7.5 cm of sea water to absorb much of the infra red. The visible intensity at the level of the snail was 20 F.C.)

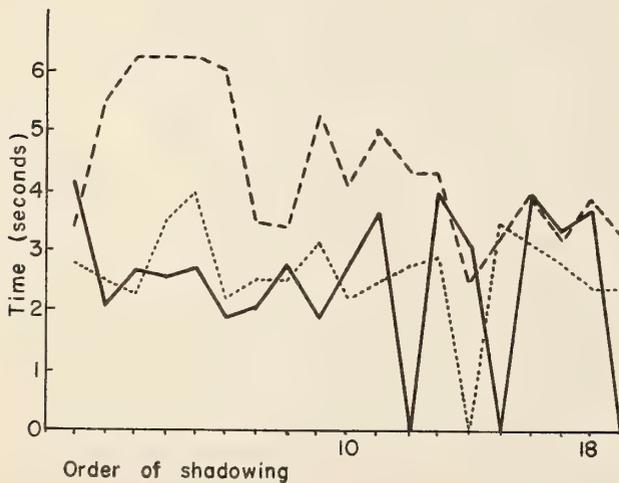


Figure 5: Duration of contraction reaction induced by 19 successive shadowings of three different snails (represented by solid, broken and dotted lines). Average duration, about 3.5 seconds (omitting the four failures, of zero durations). Light, 20 foot candles.

The same procedure was followed at different spectral regions isolated by glass filters; the intensities were adjusted to give about equal reading on a G. E. light meter, which approximates the human eye over much of the visible range. No significant difference in the duration of the response was noted to shading of either red, yellow, blue or green light (Fig. 6). However, in the far red light from a photographic ruby lamp (10 watts at 1 foot) no shadow response could be elicited.

A sudden illumination, even by bright light, does not cause such a consistent and quick reaction; it is the disappearance of light which causes the withdrawal. Nor does re-illumination visibly affect the total shadowing reaction. If a snail is left in darkness for over an hour, then put on its back, there may be a long contraction but this cannot be repeated as well as the shadow reaction. During the first minute or longer of such light exposure, the snail may be very insensitive to shadows. The amount of time

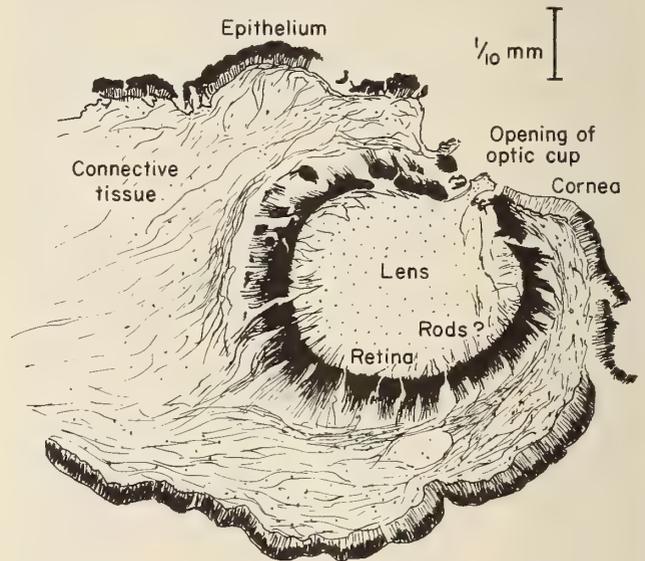


Figure 7: Sagittal section of the eye lobe of *Tegula funebris*, about 25 microns thick.

necessary for this adaptation is dependent on the brightness of the light, and the intensity of light to which the snail had been exposed before the one hour dark period. Only when the snail becomes adapted to the new intensity will it react to shadows.

(4) In avoiding light, snails move to the closest dark area. In this they are aided by their eyes. A light directly above the snail causes it to move straight out of the light beam in any direction. If the left eye is removed the snail turns in about half a circle to the left before moving straight out of range of the light. Similarly a snail turns toward the

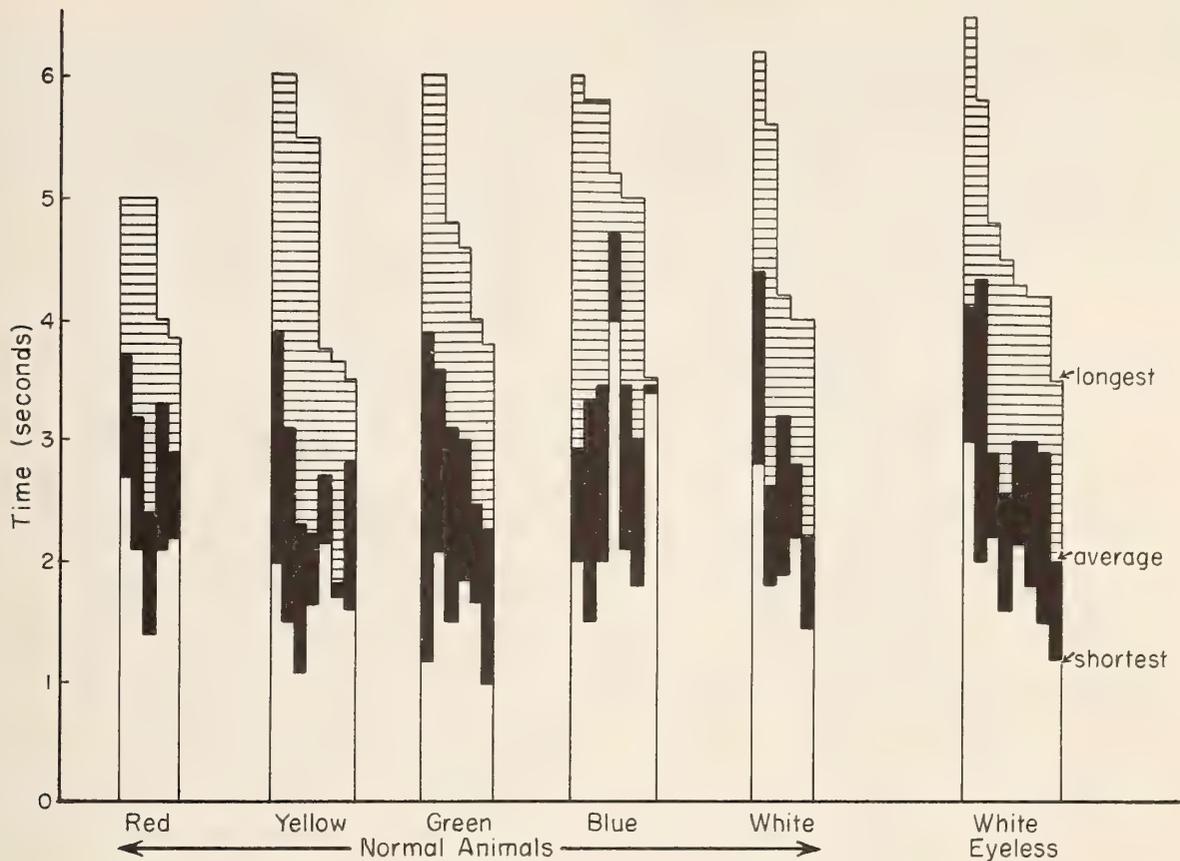


Figure 6: The effect of various spectral regions, and of white light, upon the shadowing response. The narrow columns represent different animals (5 to 8 in different histograms). Eyeless animals are shown in the last group. Intensities approximately equal, by G.E. photo-cell.

right when its right eye is removed. When both eyes are removed the snail generally turns around irregularly before leaving the lighted area.

In light from one side a normal snail moves away from the source with its head in its own shadow. The head turns from side to side, and each time that an eye is illuminated the snail turns back to its shadow or turns its head to the other side. In the same light an eyeless snail moves irregularly, even directly toward the light. Apparently it cannot distinguish direction without its eyes. A snail without its right eye will turn, usually toward the right, until its left eye is in shadow and then move directly out of the path of the light. When the left eye is removed the snail turns, usually to the left, until its right eye is in shadow before moving straight out of the beam of light.

Normal snails, snails without eyes, without epipodial tentacles and lobes, without propodial tubercles, and with none of these organs were tested for a shadow reaction.

There was no difference in their reactions. Figure 2 shows the response of eyeless snails. Apparently the shadow reaction is more the result of a general body sensitivity, than of reception by a specific light sensitive organ.

These experiments indicate that the eyes are used for directional orientation in the light. It is the only function of the eye that I have been able to discover. The anatomy of the eye suggests this as well (Fig. 7). It is a simple, small ocellus containing a firm, clear substance which may correspond to a "lens". The small opening to the outside might function like a pin-hole camera, to form an image at the retina. Around the edge of the opening is a ring of unpigmented cells which might be a cornea. The retina appears to be formed by a direct invagination of the epidermis, continuous through the clear corneal area. The optic nerve branches proximal to the optic cup, sending fibers over its entire surface to connect with the retina.

The eyes of *Tegula funebris* may represent a concentration of the same sensitive tissue present on the general body normally outside of the shell. The pigmentation of the retina resembles that of the epidermis, which contains melanin. Attempts to isolate a photosensitive pigment from the eyes, according to the recipe for squid retinas (BLISS, 1948) failed, probably because of the very small amount of tissue employed.

SUMMARY

Tegula funebris is negatively phototactic. It becomes adapted to bright light, and loses its sensitivity temporarily. It has a general body sensitivity shown by a shadow reaction. Its eyes, simple lens ocelli, seem responsible for directional orientation to light. Without eyes its orientation is irregular.

LITERATURE CITED

BLISS, A. F.

1948. The absorption products of visual purple of the squid and its bleaching products. *Journ. Biol. Chem.* 176: 563 - 569

Observations on the Epipodium, Digestive Tract, Coelomic Derivatives and Nervous System of the Trochid Gastropod *Tegula funebris*

BY

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(15 Text figures)

IN SPITE of the abundance of *Tegula funebris* (A. ADAMS, 1854) in the California intertidal, no account of its anatomy has yet appeared in the literature, although the anatomy of other trochids has been described (Randles, 1905; Fretter and Graham, 1962). To partially fill this void, a brief account of certain external and internal features of *T. funebris* is herein presented.

The specimens of *Tegula funebris* examined were collected at Mussel Point, Pacific Grove, California, during April and May, 1963. The animals were dissected alive after having been anesthetized with magnesium chloride; both frozen and paraffin sections were cut in order to make more detailed observations. Injection of suspensions of carborundum and carmine powders in sea water helped

to determine the extent of specific body cavities. Both Mallory's connective tissue stain and Harris' hematoxylin produced excellent results after fixation with Bouin's fluid, made with seawater. A silver impregnation (ROWELL, 1963) worked well for isolated nerves, but also stained muscle and connective tissue heavily in sections of the entire animal.

Epipodium: The epipodium of *Tegula funebris* is composed of five elements: the neck lobes, anterior papillæ, epipodial tentacles, epipodial papillae, and epipodial ridges (Figures 1 and 2). On both sides of the animal the anterior quarter of the epipodium is occupied by the heavily ciliated neck lobe, which runs posteriorly from near the base of the optic peduncle. The border of

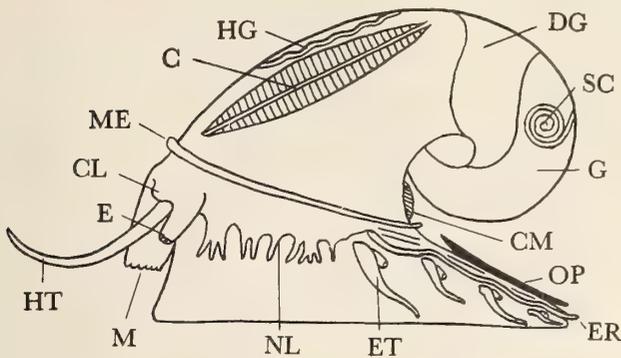


Figure 1: Entire animal, left side, shell removed

- | | |
|-----------------------|------------------------|
| C ctenidium | G gonad |
| CL cephalic lappet | HG hypobranchial gland |
| CM columellar muscle | HT cephalic tentacle |
| DG digestive gland | M mouth |
| E eye | ME mantle edge |
| ER epipodial ridge | NL neck lobe |
| ET epipodial tentacle | OP operculum |
| SC spiral caecum | |

the left neck lobe is fringed, the number and grouping of points being variable, whereas the edge of the right lobe is smooth; on both lobes the cilia beat distally, especially when the lobe is touched with a probe. The function of

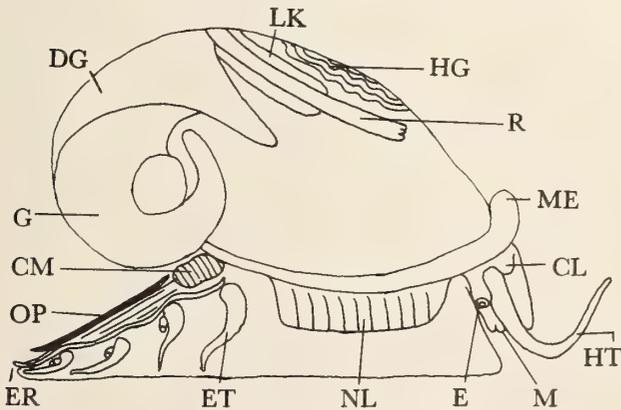


Figure 2: Entire animal, right side, shell removed.

- | | |
|------------------------|----------------------|
| CL cephalic lappet | HT cephalic tentacle |
| CM columellar muscle | LK left kidney |
| E eye | M mouth |
| ER epipodial ridge | ME mantle edge |
| ET epipodial tentacle | NL neck lobe |
| G gonad | OP operculum |
| HG hypobranchial gland | R rectum |

these neck lobes may be the removal of particles expelled from the mantle cavity, though FRETTER & GRAHAM (1962, p. 532) state that the neck lobes of British trochids are rolled into half-siphons for channeling water in and out of the mantle cavity. No evidence of this was seen in *Tegula funebris*.

Beneath the overhang of each neck lobe are from one to ten anterior papillæ, each with a central spot of ciliated unpigmented epithelium (Fig. 3). They retract slightly when touched; this reaction and their structure suggest that they may be sensory receptors.

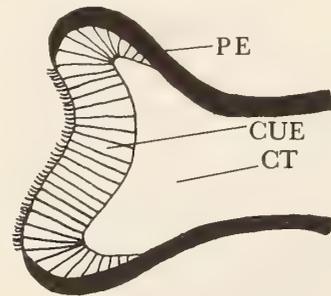


Figure 3: Anterior papilla, diagrammatic longitudinal section

- | | |
|-------------------------|-------------------------------------|
| CT connective tissue | CUE ciliated unpigmented epithelium |
| PE pigmented epithelium | |

Just posterior to the neck lobe is the first epipodial tentacle, which on the left side bears an epipodial papilla (Fig. 6) similar in appearance to an anterior papilla; the first epipodial tentacle on the right side does not bear such a papilla. The other three tentacles on each side bear papillæ (Fig. 4). The epipodial tentacles are similar in structure to the cephalic tentacles and are innervated from the pedal cords; observations of the use of both cephalic and epipodial tentacles in the field and in aqua-

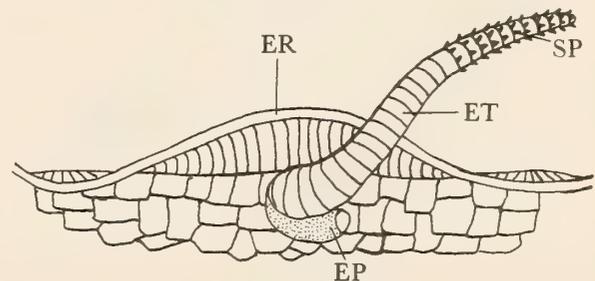


Figure 4: Epipodial tentacle, diagrammatic

- | | |
|----------------------|-----------------------|
| EP epipodial papilla | ET epipodial tentacle |
| ER epipodial ridge | SP sensory papillæ |

ria seem to indicate that they are tactile, and perhaps olfactory, receptors. An active animal will be seen to draw its tentacles repeatedly over the substrate as it advances. Resting animals either "caress" their shells with the tentacles, or gently wave them. In the presence of predaceous asteroids such as *Pisaster ochraceus* (BRANDT, 1835), *T. funebris* waves cephalic and epipodial tentacles vigorously while trying to escape; Mc GEE (unpubl.) has noted a similar response in *Tegula brunnea* (PHILIPPI, 1848) exposed to spawning males of their own species.

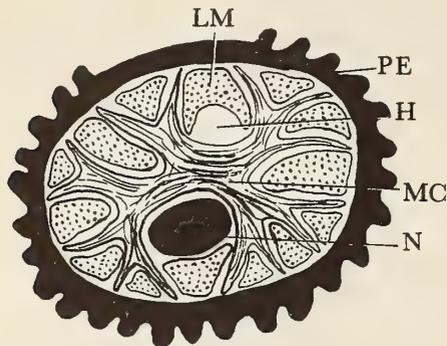


Figure 5: Epipodial tentacle, diagrammatic cross section

- | | |
|-----------------------------|--|
| H haemocoel | MC column of transverse muscle and connective tissue |
| LM longitudinal muscle band | PE pigmented epithelium |
| N nerve | |

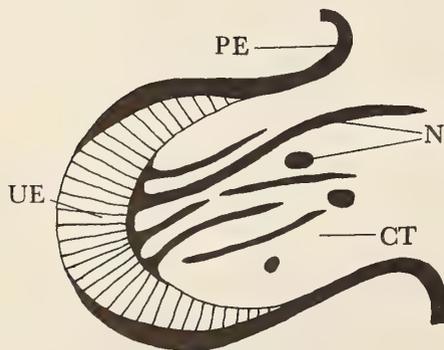


Figure 6: Epipodial papilla, diagrammatic longitudinal section

- | | |
|----------------------|---------------------------|
| CT connective tissue | PE pigmented epithelium |
| N nerve | UE unpigmented epithelium |

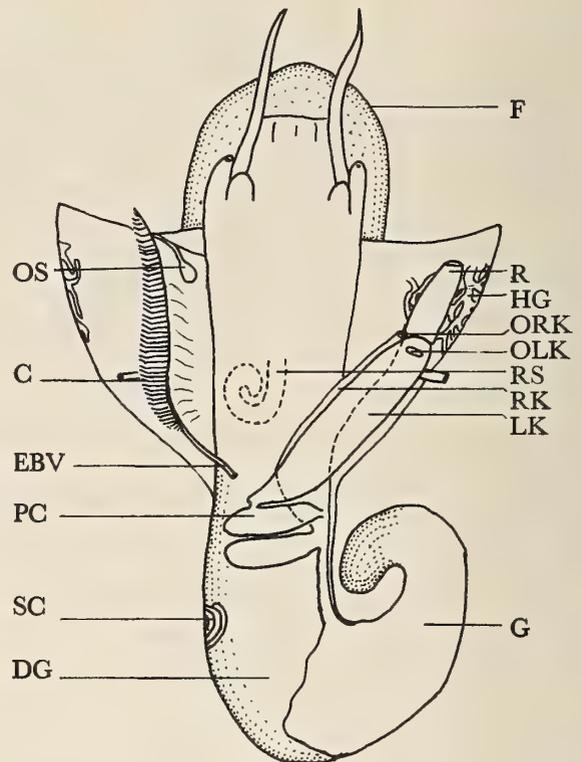


Figure 7: Dorsal view of entire animal with mantle cavity laid open; structures of coelomic origin are indicated

- | | |
|-----------------------------|--------------------------|
| C ctenidium | OLK left kidney opening |
| DG digestive gland | ORK right kidney opening |
| EBV efferent branchial vein | OS osphradium |
| F foot | PC pericardium |
| G gonad | R rectum |
| HG hypobranchial gland | RK right kidney |
| LK left kidney | RS radular sac |
| | SC spiral caecum |

The epithelium of the epipodial tentacles is heavily pigmented; distally it forms papillæ bearing non-motile sensory cilia. Similar cilia are found on the tentacles of other prosobranchs (FRETTER & GRAHAM, 1962, p. 313) and on the oral tentacles of the nudibranch *Hermisenda* (AGERSBORG, 1925). Passing down the length of the tentacle is a large central nerve, longitudinal muscle bands, and an extension of the hemocoel. The center of the tentacle is occupied by an irregular column of muscle and connective tissue fibers (Fig. 5). The epipodial ridge is a long flap of tissue which begins just posterior to the first

epipodial tentacle on either side and runs just dorsal to the other three epipodial tentacles and continues to the hindmost tip of the foot.

Digestive Tract: The anterior part of the digestive system seen in Figure 8, shows the buccal cavity to be limited ventrally by the subradular membrane, which extends posteriorly into the radular sac. Ventrally, the radular sac is anchored by striated musculature to the posterior part of the odontophore. The radula is fused to the subradular membrane anteriorly, but is free posteriorly. The complex movements of the odontophore are controlled by striated musculature acting on the four radular "cartilages."

The disposition of the rest of the digestive system is seen in outline in Figure 9. There are three main regions: the foregut, composed of buccal cavity and esophagus; the stomach and digestive gland, which comprise the mid-

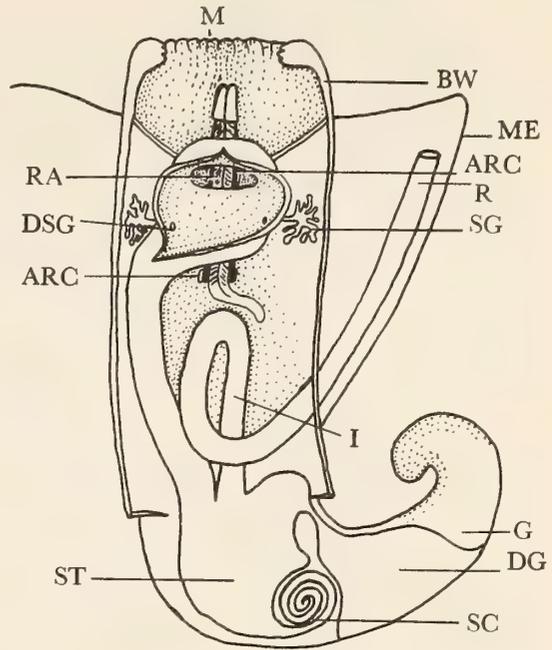


Figure 9: Dorsal view of entire digestive system

- | | |
|--------------------------------|-------------------|
| ARC anterior radular cartilage | I intestine |
| M mouth | |
| BW cut edge of body wall | ME mantle edge |
| DG digestive gland | RA radula |
| DSG duct of salivary gland | SC spiral caecum |
| G gonad | SG salivary gland |
| R rectum | ST stomach |

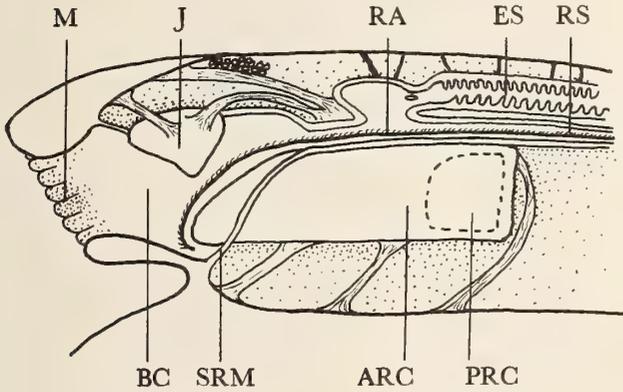


Figure 8: Buccal region, diagrammatic longitudinal section

- | | |
|--------------------------------|---------------------------------|
| ARC anterior radular cartilage | M mouth |
| BC buccal cavity | PRC posterior radular cartilage |
| ES esophagus | RA radula |
| J jaw | RS radular sac |
| SRM subradular membrane | |

gut region; and the hindgut, consisting of intestine and rectum. Only one duct is shown leading to the digestive gland from the stomach; there are also numerous fine pores in the same area which appear to lead to the gland. The areas of the posterior visceral hump occupied by the digestive gland and gonad vary somewhat from specimen to specimen. In freshly killed specimens which were not treated with magnesium chloride, peristaltic movements could be seen in the hindgut, but were not observed in the foregut.

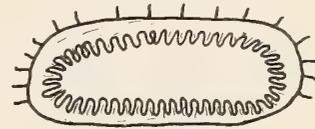


Figure 10: Cross section through esophagus

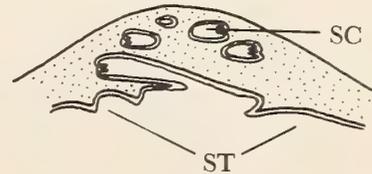


Figure 11: Cross section through spiral caecum
SC spiral caecum ST stomach

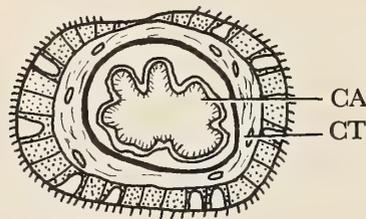


Figure 12: Cross section through rectum

CA cilia CT connective tissue

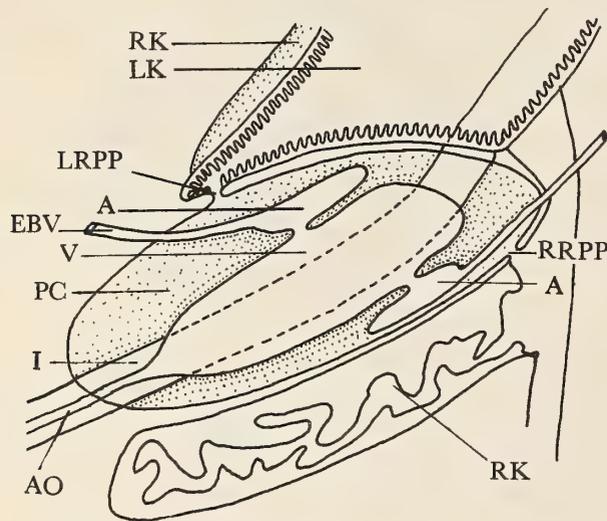


Figure 13: Diagrammatic dorsal view of pericardial cavity showing coelomic derivatives

A auricle	PC pericardium
AO aorta	RK right kidney
EBV efferent branchial vein	RRPP right renopericardial pore
I intestine	LRPP left renopericardial pore
LK left kidney	
V ventricle	

Coelomic Derivatives: Structures of coelomic origin are shown in figure 13; these include the right and left kidneys, the pericardial cavity, and the gonad. The presence of both right and left renopericardial ducts is in accord with the condition found in other trochids (RANGLES, 1905) and in *Haliotis* (HARRISON, 1961). The duct to the right kidney is very small; whether it is functional or not is undetermined. The opening to the left kidney is

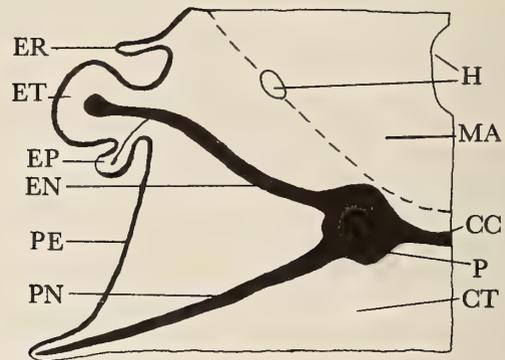


Figure 14: Left side of foot, diagrammatic cross section

CC cross connection between pedal cords	ET epipodial tentacle
CT connective tissue	H haemocoel
EN epipodial nerve	MA muscular area
EP epipodial papilla	P pedal cord
ER epipodial ridge	PE pigmented epithelium
	PN pedal nerve

relatively large, and fluid may be caused to flow between the left kidney and the pericardial space.

Nervous System: The nervous system of *Tegula funebris* (Figs. 14 & 15) is similar to that of other trochids (RANGLES, 1905, pp. 57-66, figs. 30-33). The right pleuro-parietal connective runs over the esophagus and splits into two nerves, the first running to the branchial ganglion, subjacent to the osphradium, and the second running posteriorly between the ventral ctenidial membrane and the perivisceral sinus, and crossing the esophagus and the loop of the hindgut to end in a pair of visceral ganglia above the right kidney. The left pleuro-visceral connective crosses beneath the esophagus and runs posteriorly to connect with the visceral ganglia. RANGLES (1905) found a dialyneury between the left pallial nerve and the right pleuro-parietal connective in *Trochus*; no such connection was observed in *Tegula funebris*.

ACKNOWLEDGMENTS

We are indebted to the faculty, staff, and graduate students of the Hopkins Marine Station, especially to Mr. Nick Holland and Mr. Welton Lee, for advice, technical assistance, and encouragement in the execution of this work.

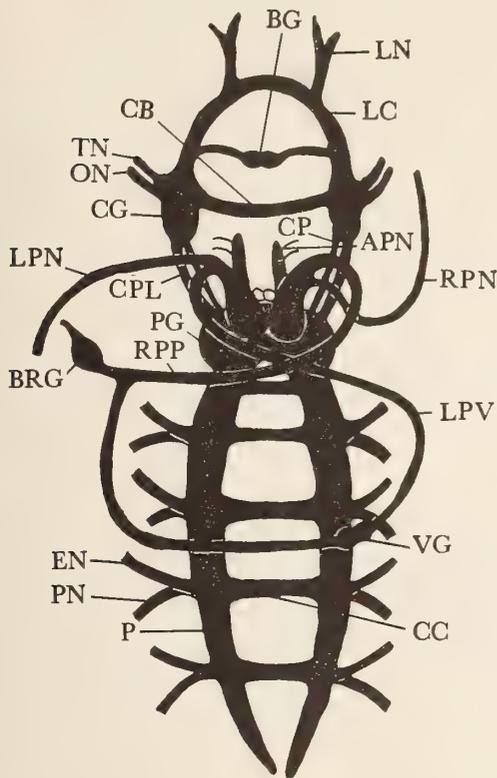


Figure 15: Nervous system, diagrammatic dorsal view. The large masses dorsal to the pedal ganglia represent the pleural ganglia; the small hollow objects between the pleural ganglia are the statocysts

APN anterior pedal nerve	LN labial nerve
BG buccal ganglion	LPN left pallial nerve
BRG branchial ganglion	LPV left pleuro-visceral connective
CB cerebral commissure	ON optic nerve
CC cross connection between pedal cords	P pedal cord
CG cerebral ganglion	PG pedal ganglion
CP cerebro-pedal connective	PN pedal nerve
CPL cerebro-pleural connective	RPN right pallial nerve
EN epipodial nerve	RPP right pleuro-parietal connective
LC labial commissure	TN tentacle nerve
	VG visceral ganglia

LITERATURE CITED

AGERSBORG, H. P. KJERSCHOW

1925. The sensory receptors and the structure of the oral tentacles of the nudibranchiate mollusk *Hermisenda crassicornis* (ESCHSCHOLTZ, 1831). *Acta Zool.* 6: 167 - 182

FRETTER, VERA, & ALASTAIR GRAHAM

1962. British prosobranch molluscs; their functional anatomy and ecology. London, Ray. Soc.; xvi + 755 pp.; 317 figs.

HARRISON, F. M.

1961. Some excretory processes in the abalone *Haliotis rufescens*. *Journ. Exp. Biol.* 39: 179 - 192

RANDLES, W. B.

1905. Some observations on the anatomy and affinities of the Trochidae. *Quart. Journ. micr. Sci.* 48: 33 - 78

ROWELL, C. H. F.

1963. A new technique for silvering invertebrate central nervous systems. *Quart. Journ. micr. Sci.* 104: 81 - 87



The Responses of *Tegula funebris* to Starfishes and Predatory Snails

(Mollusca : Gastropoda)

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(2 Tables)

INTRODUCTION

THE RESPONSES of some gastropods to predators are well known (BULLOCK, 1953; CLARK, 1958; FEDER, 1956; SMITH, 1960). This study was designed to investigate the responses of a single herbivorous snail, *Tegula funebris* (A. ADAMS, 1854), to a number of predatory and related forms. They include: the sea stars *Pisaster ochraceus* (BRANDT, 1835), *Pisaster brevispinus* (STIMPSON, 1857), *Pisaster giganteus* (STIMPSON, 1857), *Patiria miniata* (BRANDT, 1835), *Pycnopodia helianthoides* (BRANDT, 1835), *Leptasterias aequalis* (STIMPSON, 1862), *Dermasterias imbricata* (GRUBE, 1857), and the carnivorous snails *Thais emarginata* (DESHAYES, 1839), and *Acanthina spirata* (BLAINVILLE, 1832). All of these animals occur in the rocky intertidal zone, at Mussel Point, Pacific Grove, California, with the exception of *Pisaster brevispinus*, which is found in the nearby sandy subtidal zone. Hereafter the name *Tegula* will refer to *Tegula funebris* only.

CONTACT EXPERIMENTS

FEDER, (1956) and BULLOCK, (1953) indicate that the tube feet of starfishes, when they are placed in contact with a snail, elicit a greater response from gastropods than do any other portions of the starfish body. The responses of *Tegula* to the tube feet of most of the starfishes tested are essentially the same as those described by FEDER, (1956 pp 143-145) for *Pisaster ochraceus* and *Tegula*. If a *Tegula* is stimulated in the head region the snail rears back, raising its head and the anterior portion of its foot. This is followed by a turn of approximately 90 degrees and the snail crawls away rapidly. Lateral stimulation of the foot and epipodium causes a tipping or twisting of

the shell away from the point of contact and the snail either turns away or crawls obliquely away. Contact with the posterior portion of the foot results in the shell being tipped far up over the head and is often accompanied by violent rocking of the shell through an arc of almost 180 degrees. As before, the snail crawls away at 2 or 3 times normal speed. In the following contact experiments a tube foot, excised from a test starfish, was slipped over the end of a probe and touched to various soft parts of *Tegula*. All of the tube feet were of the grasping type, taken from the middle $\frac{1}{3}$ of a starfish ray.

Contact with the sole of the foot of the carnivorous snails *Thais emarginata* and *Acanthina spirata* produces a greater response in *Tegula* than a similar touch with their shell, proboscis, or tentacles. Therefore, in tests with these species, small pieces of the foot were applied to *Tegula* in the manner used for the tube feet of sea stars.

The responses elicited by contact with the foot of *Thais emarginata* or *Acanthina spirata* were essentially the same as those following contact with starfish tube feet with one exception. A *Tegula* stimulated laterally or posteriorly first twists its shell away from the area of stimulation, but instead of crawling away it raises its head and foot and turns toward the point of contact, crawling up onto the predator tissue. Placing a shell of the carnivore in the path of the *Tegula* causes it to climb rapidly onto the shell.

The responses enumerated above were not merely reactions to any foreign object. Contact with a clean bare probe only causes a *Tegula* to retract that part of its body which has been touched and to clamp its shell down tightly against the substrate.

Each predator was tested against 50 *Tegulas*, 25 of which were stimulated first with the control probe and

then the predator tissue. The order of applying the two stimuli was reversed for the other 25. The *Tegulas* tested ranged in size from 5 mm to 30 mm in maximum basal diameter of the shell. To avoid any possible habituation to the various stimuli, each *Tegula* was taken from the shore, used once, and then returned to the beach.

In Table 1 responses to contact with both predator tissue and the control (probe) are indicated. All responses were typical of the descriptions above but varied in intensity. A strong response consists of an immediate reaction following a single stimulus. Moderate responses are those in which the reaction was slower and more than one application of the stimulus was required. Where no response is recorded the animal completely ignored the stimulus. The test animals are listed in the table in order of strength of response elicited, the strongest first.

DIFFUSION EXPERIMENTS

PHYSICAL contact between *Tegula* and predatory starfishes is not always necessary to produce a response on the part of the mollusk (Bullock, 1953; Feder, 1956). To further test the hypothesis that substances diffusing from a predator can cause a reaction in *Tegula* the following series of experiments was performed. A clean, plastic dishpan was filled to a depth of 6 cm with fresh

Table 1

The Responses of *Tegula funebris* to Contact with Predator Tissue and with a Clean Probe

Predator	Response of <i>Tegula funebris</i> to contact with:							
	Predator Tissue				Clean Probe			
	S	M	W	O	S	M	W	O
<i>Pisaster giganteus</i>	94	4	2	0	6	82	12	0
<i>Pisaster ochraceus</i>	88	10	2	0	16	70	14	0
<i>Acanthina spirata</i>	84	12	4	0	6	82	12	0
<i>Pisaster brevispinus</i>	80	12	8	0	10	84	6	0
<i>Thais emarginata</i>	76	20	4	0	26	70	4	0
<i>Pycnopodia heli-anthoides</i>	64	32	4	0	16	76	8	0
<i>Leptasterias aequalis</i>	44	38	16	2	12	80	8	0
<i>Dermasterias imbricata</i>	0	0	14	86	6	84	10	0
<i>Patiria miniata</i>	0	0	8	92	6	88	6	0

Figures are percentages of animals tested which gave the response indicated. N = 50, S = Strong response, M = Moderate response, W = Weak response, and O = No response

sea water, and 25 *Tegulas*, ranging in basal shell diameter from 5 mm to 30 mm, were aligned on the periphery of the bottom. Five minutes later the number of snails with their heads out of water was recorded, and the same snails were again placed along the bottom of the pan. A predator was placed in the center of the pan and the number of snails with their heads out of water at the end of 5 minutes was again noted. The snails were used in only one experiment (including control) and each experiment was repeated 5 times. When necessary the predator was placed in a plastic bag to prevent contact with the *Tegulas*. Because of the small size of a few of the predators, several were placed in a cage and used at one time.

Table 2

The Responses of *Tegula funebris* to Diffusible Substances from Predators

Predator	Trial				
	1	2	3	4	5
<i>Pycnopodia heli-anthoides</i>	19/4	4/0	17/1	19/0	13/0
<i>Pisaster giganteus</i>	11/1	6/2	19/3	6/2	9/0
<i>Pisaster ochraceus</i>	17/3	5/1	8/0	7/3	5/0
<i>Leptasterias aequalis</i>	10/1	8/1	4/1	11/1	8/1
<i>Pisaster brevispinus</i>	3/0	6/0	5/0	13/0	5/0
<i>Acanthina spirata</i>	0/1	4/1	2/1	3/0	1/2
<i>Thais emarginata</i>	0/0	0/0	0/0	4/1	2/4
<i>Patiria miniata</i>	0/0	2/0	1/0	0/1	1/1
<i>Dermasterias imbricata</i>	1/0	1/1	0/0	1/1	0/1

Experimental situation/Control situation. Figures represent the number of *Tegula funebris* with heads out of water at the end of five minutes; N = 25 for each trial.

Animals used in this manner were *Leptasterias aequalis* (16), *Thais emarginata* (26), *Acanthina spirata* (21). In all other cases a single predator was used. The results of the diffusion experiments are indicated in Table 2. The test animals are listed in order of number of *Tegulas* responding to them, greatest number first.

DISCUSSION

The responses tabulated in Table 1 indicate that *Tegula* responds differently to the predators and the non-predators used in these tests. *Patiria miniata* is an omnivorous scavenger and herbivore and *Dermasterias imbricata* is thought to be a scavenger on dead animal matter, while the remainder of the test species are active carnivores, all of which have been observed eating *Tegula* either in the laboratory, in the field, or both. The survival ad-

vantages of escape behavior have been pointed out by Feder (1959), in his discussion of the food habits of *Pisaster ochraceus*. He finds that although *Tegula* is relatively abundant it is not eaten as frequently as its numbers might suggest, and that this is due, in part, to the effective escape mechanisms it has developed. Clark (1958) has been able to induce responses in herbivorous gastropods by stimulating them with carnivorous ones. The reactions are described as similar to those mentioned by Bullock (1953). *Tegula*'s response to 2 carnivorous snails, however, has been to go toward the carnivores and attempt to crawl up over them. This, too, appears to have survival value.

That the responses are stimulated by a chemical signal is indicated by the difference in type of response elicited by contact with predator tissue and clean probes. The substance appears to be diffusible in the case of starfishes and non-diffusible in the case of snails (Table 2).

While *Leptasterias aequalis* is too small to eat the larger *Tegula* specimens it can certainly eat the smaller ones, and the reactions of the large *Tegulas* may be a retention of a response adaptive in earlier life or to starfish in general. The one *Tegula* which gave no response to *L. aequalis* and 6 of those which gave a weak response were 20 mm in basal shell diameter or larger.

From the small number of predator species tested it is difficult to predict any correlation between sympatry of the predators and *Tegula*, and the responses of *Tegula* to the predators. However, *Pisaster brevispinus* must seldom, if ever, be encountered by *Tegula* yet this starfish elicits a strong escape reaction. It may be that there are substances peculiar to the physiology of predatory asteroids and gastropods in general which *Tegula* can recognize. If this is so then little, if any, correlation between response and sympatry of predator and *Tegula* is to be expected, but rather a correlation between feeding habit and escape reaction.

SUMMARY

THE REACTIONS of *Tegula funebris* were tested to a number of starfishes and carnivorous snails. The responses vary according to the type of animal used as a source of the stimulus. *Tegula* flees from the contact or presence of predatory starfishes, ignores non-predaceous ones, and attempts to escape from or crawl upon the shell of the carnivorous snails used in these tests. Strong escape responses were elicited on contact with predatory starfishes such as *Pisaster ochraceus*, *P. brevispinus*, *P. giganteus*, *Pycnopodia helianthoides*, *Leptasterias aequalis* and the carnivorous snails *Thais emarginata* and *Acanthina spirata*, but not to the non-predatory sea stars *Patiria miniata* and *Dermasterias imbricata*. Escape reactions are also elicited by substances diffusing from the 5 predaceous sea stars listed above. No similar response is caused by the other test animals.

LITERATURE CITED

BULLOCK, THEODORE HOLMES

1953. Predator recognition and escape responses of some intertidal gastropods in the presence of starfish. *Behaviour* 5 (2): 130 - 140

CLARK, W. C.

1958. Escape responses of herbivorous gastropods. *Nature* 181: 137 - 138

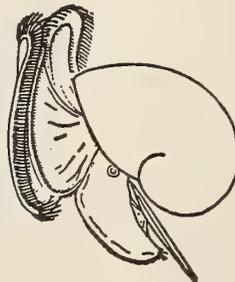
FEDER, H. M.

1956. Natural history studies on the starfish *Pisaster ochraceus*, in the Monterey Bay area. unpubl. Ph. D. Thesis, Stanford Univ.; Stanford, Calif.

1959. The food of the starfish, *Pisaster ochraceus*, along the California coast. *Ecology* 40 (4): 721 - 724

SMITH, DEBOYD L.

1960. Stimulus-response relationship between certain mollusks and starfish. unpubl. student report, Hopkins Marine Sta., Stanford Univ., Calif.



Shell Growth and Repair in the Gastropod *Tegula funebris*

(Mollusca : Gastropoda)

BY

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(3 Text figures; 2 Tables)

SHELLS OF *Tegula funebris* (A. ADAMS, 1854) inhabiting the intertidal areas of Mussel Point, Pacific Grove, California, are rarely found to have more than four whorls, irrespective of the size of the snail, due to heavy erosion of the upper parts. Questioning the nature of repair of erosion damage led to a consideration of the more general question of shell repair in *T. funebris*. FRETTER & GRAHAM (1962) discuss shell formation in prosobranch molluscs, but little is understood of shell repair mechanisms.

Tegula funebris lives in what is essentially a tapered tube, closed at the small end. This is clearly seen in Figs. 1 and 2. Macroscopically, there are three layers in the shell. The thin, transparent periostracum on Mussel Point specimens is present only on the body whorl near the shell aperture, if at all. Underlying the periostracum is a black prismatic layer. These two layers are secreted only by the mantle margin. Innermost is a thick nacreous layer, white over most areas, but sometimes yellow or greenish in the upper whorls. Slides of decalcified shells embedded in paraffin show the laminar character of the nacreous matrix.

Most of the specimens of *Tegula funebris* from Mussel Point have shells which are conspicuously eroded. Although some of the erosion appears to be due to the radular action of predaceous snails, boring of bryozoans and polychaetes, or mechanical wear, all save a minority of *T. funebris* (individuals measuring 5 mm or less at the greatest basal diameter) are pitted over most of the eroded surface. Under 30x magnification, this damage closely resembles that caused by a fungus described as infesting shells of marine animals by BONAR (1936). Attempts were made to culture the fungus on *T. funebris* on a medium of 100 ml sea water, 1 gm CaCO₃, 1 ml 1 M NaNO₃, 1 ml 1 M KH₂PO₄, 1.5 gm agar, 1 gm humus, 5 gm *T. funebris* shell, finely ground, 0.1% glucose, and 0.01% yeast extract. The fungus in culture shows

chlamydozoospores (see Fig. 3) which differ from those on the species raised by BONAR, and also from those found by JOHNSON (1962) in a fungus growing on smooth jingle shells (*Anomia simplex* D'ORBIGNY) from Pivers Island beach, North Carolina.

Normal shell growth in *Tegula funebris* was measured for a fifteen-day period (May 14-29, 1963) on individuals ranging 13.0-27.5 mm in greatest basal diameter. Measurements were made with an ocular micrometer of growth increments on the outer lip of the aperture, secreted on

Explanation of abbreviations used in the figures:

a - shell aperture; an - anus; cm - columellar muscle;
ct - ctenidium; e - eye; f - foot; g - gonad; h - heart;
ht - head tentacle; k - kidney; mc - mantle cavity;
op - operculum; os - osphradium; r - rectum; s - shell;
sc - spiral caecum; st - stomach.

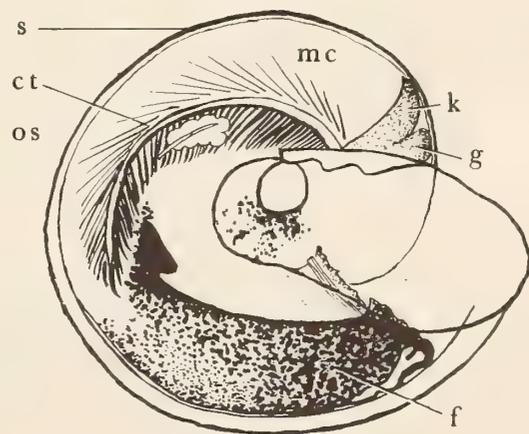


Figure 1: Ventral view of *Tegula funebris*, 8 mm in basal diameter; decalcified, cleared in cedarwood oil, and with black prismatic layer removed.

Table 1
Growth Studies on the Shell of *Tegula funebris*
Addition to Shell at Aperture on Successive Days

Snail no.	Greatest basal diam. (mm)	(mm)										Average growth per day
		1	2	5	6	8	9	11	12	15		
1	13.0	0	0	0	—	—	0	—	.060	.090	.006	
2	13.5	0	0	0	—	—	.090	—	.120	.210	.014	
3	16.0	0	0	0	—	—	.030	—	.060	0	.004	
4	17.0	0	0	0	—	—	.030	—	.060	.090	.006	
5	17.0	0	0	0	—	—	.030	—	.060	0	.004	
6	18.0	0	0	0	0	—	0	—	0	.030	.002	
7	18.0	0	0	0	—	—	0	—	.030	.060	.004	
8	19.0	0	0	0	—	—	—	—	0	X	0	
9	20.0	0	0	0	—	—	.090	—	.120	0	.008	
10	20.5	0	0	0	—	—	.090	—	.120	0	.008	
11	21.0	0	0	0	—	—	X	—	—	—	0	
12	21.0	0	0	.100	—	0	—	.165	—	0	.011	
13	22.0	—	.033	.100	—	.132	—	.165	—	0	.011	
14	23.0	0	0	0	—	—	.060	—	.090	0	.006	
15	23.0	0	0	0	—	—	.090	—	.120	.150	.010	
16	23.0	0	0	0	—	—	.030	—	.060	.090	.006	
17	23.0	0	0	0	—	—	.030	—	.060	0	.004	
18	23.0	0	0	—	—	—	—	0	—	0	0	
19	24.0	0	0	0	—	—	.030	—	.060	.090	.006	
20	24.0	0	0	0	—	—	0	—	0	—	0	
21	24.0	0	0	0	0	—	.060	—	.090	0	.006	
22	24.5	0	0	0	—	—	.060	—	.090	.120	.008	
23	25.0	0	0	0	—	—	.015	—	.030	.120	.008	
24	25.0	0	0	0	—	—	.030	—	.090	.120	.008	
25	25.5	0	0	0	0	—	0	—	.030	0	.002	
26	25.5	0	0	.132	—	—	—	.165	—	0	.011	
27	27.5	0	0	0	0	—	.060	—	X	—	.007	
28	27.5	0	0	0	—	—	.060	—	.120	0	.008	

Legend:

- O no change since last observation
— no observation
X dead

top of a baseline of fingernail polish painted on the edge of the aperture at the beginning of the study. Results are shown in Table 1. The average overall addition to shell aperture was six microns per day, but growth occurred in spurts, not evenly each day. Total growth over the fifteen-day period did not measurably affect the greatest basal diameter of the shells.

In order to assess the ability of *Tegula funebris* to repair damage incurred to the shell, snails were operated on

in various ways, inflicting different types of shell damage, as indicated in Table 2. Five individuals were operated in each way. The holes (windows) made in the shell back of the aperture were ground on an emery wheel, care being taken to keep the shell wet and cool, and the internal tissues intact. Table 2 gives the average change in each group on successive days. The range of variation within each group was not so great as to make the average irrelevant. In every case of damage to the shell

Table 2
Repair of Shell Damage in *Tegula funebris*

Type of Operation		Repair on Successive Days After Operation (mm Added to Shell at Aperture)					
		2	5	6	8	11	15
	control (no operation; normal growth at aperture lip recorded)	O	.1	-	O	.165	O
	mantle margin slit	O	.2mm notch	notch filled			
	2.6 mm notch filed in edge of shell aperture	.066mm of notch filled	.240mm of notch filled	-	.388mm of notch filled	.479mm of notch filled	.677mm of notch filled
	window over visceral hump	M	CaCO ₃	O	O	2 CaCO ₃ layers	O
	window over heart and kidney area	M	CaCO ₃	-	X		
	window over mantle cavity	O	.18 added to hole edge	-	.198	.353	.397
	shell cracked (with a vise)	M	CaCO ₃	-	white nacreous secretion over crack (xx)	O	O
	shell broken at aperture (with pliers)	T	.187	O	.221	.386	.354
	shell aperture ground off	T	.333	-	.353	.397	.583

O no change since last observation

- no observation

T just visible trace of nacreous layers secreted

M soft, membranous layer secreted over opening

CaCO₃ dead

X calcium carbonate embedded in soft layer

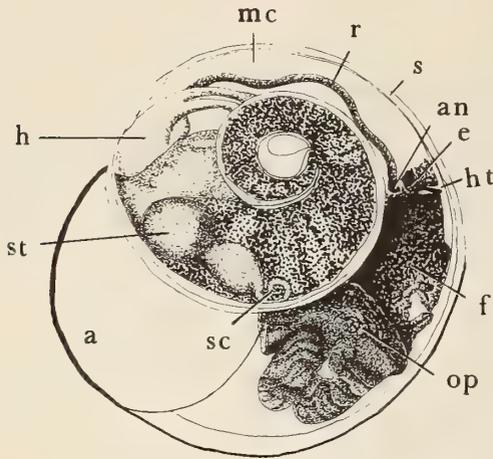


Figure 2: Dorsal view of *Tegula funebris*, same individual as shown in Figure 1.

aperture, growth of the damaged part proceeded faster than the growth at apertures of undamaged controls. All such operations on the apertures were repaired by the folds at the border of the mantle. The same was the case with the windows over mantle cavities. New shell material included a black prismatic layer.

When the mantle margin was slit in an otherwise undamaged specimen, within two days a notch appeared in the shell aperture at the point apposed to the incision. It is not clear whether the notch was due only to lack of growth, or in part due to active resorption of shell at the point, but within six days the notch was repaired.

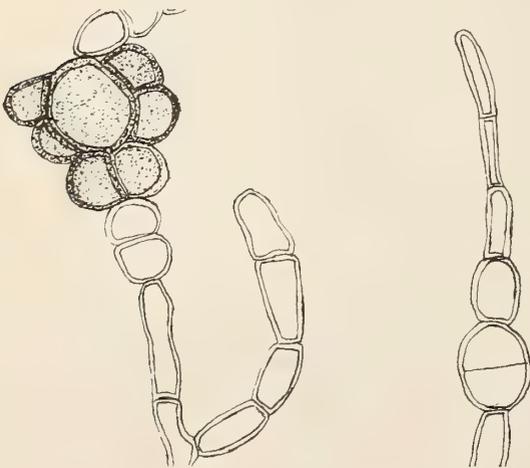


Figure 3: Fungus found on *Tegula funebris* shell; part of mycelium with chlamydozoospores.

Snails with openings over the visceral hump first secreted a soft, membranous layer across the inside of the hole; this later became impregnated with calcium carbonate. Successive layers, similar in appearance, were built up beneath the first layer, which bulged through the opening. After thirty days (April 30-May 29, 1963), one specimen had plugged the shell window with a hard patch of white material, apparently calcium carbonate embedded in an organic matrix. The patch protruded through the opening like a bubble, and was translucent at the periphery, opaque in the center portion. Of three females and two males, with windows cut over the visceral hump, the females began repair sooner than the males. None of the snails with windows over the visceral hump died, although the gonad was frequently ruptured. On the other hand, animals with the shell damaged by grinding a hole over the region of the heart and kidney died in all cases except one. Death was due not to the operation, but to the later rupture of the kidney or pericardial sac against the sharp edge of the opening produced by the operation. One specimen which lived an entire month with this operation failed to successfully repair the damage, for each time the soft membranous layer covering the hole became embedded with calcium carbonate, it was sloughed off through the opening.

In the "windowed" animals, even where the holes penetrated yellow and green layers, I observed no secretion of yellow or green material by the mantle covering the body, nor is it secreted by the mantle margin. Secretions by other than the mantle margin were always either transparent membranous layers or white inorganic material. However, natural repair does show yellow or green material, particularly in eroded areas at the shell apex. Perhaps the inner layers of nacreous material are dyed by pigments secreted by the visceral hump, specifically either the digestive gland or the gonad (see McGEE, 1964).

Cracked shells were bound firmly together in a solid unit within five days by a calcium carbonate-embedded membrane on the inner surface. Additional white nacreous material was laid over the outer surface of the crack within eight days where the break passed through the underside of the body whorl adjacent to the shell aperture.

SUMMARY

1. Shell erosion is caused by the activities of several animals (bryozoans and polychaetes), by mechanical wear, and by a fungus, which was cultured on agar plates.
2. Normal shell growth, recorded over a period of fifteen days in twenty-eight animals, was intermittent, but averaged six microns per day added to the outer lip of the aperture.

3. Repairs to shells damaged mechanically, by filing the aperture, grinding holes in the body and upper whorls, and by cracking in a vise are described.

LITERATURE CITED

BONAR, L.

1936. An unusual ascomycete in the shells of marine animals. Univ. Calif. Publ. Bot. 19: 187 - 194

FRETTER, VERA, & ALASTAIR GRAHAM

1962. British prosobranch molluscs; their functional anatomy and ecology. London, Ray Soc.; xvi + 755 pp.; 317 figs.

JOHNSON, T. W., JR. & W. A. ANDERSON

1962. A fungus in *Anomia simplex* shell. Journ. Elisha Mitchell Sci. Soc. 78: 43 - 47

MCGEE, PATRICIA

1964. A new pigment from *Tegula funebris* (Mollusca: Gastropoda). The Veliger 6; Supplement: 25 - 27; 1 text fig.

The Dispersal of Young of the Commensal Gastropod *Crepidula adunca* from its Host, *Tegula funebris*

BY

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(4 Text figures)

INTRODUCTION

Crepidula adunca SOWERBY, 1825 is a protandric marine prosobranch commonly found on the shells of *Tegula funebris* (A. ADAMS, 1854), both when the latter is occupied by the snail and when it is occupied by *Pagurus* spp. MORITZ (1938) gives the range of *C. adunca* as being similar to that of *T. funebris*: from Vancouver, British Columbia, to the tip of Lower California. CONKLIN (1897) has followed the cell lineage of *C. fornicata* and *C. plana*, and MORITZ (1938, 1939) has treated the anatomy and organogenesis of *C. adunca*.

Crepidula adunca undergoes a very direct development from large, yolky eggs which are brooded by the female. The hatching young crawl out of the egg cases as juveniles which are similar to adults. At hatching there may be from 150 to 200 young released. Although no pelagic stage is present, the adult population of *C. adunca* is quite well dispersed over the *Tegula funebris* population near the Hopkins Marine Station, Pacific Grove, California. The number of adult *C. adunca* per *T. funebris* shell is relatively low (eight was the maximum number seen) as compared to the large number of young per brood. Clearly, the young become dispersed to new hosts without benefit of a pelagic stage. How this is accomplished is the subject of the present investigation.

HATCHING

Crepidula adunca breeds the year round (MORITZ, 1938). The animals used were gathered from Mussel Point, Pacific Grove, California. *Tegula funebris* with the brooding *Crepidula* females were kept in glass finger bowls at 12 to 18° C. Young when hatched were kept similarly. All young used in all experiments were hatched without human assistance, both to avoid harming the young through attempts to liberate them artificially, and to establish their age, as the period of development to hatching is not known.

In the four cases where hatching was observed, young *Crepidula adunca* were released between 8:30 and 10:30 a. m. The egg cases are attached by individual stalks to one spot on the *Tegula funebris* shell, immediately ventral and posterior to the head and anterior to the foot of the female *C. adunca*. Normally, the female's shell is lifted no more than 0.5 mm above the substrate, only enough to allow water to flow through the mantle cavity for filter-feeding and respiration. During hatching, however, the female intermittently lifts her shell 1 to 3 mm above the substrate, for periods which varied from 3.5 seconds to about 4 minutes. Then with a forward and downward motion of her head over the egg cases, the female pushes out those of her young which are loose

and in the path of her head. Other hatched young may crawl out. The young usually escape from the anterior region of the mother's shell, which is typically oriented on the host as shown in Figure 1.

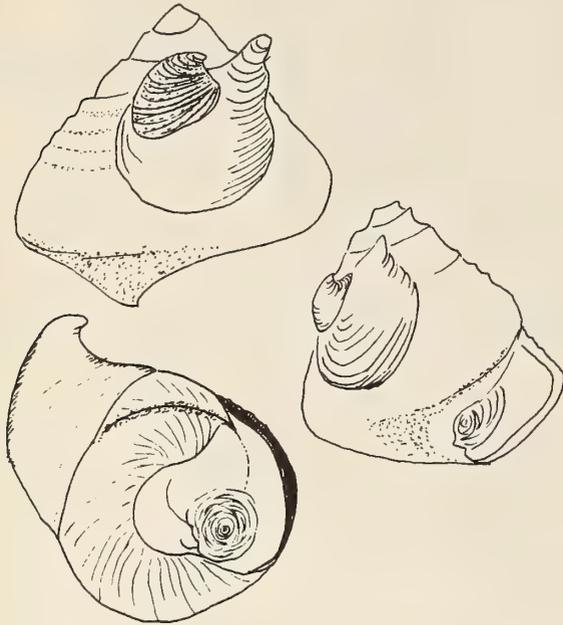


Figure 1: Orientation of *Crepidula adunca* on *Tegula funebralis*.

The egg cases themselves may be expelled immediately at the end of hatching, which takes approximately one half hour, or after several days. Not all egg capsules under a given female are necessarily at the same stage of development or hatch at the same time.

THE NEWLY HATCHED YOUNG

The average newly hatched *Crepidula adunca*, based on the measurement of six broods, is 1.19 mm long and 0.91 mm wide. The spat when hatched are very motile. They show no tendency to avoid either the mother or the host; however, many of the spat fall off the *Tegula funebralis* immediately. The number of spat leaving the host is increased by any current present; mucus still covers the spat, and they do not adhere well to any surface. Less than ten percent of a brood remain on the parental host even in still water, where the only motion is that resulting from the creeping of *T. funebralis*. The few young remaining on the host become quiescent sooner and remain so longer than those which fall off.

The young which fall off sink to the bottom. Mucus adhering to the young affects the rate of sinking, which ranges from about 1.1 to 2.6 cm/sec (average 1.4 cm/sec). Once off the host, the young are quite active. Their movement seems random; they are neither attracted to nor repelled by each other. There is a net movement upward and towards a light, if this is not too intense. These actions may even lead the spat to crawl out of the water, where they desiccate and die within 15 to 20 minutes on a sunny day. It is perhaps an advantage, therefore, for the newly hatched spat to be washed off the host *Tegula funebralis*, which is normally exposed during the tidal cycle. Sunlight alone has no effect on the newly hatched *Crepidula adunca* when they are immersed.

The spat are very active even in still water, and their random movements tend to disperse them. Simple dispersal experiments were carried out in eight finger bowls with newly hatched young. Ten juveniles were placed in the center of each bowl and their positions marked on a grid at five minute intervals. Average motility, based on these runs, is plotted in Figure 2. Maximum rate of locomotion measured over a short distance was about 0.2 mm/sec.

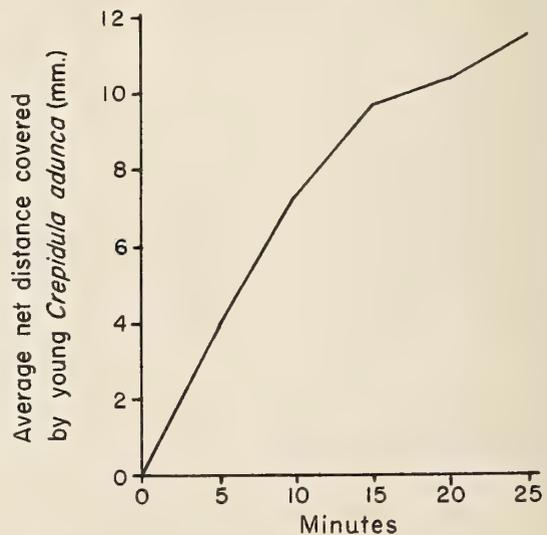


Figure 2: Average net distance covered by young *Crepidula adunca*.

A weak current of water stimulates the spat, which tend to orient upstream and move into the current. In stronger currents the spat clamp down and remain immobile unless torn loose by the current. The ability of spat to cling in currents of varying rates of flow is shown in Figure 3.

RESPONSES OF JUVENILE *Crepidula adunca*
TOWARD *Tegula funebris* AND ADULT
Crepidula adunca

Preliminary experiments indicated that adult female *Crepidula adunca*, removed from their hosts, usually attempted to climb back on, and that adult males are attracted by *Tegula funebris*, but even more strongly by female *C. adunca*. In contrast, the newly hatched spat do not appear to be strongly attracted either to *T. funebris* or to older *C. adunca*, male or female. The reactions of juveniles to parents and host were tested as follows.

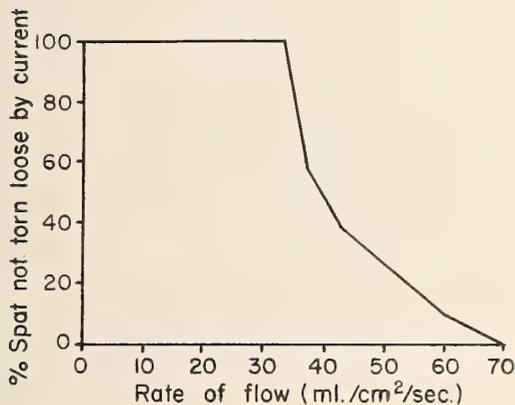


Figure 3: Ability of juvenile *Crepidula adunca* to cling to a glass surface in a current. Up to 34 ml/cm²/sec flow, random movement continued, with a slight net orientation into the current. Above this, the spat clamped down tightly.

Ten newly hatched young were placed in the center of each of four finger bowls. To each of three bowls was added, near the edge, one of the following: 2 living male *C. adunca*, an empty *T. funebris* shell, or a living female *C. adunca*. The fourth bowl served as a control. The positions of the young free in the bowls or on the various proffered substrates were recorded daily for a period of twelve days (Figure 4).

There is no evidence that the spat are attracted to *Tegula funebris* or *Crepidula adunca*. Instead, the young appear to move at random. However, when they come in contact with any one of these shells, they crawl upon it, and their motility thereafter is greatly decreased. The presence of the living animal is not a factor; as many settle on an empty *C. adunca* shell as on one that is occupied. In supplementary experiments fewer settled on

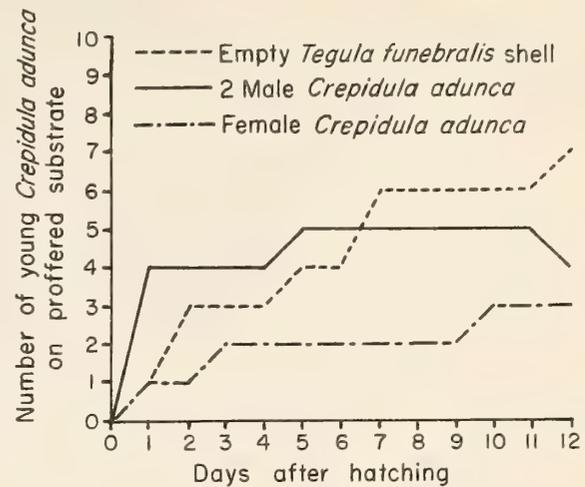


Figure 4: Settlement of spat on various substrates.

an occupied *T. funebris* shell than an empty one, presumably due to the comparatively rapid motion of the larger snail.

The attraction to *Tegula funebris* must increase as spat grow older, since the adult population lives on this host and shows a clear positive response to it. However, this investigator found no *Crepidula adunca* smaller than 3.8 mm in length, 2.8 mm in width and 2.0 mm in height, on a *T. funebris* in the field. Searches for spat or young adults on rocks, in shells and gravel, and on algae were unsuccessful.

Adult *Crepidula adunca* are filter-feeders. However, the ciliated food groove does not appear until after hatching, nor does the food pouch develop until after the young adult stage (MORITZ, 1939). Scraping motions with the radula in the young have been observed, which strongly suggests that the spat may obtain microscopic food by this means. The young might not be strongly attracted to *Tegula funebris* or to another, older *C. adunca* until their filter-feeding apparatus has developed.

SUMMARY

Crepidula adunca is a protandric marine prosobranch commonly found on the shells of *Tegula funebris*. Female *C. adunca* are oriented in a consistent manner on the whorls of the *T. funebris* shell. There is no free-swimming larval stage; the brooded young crawl or are pushed out from under the mother as juveniles similar in form to the adults. The newly hatched spat are very motile; the great majority drop off the host and sink. Weak water currents stimulate the spat; there is net orientation into current, against gravity, and toward moderate light.

Spat are only weakly attracted to either *T. funebris* or older *C. adunca*; this attraction is clearly present in older individuals.

LITERATURE CITED

CONKLIN, E. G.

1897. The embryology of *Crepidula*. Journ. Morph. 13: 1 - 226; pls. 1 - 9; 13 text figs.

MORITZ, CHARLES E.

1938. The anatomy of the gasteropod *Crepidula adunca* SOWERBY. Univ. Calif. Publ. Zool. 43: 83 - 92; 6 text figs.

1939. Organogenesis in the gasteropod *Crepidula adunca* SOWERBY. Univ. Calif. Publ. Zool. 43: 217 - 248; 22 text figs.

Studies on the Commensal Limpet *Acmaea asmi* in Relation to its Host, *Tegula funebris*

BY

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(11 Text figures; 2 Tables)

Acmaea asmi (MIDDENDORFF, 1849) is a stenotopic limpet which inhabits the rocky intertidal, and lives almost exclusively on *Tegula funebris* (A. ADAMS, 1854). By studying distribution in relationship to horizontal and vertical position in the intertidal and by considering distribution in relationship to food and substrate preferences, we hoped to establish a clearer understanding of the adult commensal relationship between *A. asmi* and *T. funebris*. The following work is a continuation and refinement of studies carried out by FREDERICK H. TEST in 1945, and RUTH RADFORD in 1959.

DISTRIBUTION

During April and May, 1963, distribution of *Acmaea asmi* was studied along Mussel Point on Monterey Bay, California. Every *A. asmi* noted along five transects by W. WARA & B. WRIGHT (1964, see Figures 1 - 5) was collected

with its host and both organisms were measured. Notation of horizontal and vertical position was made.

Since the five transects varied both in length and in slope, horizontal distribution in terms of absolute distance from shore is not particularly significant. However, in all five transects populations were concentrated in the middle areas, the regions affected neither by shore line wave action nor the wave battering of the outer intertidal.

Furthermore, observations at high tide (WARA & WRIGHT, 1964) revealed a qualitative difference in wave action between the transects and showed that the number of *Acmaea asmi* was generally inversely proportional to the wave battering received by the area. Qualitatively, Area B had very heavy wave action and no *A. asmi* were found; Area A received a heavy battering and the density of *A. asmi* was low. As the wave action decreased from

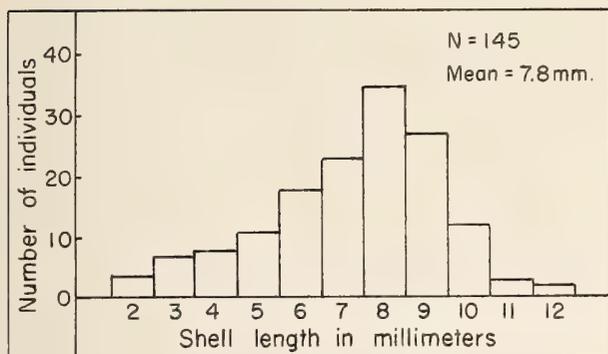


Figure 1: Size frequency of *Acmaea asmi* in the rocky intertidal.

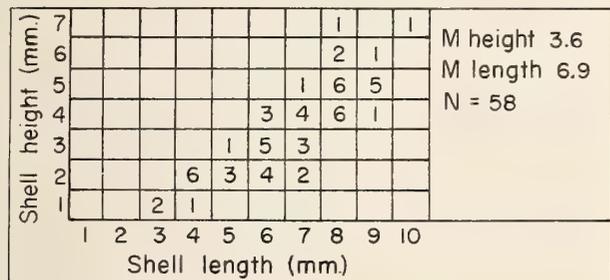


Figure 2: *Acmaea asmi* shell length in relation to position in the intertidal zone.

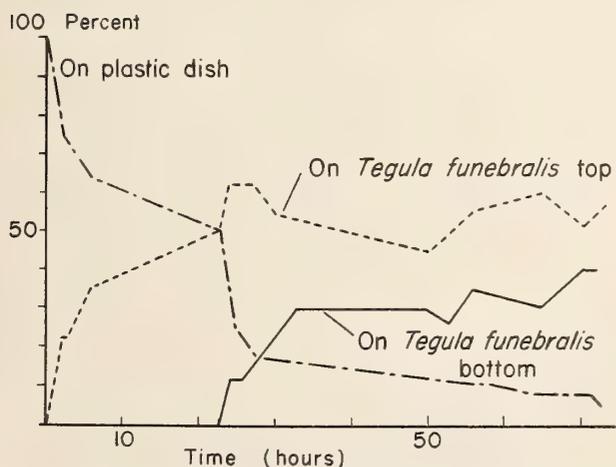


Figure 3: 40 *Acmaea asmi* placed in sea water at 15° C with shell top fragments of *Tegula funebris*. Later, fragments of shell bottoms were introduced.

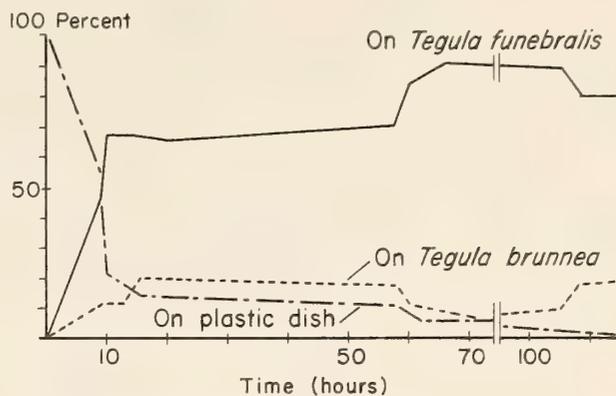


Figure 4: 35 *Acmaea asmi* in sea water at 15° C with living *Tegula funebris* and *T. brunnea*.

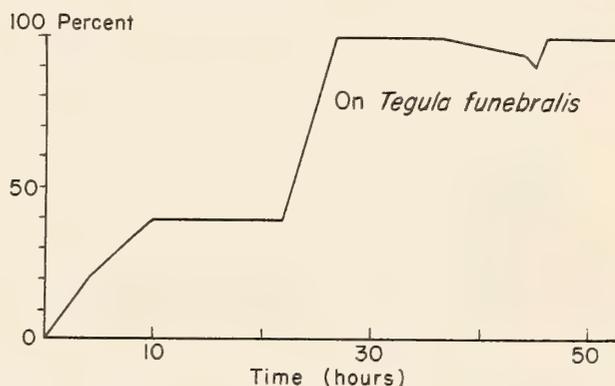


Figure 5: 20 *Acmaea asmi* in sea water of 15° C on *Tegula brunnea* shells either empty or inhabited by *Pagurus* spp., in plastic dishes, with living *Tegula funebris*.

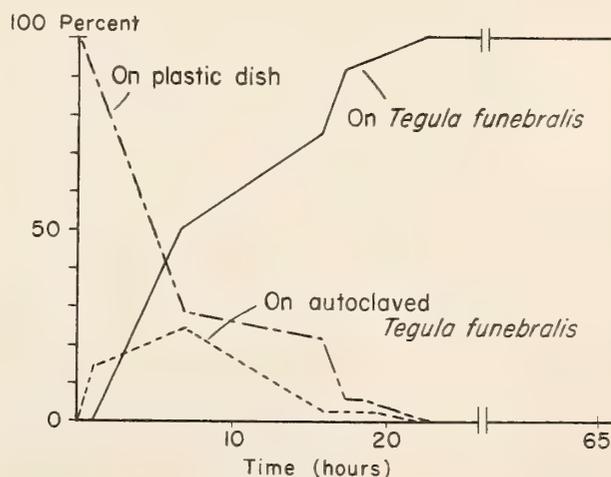


Figure 6: 36 *Acmaea asmi* with autoclaved *Tegula funebris* shells in sea water of 15° C. An hour later living *Tegula funebris* were introduced.

areas C to E, the density of *A. asmi* increased more or less proportionately.

Data concerning vertical distribution are shown in Table I; *Acmaea asmi* ranged from 0-6 feet above mean low water with greatest population density at 2-4 feet.

A size frequency histogram of *Acmaea asmi* appears in Figure 1. The anterior-posterior length of the shell taken at the margin of the aperture was measured. Shells under 2 mm in length were observed but could not be identified

Table 1

	Height in the intertidal		
	0-2 ft.	2-4 ft.	4-6 ft.
Range: no. <i>A. asmi</i> per sq. meter	0-8	0-15	0-2
Mean no. <i>A. asmi</i> per sq. meter	0.33	1.51	0.6
Range: % <i>T. fune-</i> <i>bralis</i> with <i>A. asmi</i> per sq. meter	0-2 %	0-20%	0-8%
Mean % <i>T. fune-</i> <i>bralis</i> with <i>A. asmi</i> per sq. meter	0.12%	0.35%	0.35%

Table 1: *Acmaea asmi* distribution in relation to height in the intertidal region.

with certainty, because *A. asmi* resembles other species of *Acmaea* at this size. Sixty shells were measured from base to apex in the middle of the shell; the results, plotted against shell length, appear in Figure 2.

There seemed to be no consistent relationship between *Acmaea asmi* shell size and either vertical or horizontal position. In all vertical positions in areas C through E, mean shell length varied between 7.1 and 7.5 mm and ranged from 4 to 10 mm. In area A, where wave action is greatest, no *A. asmi* measuring less than 8 mm were found, and mean size was 8.7 mm.

The distribution of *Acmaea asmi* on its host was considered next. Numerous *Tegula funebris* examined showed radulation of the lower part of the shell, while little or none occurred on the shell apex. In the field we noted that *A. asmi* inhabits the lower whorls of the *T. funebris* shell almost exclusively; only four were observed on the shell apex. F. H. TEST (1945) reported he had never seen them on the apex. *Acmaea asmi* measuring 2 mm or less long were generally located on the flattened base of the shell close to the aperture, a position better protected from dessication, direct sunlight, predation, and wind and wave action.

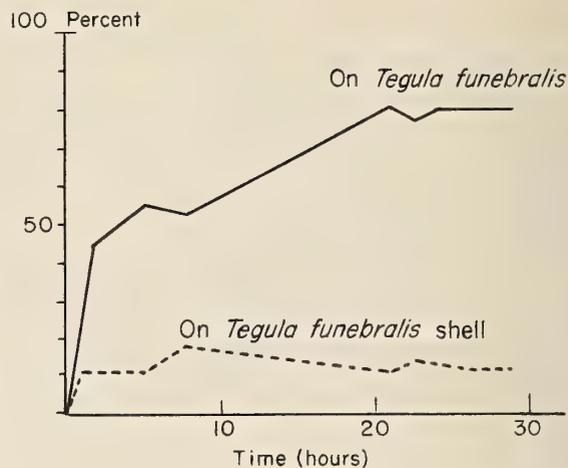


Figure 7: 36 *Acmaea asmi* in sea water of 15° C with (living) *Tegula funebris* and *T. funebris* shells from which the animal was removed; the aperture was plugged with plasticene and plaster of paris.

The algal growth on the *Tegula funebris* shell is relatively uniform; the main organism is a microscopic filamentous green alga tentatively identified as *Gongrosira incrustans* (DE WILDEMANN) KTZG. (see SCHMIDLE, 1901). An apparently identical alga encrusts the shells of *Acanthina spirata* and *Tegula brunnea*. We observed *Acmaea asmi* feeding on the shells of these animals. Only twice was *A. asmi* seen in the field on *T. funebris* shells, inhabited by *Pagurus* spp. The pattern that results from radulation is fan-shaped and is produced by the animal feeding from side to side and in a forward direction.

In successive tests, *Acmaea asmi* was placed in varying situations (see Figures 3,4,5,6, and 7). Shells with intact

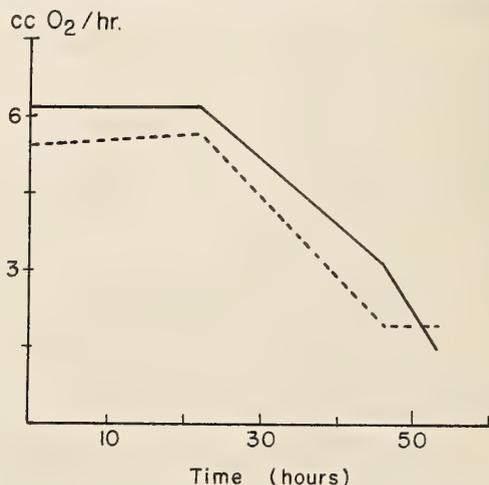


Figure 8: Net O₂ produced by algae after removal of *Acmaea asmi*.

algae but deprived of snails hold a very slight attraction for *A. asmi* in the presence of living *Tegula funebris* or *T. brunnea*. In an aquarium containing both species of snails, as many as 20% of the *A. asmi* population were found feeding on *T. brunnea*, contrary to the findings of RADFORD (1959). *Acmaea asmi* is found only rarely on *T. brunnea* in the field. However, *T. brunnea* is found only in the lower intertidal and is exposed to heavier wave action.

From these experiments we conclude that *Acmaea asmi* is attracted to living *Tegula funebris* or *Tegula brunnea* due, not only to the source of food on the shell but also to some property of the living snails, possibly a secreted or excreted substance or substances.

Attempts were made to determine the feeding rate and food preferences of *Acmaea asmi* and the rate of recovery of the algal crop on *Tegula funebris*. Respiration and photosynthesis as measured by the Winkler method were used as an index of grazing.

Tegula funebris were removed from their shells with a dissecting needle. The shell was filled with plaster of Paris coated with paraffin to prevent exchange of gas of any remaining tissues. The shells were placed in a 150 cc jar, in a water bath at 14.5-16° C, and exposed to an incandescent light source kept at constant intensity of 250 foot-candles.

Acmaea asmi starved for 52 hours to insure maximum feeding were placed on the shells. A ratio of one *A. asmi* to one *Tegula funebris* shell was used since this is the normal condition in the field.

After the animals had grazed on the shells, the shells were placed for three hours in the dark. Consumption of oxygen decreased, indicating less algae present, presumably due to removal by *Acmaea asmi*. These results indicate that one group of three starved *A. asmi* may eat from

2.7 to 7.0% of the algae on three *Tegula funebris* shells per hour. (see Table II).

Six of the above 12 shells (see Figure 8) were exposed to light and algal recovery was measured. The results indicated a further decrease of photosynthesis after *Acmaea asmi* had been removed.

Finally, we attempted to determine rate of transfer by *Acmaea asmi* under laboratory conditions. Disagreement exists in the literature on the frequency with which *A. asmi* changes hosts. F. H. TEST (1945) noted that *A. asmi* generally spend less than 24 hours on one host. RUTH RADFORD (1959) observed several *A. asmi* remaining over a week on one host.

Experimental results favored TEST's statement. In Group A, 45 *Acmaea asmi* on 35 *Tegula funebris* were marked with nail polish in a dot-dash code. They were placed in a 12 inch diameter bowl, provided with running

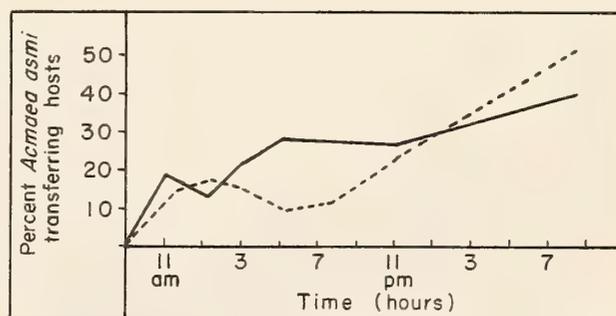


Figure 9: Transfer rate of *Acmaea asmi* from one *Tegula funebris* to another, plotted in two hour periods in normal diurnal change (solid line) and in constant darkness (dashed line).

Table 2

Oxygen consumption and evolution by *Acmaea asmi* and algae. Values for groups of 3 *Tegula funebris* shells, with and without 3 *Acmaea asmi*.

<i>A. asmi</i> non-feeding O ₂ intake	Shells in dark	Shells in light	Shells with <i>A. asmi</i> in light	Shells in dark w/o <i>A. asmi</i>	% algae eaten/hr
-0.102cc	-0.0375	+0.084	+0.0165	-0.0345	2.7
O ₂ /g/hr	-0.042	+0.114	+0.027	-0.036	4.7
	-0.0465	+0.106	+0.009	-0.0405	4.3
	-0.036	+0.085	+0.010	-0.0285	7.0

Table 2: Oxygen consumption and evolution of *Acmaea asmi* and algae to obtain % of algae eaten and feeding rate of *Acmaea asmi* (cc/l/hr). Figures represent 4 groups, each with 3 *Acmaea asmi* on 3 *Tegula funebris* shells.

sea-water and subjected to normal light fluctuations. After a twelve hour adjustment period the *A. asmi* were followed individually and their positions recorded every two hours. A second group with 45 *A. asmi* on 31 *T. funebris*, similarly marked, was run in the dark. The results are shown in Figure 9. Although conditions were crowded, *T. funebris* in the field is closely clustered.

The *Acmaea asmi* were separated arbitrarily into three size classes and rate of transfer within each class was plotted (see Figure 10). The small and the large transferred less frequently than the medium sized animals.

Figure 11 illustrates the results of three transfer experiments, all run from 6:00 PM to 8:00 AM. Experiments B, C, and D were run in a tank with circulating water, one *Acmaea asmi* per *Tegula funebris* in the experimental group and an overall ratio of approximately one *A. asmi* to two *T. funebris*. These tanks were not checked hourly, and it was only noted whether the animals were on their original host after 14 hours.

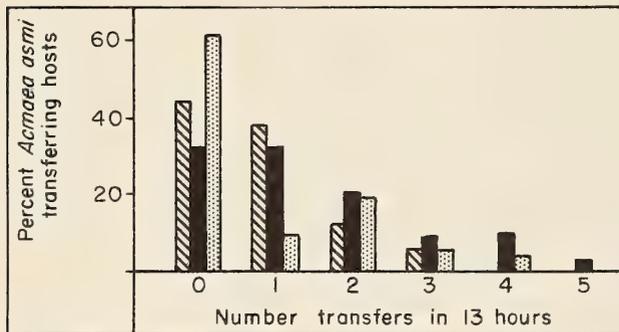


Figure 10: Percent of *Acmaea asmi* (in each size group) transferring in 13 hours in relation to shell length. Dashed line indicates small *Acmaea asmi* (3 - 6 mm); solid line indicates medium size shells (7 - 8 mm); dotted line indicates large size shells (9 - 11 mm).

SUMMARY

Acmaea asmi is distributed in the rocky intertidal at Mussel Point between the vertical height of 0-6 feet (with

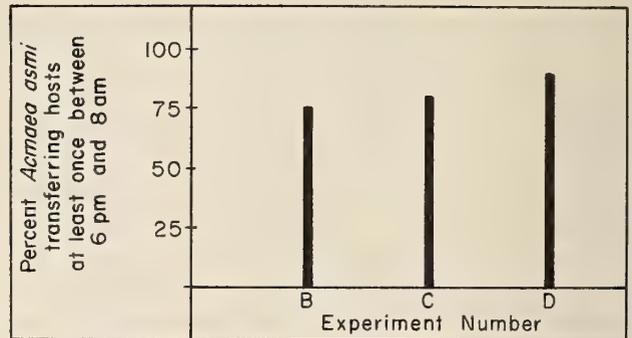


Figure 11: Percent of *Acmaea asmi* transferring from one host to another at least once in the period between 6 p.m. and 8 a.m.

maximum density from 2-4 feet and from 0-52 meters from the higher high water mark. The animal lives on the shell of *Tegula funebris* and seems to be attracted not only by microscopic algae as a food source, but also by some property of living *T. funebris*. Experiments were carried out to determine preference of *A. asmi* for various shell substrates, in addition to investigating the transfer rate. The respiration of the algal crop of *T. funebris* and of *A. asmi* was measured to find an index of feeding rate.

LITERATURE CITED

- RADFORD, RUTH
1959. A Study on *Acmaea asmi*. unpubl. Stanford Univ. honors paper.
- SCHMIDDE, W.
1901. Über drei Algengenera. Ber. d. deutsch. bot. Ges. 19: 10 - 15
- TEST, F. H.
1945. Substrate and movements of the marine gastropod *Acmaea asmi*. Am. Midland Nat. 33: 791 - 793
- WARA, WILLIAM M., & BENJAMIN B. WRIGHT
1964. The distribution and movement of *Tegula funebris* in the intertidal region, Monterey Bay, California (Mollusca: Gastropoda). The Veliger 6; Supplement: 30 - 37; 9 text figs.



Distribution and Utilization of Gastropod Shells by the Hermit Crabs

Pagurus samuelis, *Pagurus granosimanus*, and *Pagurus hirsutiusculus* at Pacific Grove, California

BY

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(6 Text figures; 1 Table)

SEVERAL SPECIES OF *Pagurus* occur in the rocky intertidal zone at Pacific Grove, California. The majority of the larger hermit crabs are found in shells of *Tegula funebris* (A. ADAMS, 1854), this being the only snail in the area which is both large enough and abundant enough to supply the larger pagurids with homes. It therefore appears that the *T. funebris* population might be one of the factors limiting the hermit crab population. In inquiring into the relationship between snail and crab I tried to determine the following: (1) What species of *Pagurus* are present, how are these distributed, what factors influence this distribution? (2) What shells are used by the different species and how does this correlate with the size and distribution of the *T. funebris* population?

The hermit crabs collected intertidally at the Hopkins Marine Station, Pacific Grove were identified using the descriptions in SCHMITT (1921). The following species were found: *Pagurus samuelis* (STIMPSON, 1857), *P. granosimanus* (STIMPSON, 1859), and *P. hirsutiusculus* (DANA, 1857). Of the 1873 hermit crabs collected, 50% were *P. samuelis*, 40% *P. hirsutiusculus*, and only 10% were *P. granosimanus*. Samples included both young and adult specimens from each species. The young were identified by using a series of animals of graded size for each species, and noting color patterns on both antennae and body. Identifying characteristics for the younger hermit crabs are as follows: *P. samuelis* - red antennae and either white or blue bands on the walking legs; *P. granosimanus* - like adult in color; *P. hirsutiusculus* - dark olive-green antennae striped with white, ambulatory legs striped with white (never with blue), merus on both large and small

cheliped very dark brown contrasting with the lighter brown of the rest of the leg. In general, both *P. samuelis* and *P. granosimanus* are relatively large, reaching an overall extended length of 6 and 7 cm, respectively, whereas *P. hirsutiusculus* is a smaller species, not frequently exceeding 4 cm in length.

To study the distribution problem, transects were taken running seaward from the shore in three different areas:

Area A. Rocky exposed coast, rich in algal growth.

Area B. Large granite outcrop with rough surf and surge, barnacles and mussels predominate.

Area C. Semi-protected rocky area, rich in algal growth. (see WARA, W., & B. WRIGHT, 1964, for detailed descriptions and profiles of these areas.)

In each transect, samples were collected at two meter intervals, starting at the shore. The first 100 hermit crabs seen at each site were taken, or as many as could be found if 100 were not present. Collecting was not done at low tide, since at that time the hermit crabs are most difficult to find, being hidden under rocks and in crevices. The hours immediately preceding or following a low tide are better, when water covers most areas yet is shallow enough to allow collecting. Results are shown in Figures 1 and 2.

Of the three species, *Pagurus samuelis* was the only one found at the highest levels in the intertidal, while both *P. granosimanus* and *P. hirsutiusculus* occupied lower regions, areas usually covered by water. In area C, the *P. samuelis* represent the only hermit crabs found both close to shore and at the outer part of the transect because of a large rock outcropping at the outer margin.

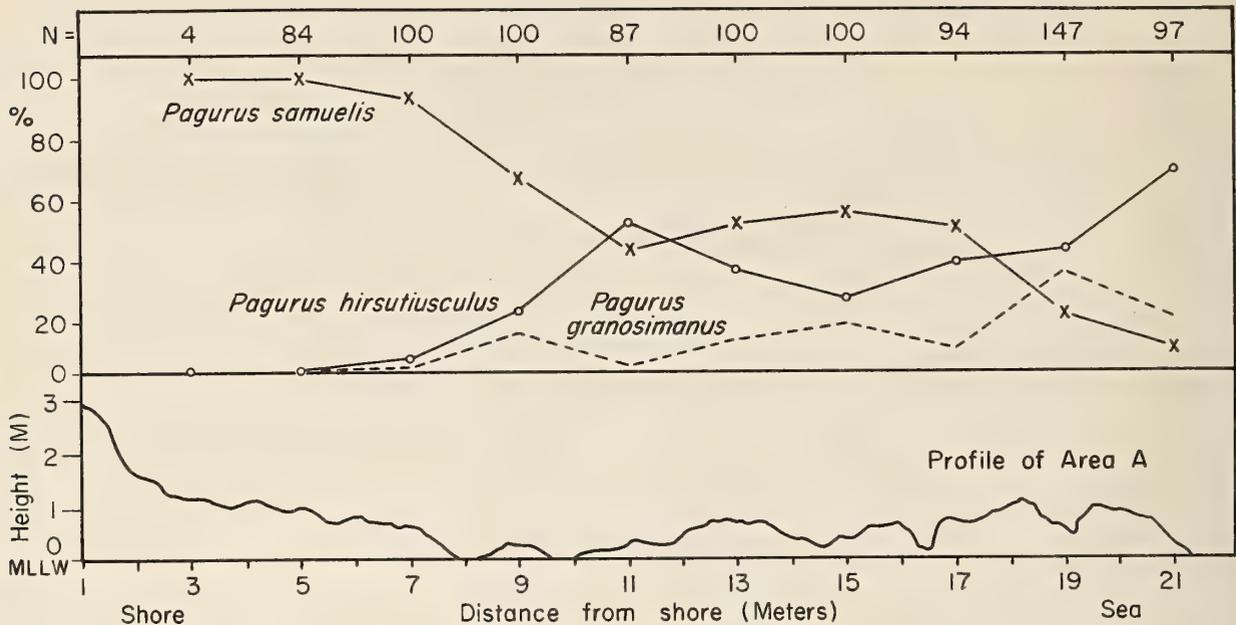


Figure 1: Relative Abundance of Three *Pagurus* Species in Area A

Collecting was done on two consecutive days, May 8 and 9, 1963, the first sunny and the second overcast, from 6:15 a. m. to 10:00 a. m. and from 7:00 a. m. to 10:30 a. m. respectively. This was from the low tide until it became too rough to collect. No sample size.

The *P. hirsutiusculus* and the *P. granosimanus* are again concentrated in the deeper lying regions, which this time are in the center of the transect. As shown by the sample size (N) there were far fewer hermit crabs at the higher sites along the transect, all that were found being taken, whereas in the lower areas there was no difficulty in finding 100 for the sample.

What can be seen intuitively in these first two graphs — that the three species are probably distributed differentially with respect to height — is clearly illustrated in Figure 3, in which the data from areas A and C are combined and species distribution is plotted against vertical position in the intertidal. Above 1.2 m only *Pagurus samuelis* is found, while this species represents over 50% of all the hermit crabs found at 0.6 m. With increasing depth the proportion of *P. samuelis* declines while that of both *P. granosimanus* and *P. hirsutiusculus* increases.

The data from area B (not shown) confirm these findings, but in this transect *Pagurus granosimanus* was entirely absent; however, *P. hirsutiusculus* was found at the lowest extremity of this steep transect and in approximately the same numbers as in the other two areas.

Pagurus samuelis was found up to a height of about 4 feet but in far fewer numbers, sample sizes at each collecting station averaging 10.1 for this transect as a whole. Of the 97 *Pagurus* collected, only 44.3% were *P. samuelis*, 55.7% were *P. hirsutiusculus*.

Since the differences in distribution might reflect differences in ability to withstand the effects of exposure, an experiment was conducted to see if there was any difference in the survival between the three species when exposed out of water in daylight. The bottoms of three plastic dishpans were covered with dry sand. Each pan received 30 hermit crabs of one species. The *Pagurus samuelis* and *P. granosimanus* used were all large adult specimens. The *P. hirsutiusculus*, while adults, were necessarily smaller. The data are shown in Figure 4. From this test it appears that *P. hirsutiusculus* and *P. granosimanus* are less able to survive exposure than *P. samuelis*; the smaller individuals died sooner on exposure out of water than the larger ones. Although more experiments would be desirable, these results suggest that differences in the ability to withstand exposure help to explain the differences in distribution of the three species.

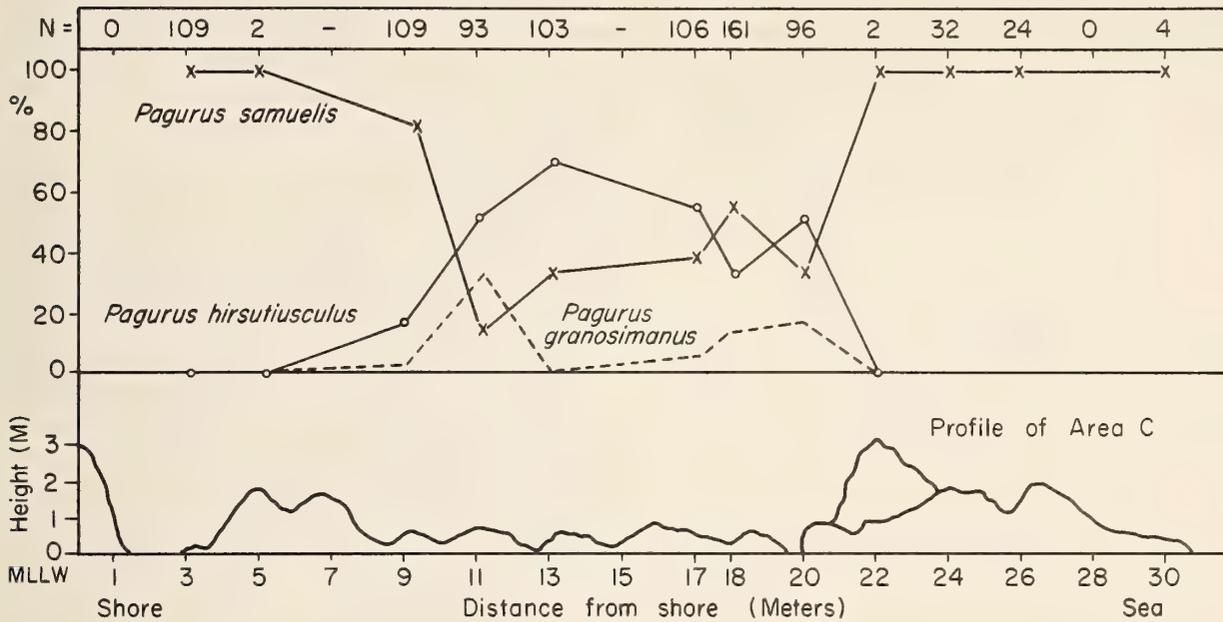


Figure 2:

Collecting was done on two consecutive days, May 16 and 17, 1963, both cloudy, from 9:00 a. m. to 12:10 p. m. and from 9:30 a. m. to 12:30 p. m., respectively. This was from a period just preceding low tide up until low tide.

N = sample size; (—) = no sample taken

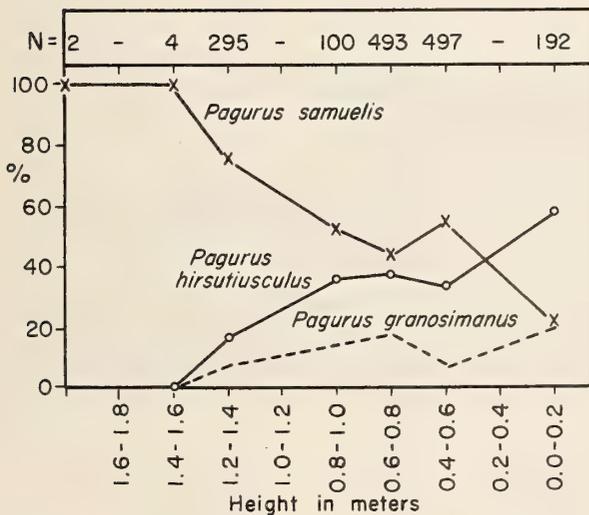


Figure 3: Relative Abundance of *Pagurus* Species at Different Elevations, Areas A and C.

N = sample size; (—) = no sample taken

Of the commonest pagurid, *Pagurus samuelis*, the smaller individuals generally live higher up in the intertidal, the largest members only deeper down. It was

noted previously that the smaller *P. samuelis* seemed less able to survive exposure. That the smaller specimens seem also to live higher in the intertidal is not necessarily a contradiction because the small hermit crabs (1) are not found exposed, but rather stay under rocks, etc., and (2) are more readily able to find such protection than the larger *Pagurus* which stay in areas where they are usually submerged.

In the field it was noted that the majority of the larger hermit crabs occupied *Tegula funebris* shells. Figure 5 compares the use made of various shells by the three species. It would appear that both *Pagurus granosimanus* and *P. samuelis* are extremely dependent on *T. funebris* for homes, since 89% and 76%, respectively, are found in these shells. REESE (1962) reports that larger *P. granosimanus* in southern California were usually found in large *Tegula* shells, and suggests this was because, of the shells available, only those of *Tegula* were large enough to accommodate the larger crabs. Of all the *P. hirsutiussculus*, however, only 10.9% occupy *T. funebris* shells. This latter species is much more dependent on a number of smaller snails including *Littorina spp.*, *Calliostoma spp.*, *Epitonium spp.*, *Mitrella spp.*, *Homalopoma spp.*, etc. In area B, however, the situation is interestingly different.

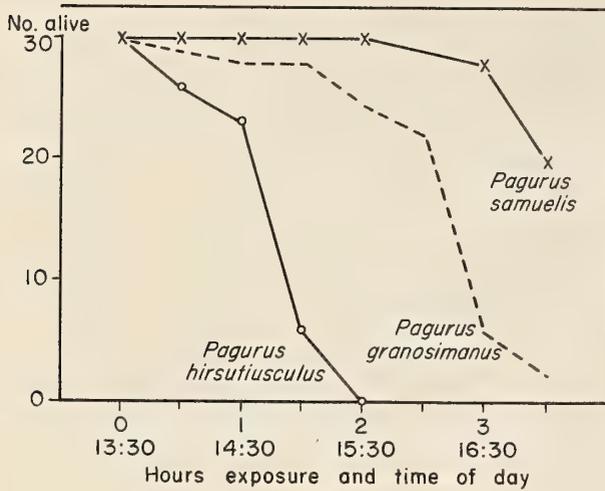


Figure 4: Survival of *Pagurus* Species on Exposure to Air and Sunlight

Of the *P. hirsutiussculus* found, none were in *T. funebris* shells, while much greater use was made of *Littorina* and *Thais* shells than in the other two areas.

Figure 6 shows the relative utilization, by the three species of hermit crabs, of various shells which are common in the locality. For instance, of all the *Tegula funebris* shells occupied by hermit crabs which were

collected from the three transects, 73.9% were inhabited by *Pagurus samuelis*, 17.5% by *P. granosimanus*, and 8.5% by *P. hirsutiussculus*. It is quite obvious that most of the *T. funebris* shells are used by the two larger species of hermit crabs while the smaller shells ("other") are 94.6% occupied by *P. hirsutiussculus*.

The shells utilized by different sizes of hermit crabs vary also in size. Although the hermit crabs were not measured directly, they were divided into three classes on the basis of the sizes of the shells occupied. Shell sizes in different species of snails were compared by taking the maximum basal diameter of the shells. This gives only an approximate measurement of the size of the shell and of the crabs within, because (1) any given shell can be occupied by hermit crabs of a certain range of sizes, and (2) shell sizes, as indicated by basal diameter measurements, allow only a rough size comparison when applied to shells of different species of snails. Nevertheless, the shell measurements indicate the size of the pagurid inside well enough to allow us to separate the crabs into large, medium, and small size groups. Data on species of snail shells occupied by pagurids of different size ranges are shown in Table 1. Obviously, the larger the hermit crabs grow, the more dependent they become on the *Tegula funebris* population for homes.

This raises the interesting question: do *Pagurus granosimanus* and *P. samuelis* achieve sexual maturity before they reach a size too large to fit into any shells but those

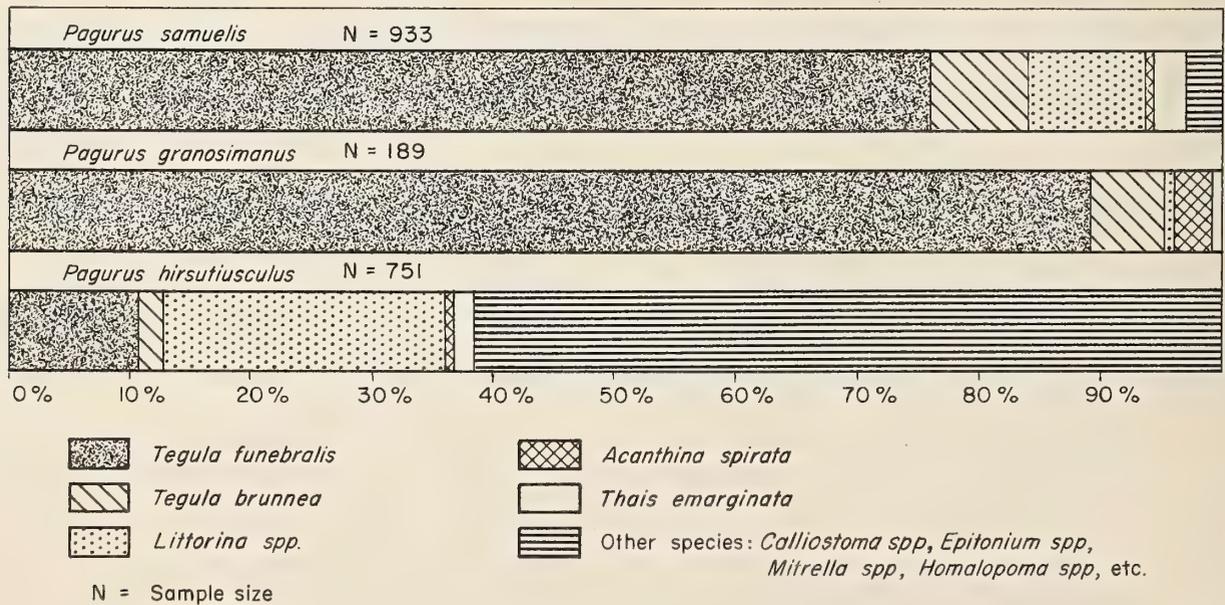


Figure 5: Comparison of Shells Occupied by Three Species of *Pagurus*

of *Tegula funebris*, locally? Information could not be obtained on *P. granosimanus*, but for *P. samuelis* specimens as small as 1.1 cm total extended length have been collected bearing eggs. Animals this size are not heavily dependent on *T. funebris* (see Table 1) since they can easily fit into shells less than 1.0 cm in greatest basal diameter. Since sexual maturity is, in *P. samuelis*, attained relatively early, this species (like *P. hirsutiusculus*) is probably able to survive and reproduce in areas where shells suitable to house larger individuals are not available. However, the number of eggs borne by the smaller sizes of *P. samuelis* is very much less than the number produced by a fully grown specimen. Therefore, reproductive potential in the absence of large (e. g. *T. funebris*) shells would be lower.

Area B, as cited already, differed from the other two transects. Insufficient food could explain its small population. Another possible factor, however, might be the lack of available shells for use as homes. The *Tegula funebris* population in this area is relatively small (see WARA, W., & B. WRIGHT, 1964). The number of *Pagurus hirsutiusculus* is not noticeably less — and this is the one species of the three that does not rely heavily on *T. funebris* shells for homes. On the other hand, there are relatively few *P. samuelis* and no *P. granosimanus* in this

area. The *P. samuelis* here make much greater use of *Thais* and *Littorina* shells — these snails being found in much greater abundance here than in the other areas. Perhaps, then, the two larger species of *Pagurus* are limited by the lack of suitable shells even though a few *P. samuelis* were found here. It is possible that the reason no *P. granosimanus* were found in this area was that they do not reach sexual maturity until they have attained a much larger size; however, this was not determined.

Table 1

	Greatest Basal Shell Diameter		
	< 1.0 cm	1.0 to 2.0 cm	2.0 to 3.0 cm
<i>Tegula funebris</i>	N = 107 % = 15.6	N = 488 % = 83.7	N = 289 % = 94.4
<i>Tegula brunnea</i>	N = 44 % = 7.5	N = 18 % = 3.1	N = 16 % = 5.3
<i>Thais spp.</i>	N = 10 % = 1.7	N = 34 % = 5.3	N = 1 % = 0.3
<i>Acanthina spp.</i>	N = 4 % = 0.7	N = 12 % = 2.1	N = 0 % = 0
<i>Littorina spp.</i>	N = 202 % = 29	N = 19 % = 2.6	N = 0 % = 0
Other species	N = 330 % = 47.4	N = 15 % = 2.5	N = 0 % = 0

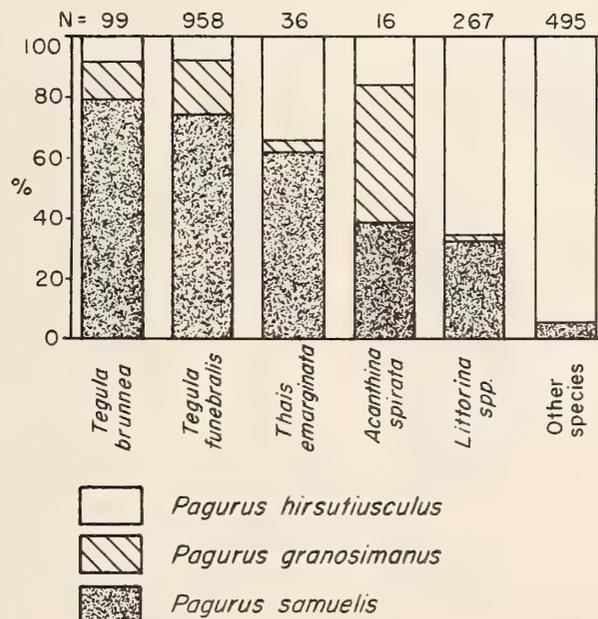


Figure 6: Utilization of Shells by *Pagurus* in Areas A, B, and C.

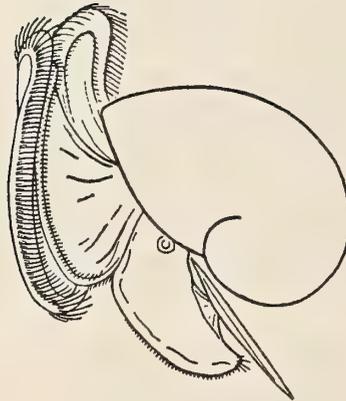
SUMMARY

1. Of the three species of hermit crabs found in the intertidal zone at Hopkins Marine Station, Pacific Grove, *Pagurus samuelis* is the only one encountered at positions higher than about 1.2 m, *P. hirsutiusculus* and *P. granosimanus* being found lower.
2. Of the three species, *Pagurus samuelis* appears to be able to survive exposure out of water better than the other two. Adults of *P. hirsutiusculus* are least able to withstand exposure to air in sunlight.
3. The three species make use of various shells to different degrees. Eighty-nine % of the *Pagurus granosimanus* and 75.9% of the *P. samuelis* collected occupied *Tegula funebris* shells, whereas, the smaller *P. hirsutiusculus* tended to occupy shells of smaller snails such as *Epitonium*, *Mitrella*, *Homalopoma*, etc., to a greater degree.
4. The bigger pagurid individuals are largely dependent on *Tegula funebris* for homes whereas the smaller sized hermit crabs are not, and occupy a variety of small shells.

5. Both *Pagurus samuelis* and *P. hirsutiusculus* attain sexual maturity at a relatively small size and thus are not completely dependent on *Tegula funebris* for the survival and reproduction of the species. However, when larger shells are not available the reproduction potential in *P. samuelis* may be greatly reduced since the smaller individuals produce far fewer eggs than the larger ones.

LITERATURE CITED

- REESE, ERNST S.
1962. Shell selection behavior of hermit crabs. *Animal Behaviour* 10: 347 - 360
- SCHMITT, WALDO L.
1921. Marine decapods of California. Univ. Calif. Publ. Zool. 23: 1 - 470; pls. 1 - 50; 165 text figs.
- WARA, WILLIAM M., & BENJAMIN B. WRIGHT
1964. The distribution and movement of *Tegula funebris* in the intertidal region, Monterey Bay, California (Mollusca: Gastropoda). *The Veliger* 6; Supplement: 30 - 37; 9 text figs.



Studies on Mollusk Populations

VI. -- *Tegula funebris* (A. ADAMS, 1855)

(Mollusca : Gastropoda)

BY

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(5 Text figures)

ON pages 316 and 317 of the Proceedings of the Zoological Society of London for the year 1854 (published on May 8, 1855) A. ADAMS described our common intertidal black turban as follows:

25. *CHLOROSTOMA FUNEBRALE*, A. Adams. *C. testa turbinata, imperforata, nigra, glabra, longitudinaliter oblique striata, ad suturas crenulata, anfractibus convexiusculis, ultimo rotundato, basi planiusculo, regione umbilicali valde impressa, callo albo oblecta; columella superne sinuata, antice bituberculata, tuberculo supremo prominente; labro nigro marginato.* *Hab.* California. (Mus. Cuming.)

This species is somewhat like *C. moestum*, Jonas, but the spiral callus surrounding the umbilicus is not prominent as in that species.

It is to be stressed that he clearly stated it to be imperforate. CARPENTER (1864) distinguished a variety which he named *subapertum* (pp. 627 and 652):

21. *Chlorostoma funebre* (et var. *subapertum*. One sp.).

277 b. *Chlorostoma funebre*, var. *subapertum*, with umbilical pit.

This variety, apparently based on a single shell, may be assumed to be from the "Vancouver district," specifically from "Neeah Bay, W. T." (CARPENTER, *l. c.*, pp. 626, 627). What was then the Washington Territory is now the State of Washington. From CARPENTER's account, however, it is not entirely clear where exactly the variant shell came from since it was contained in one of many boxes of shells received from the ardent collector, Swan, who, moreover, "trained the native children to pick up shore-shells in large quantities."

No illustrations were available for the typical species or for the variant until DALL in WILLIAMSON (1892) gave the first figure of a specimen which is presumed to be the type of CARPENTER's variety (see Figure 1). As the description by CARPENTER (*l. c.*, p. 652) is inadequate for

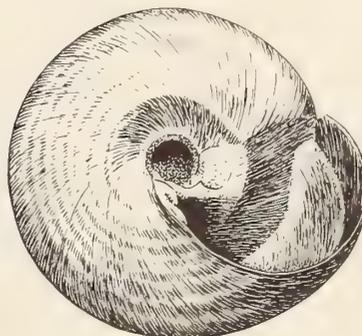


Figure 1: Copy of figure 6, plate 21, Proceedings United States National Museum, volume 15: "6. *Chlorostoma funebre* A. Adams, variety *subapertum* Cpr., basal view of type specimen showing umbilical pit; 30 millimeters, 123496"

a decision as to what constituted a pit in his view, we must rely on DALL's figure to be indeed the type figure; if we assume this to be correct, then an umbilical pit may be stated to be a shallow but distinct depression in the umbilical area.

As indicated previously (STOHLER, 1950), the presence or absence of an umbilical opening, pit or depression may vary greatly in any given population of certain species of *Tegula*. Similar results were obtained in a study of populations of *Tegula rugosa* (A. ADAMS, 1853) (STOHLER, 1963).

Table 1

Relative Frequency of Deep Umbilical Pits in Populations of *Tegula funebris* from the Eastern Pacific

	flat umbilical area	shallow depression	deep umbilical pit	total in lot		flat umbilical area	shallow depression	deep umbilical pit	total in lot
Baja California (Mexico)					Santa Cruz County				
Punta Banda	6	5	1	12	Santa Cruz	1	3	—	4
La Mision	—	2	1	3	Scott Creek	2	2	—	4
Rio Guadalupe	4	6	1	11	San Mateo County				
Punta Mesquite	7	5	—	12	Pigeon Point	1	5	—	6
Punta Piedra	12	3	1	16	Pillar Point	1	—	—	1
Rosarito Beach	2	11	—	13	Frenchman's Reef	4	5	—	9
California					Moss Beach				
San Diego County					Marin County				
Point Loma	10	18	1	29	Duxbury Reef	6	1	1	8
Flood Control Channel	2	9	3	14	Drakes Estero	2	3	—	5
La Jolla	23	19	1	43	Tomales Point	2	—	—	2
Orange County					Sonoma County				
Dana Point	3	—	—	3	Bodega	4	7	—	11
Los Angeles County					Carment by the Sea				
Point Fermin	—	2	—	2	Shell Beach	—	3	—	3
White's Point	1	1	—	2	Russian Gulch I	2	—	—	2
Ventura County					Salt Point				
San Nicolas Island	—	1	—	1	Horseshoe Point	9	2	—	11
Rincon Beach	2	3	1	6	Stewarts Point	1	6	—	7
Santa Barbara County					Del Mar Point				
Santa Rosa Island	2	1	—	3		10	6	—	16
San Miguel Island	1	5	1	7	Mendocino County				
Gaviota	9	6	—	15	Havens Neck	2	7	1	10
Government Point	2	8	—	10	Arena Cove	7	17	2	26
San Luis Obispo County					Elk				
Morro Bay	1	—	—	1	Fort Bragg	2	3	—	5
Cayucos	6	4	—	10	Hardy	4	7	—	11
Moonstone Beach	4	2	—	6	Humboldt County				
San Simeon	9	14	—	23	S. of Cape Mendocino	5	9	—	14
Monterey County					Del Norte County				
Soberanes Point	—	6	—	6	1 mi S. of Oregon Border	—	8	—	8
Yankee Point	3	3	—	6	at Oregon Border	2	1	—	3
Point Lobos	4	4	—	8	Subtotal:				
Mission Point	4	2	—	6		199	249	17	465
Spanish Bay	6	—	—	6	Point Buchon	41	5	2	48
Monterey Harbor	2	1	—	3	Cañada Tecelate	45	34	4	83
					Total:				
						285	288	23	596

In the collection of the Department of Zoology of the University of California in Berkeley there is a number of small lots of *Tegula funebris* from the shore of the Eastern Pacific extending from Lower California to the northern border of California. A total of 596 shells was examined for the presence or absence of an umbilical pit. This examination revealed that *T. funebris* is indeed imperforate exactly as ADAMS stated, for not a single specimen in the 55 lots studied had an open umbilicus. However, it was also noted that a deep umbilical pit could be observed in many lots regardless of the place of origin (see Table 1); this was true for 13 of the 55 lots examined; a shallower pit was seen in 47 of the 55 lots, all of the previously mentioned 13 lots also containing such specimens. On the other hand, only 7 of these lots showed a complete absence of specimens with an entirely flat umbilical area.

It is my impression that had larger samples been taken in all localities the three types of umbilical areas (i. e. deep pit, shallow pit, and smooth area) would have been found to be more evenly distributed. Unfortunately, at the time these collections were made the problem of the umbilical area was not considered and usually only very small samples were retained as indicators of the presence of *Tegula funebris* in a particular locality. Through the generous cooperation of Mr. Glen Bickford from the California Department of Fish and Game I have been able to examine two larger lots, one from the mainland shore in San Luis Obispo County and one from Santa Rosa Island. These two lots I considered large enough for taking some measurements (see Tables 2 and 3). Measure-

Table 2

Population of *Tegula funebris* from about $\frac{1}{2}$ mile North of Point Buchon, San Luis Obispo County
(Measurements in millimeters)

		flat	shallow	deep
largest	height	31.4	26.5	25.9
	width	31.7	25.7	27.4
smallest	height	4.5	12.9	21.5
	width	6.1	15.4	23.5

ments of height in *T. funebris* cannot be considered significant, generally speaking, because of the varying degrees of corrosion. More reliance may be put on the largest diameter of the shell.

Scanning Tables 2 and 3 one must gain the impression that a deep umbilical pit is limited to large (that is, older) shells. But studying the smaller lots in the collection this impression is dissipated. The smallest specimen in the

Table 3

Population of *Tegula funebris* from West of Cañada Tecelate, Santa Rosa Island, Santa Barbara County
(Measurements in millimeters)

		flat	shallow	deep
largest	height	35.5	36.1	41.2
	width	31.4	31.0	30.7
smallest	height	11.2	11.0	17.3
	width	11.8	13.4	20.8

collection, having a deep umbilical pit, is from Rio Guadalupe, Baja California, Mexico, and measures 17.0 mm in diameter. It is perhaps worth noting that the proportion of shells with a deep umbilical pit to the total population is fairly constant, i. e. 4%, while "flat" and "shallow" vary from approximately 85:10 (at Point Buchon) to 52:42 (at Cañada Tecelate). The percentage of shells with the deep pit seems to remain fairly constant in all populations, that is if we may make this deduction based on the two larger samples just discussed, either separately or together, or basing the assumption on the total figures of all samples studied.

Two other observations were made during this particular study. The first one is that the sculpture of the whorls is fairly constant throughout the range of distribution of the species; the "*aureotincta*" sculpture, as discussed in connection with *Tegula brunnea* (PHILIPPI, 1848) (STOHLER, 1958) and *T. rugosa* (STOHLER, 1963) has not been seen in any specimen; not even the faintest indication of such a sculpture has been noticed, although I paid special attention to this feature of the shell.



Figure 2: *Tegula funebris* (A. ADAMS, 1855).
Duxbury Point, Marin County, California. Oct. 30, 1947.
Lateral aspect. ex Coll. Dept. Zool., Univ. Calif., Berkeley.
(x 1)

The second observation is, however, of a more positive nature. At Duxbury Reef in Marin County a large proportion of the *Tegula funebris* shells encountered are



Figure 3: Same shell as shown in Figure 2.
Ventral aspect. ex Coll. Dept. Zool., Univ. Calif., Berkeley.
(x 1)

unusually high (Figures 2, 3); rough estimates made in the field vary slightly, depending on certain closely circumscribed areas scrutinized. In the sandy areas, devoid of all rocks, no *T. funebris* are encountered, except very rarely a stray specimen ploughing through the sand on its way from one rocky area to another one. In areas with small rocks up to the size of a large fist, Tegulas abound and here the proportion of the high forms is estimated at about 40% of the total number; these rocky areas are bounded by large rocks forming actual reefs; Tegulas inhabiting this particular environment seem to comprise a larger percentage of high shells, probably as many as 75% or even more being of the type shown in Figure 2. The other members of these various *Tegula* populations conform to the more usual shape pattern (see Figures 4 and 5).

It seems plausible that these high forms represent an ecological variant, although I have not seen similar shells in any other collecting station along the coast of California and Lower California, even though in one or two places



Figure 4: *Tegula funebris* (A. ADAMS, 1855).
Mission Point, Carmel, Monterey County, California.
November 13, 1947.
Lateral aspect. ex Coll. Dept. Zool., Univ. Calif., Berkeley.
(x 1)

ecological conditions similar to those at Duxbury Reef seem to prevail. On the other hand, in general collections of *Tegula funebris*, covering wide ranges of its distribution, such as are housed in the California Academy of Sciences in San Francisco, these large, high specimens can be readily picked out; when the museum label is examined it is found to read "Baulinas," "Bolas" or "Duxbury," all three being, to some collector or other, the same spot.



Figure 5: Same shell as shown in Figure 4.
Ventral aspect. ex Coll. Dept. Zool., Univ. Calif., Berkeley.
(x 1)

For the same reason as given in our previous papers, cited above, we do not consider the variety *subapertum* to be taxonomically valid; it is merely a variant, perhaps at the end of the range of variability for the particular character, but still one that is difficult to define exactly since what is a "depression" in the umbilical area must remain open to a very subjective appraisal by the observer.

On the other hand, a decision whether the Duxbury variant should be considered a taxonomically valid subspecies must be deferred, I think, until breeding experiments can be conducted to ascertain whether this is a heritable character, unaffected by environmental factors, or a character influenced only by some as yet unrecognized environmental condition.

ACKNOWLEDGMENTS

The illustrations reproduced here are the product of the fine artistic skill of Mrs. Emily Reid, Staff Artist in the Department of Zoology. I also wish to express my appreciation to Mr. Glen Bickford, not only for his generous donation of the shells discussed here, but also for many other sizable lots and numerous important data, which, it is hoped, will be used in a forthcoming study.

LITERATURE CITED

- ADAMS, ARTHUR
1855. Descriptions of twenty-seven new species of shells from the collection of Hugh Cuming, Esq. Proc. Zool. Soc. London 22: 311 - 317 (8 May 1855)

CARPENTER, PHILIP PEARSALL

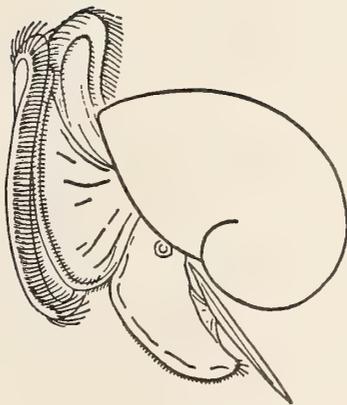
1864. Supplementary report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America. Rept. Brit. Assoc. Adv. Sci. for 1863: 517 - 686

DALL, WILLIAM HEALEY in M. BURTON WILLIAMSON

1892. An annotated list of the shells of San Pedro Bay and vicinity with a description of two new species by W.H. Dall. Proc. U. S. Nat. Mus. 15: 179 - 220; pls. 19 - 23

STOHLER, RUDOLF

1950. Studies on mollusk populations: I. [*Tegula gallina* (FORBES)] Nautilus 64 (2): 47 - 51 (October 1950)
1958. Studies on mollusk populations: IIIa [*Tegula brunnea* (PHILIPPI)] Nautilus 71 (4): 129 - 131; 1 text fig. (April 1958)
1963. Studies on mollusk populations V. — *Tegula rugosa* (A. ADAMS, 1853) The Veliger 5 (3): 117 - 121; 4 text figs. (1 January 1963)



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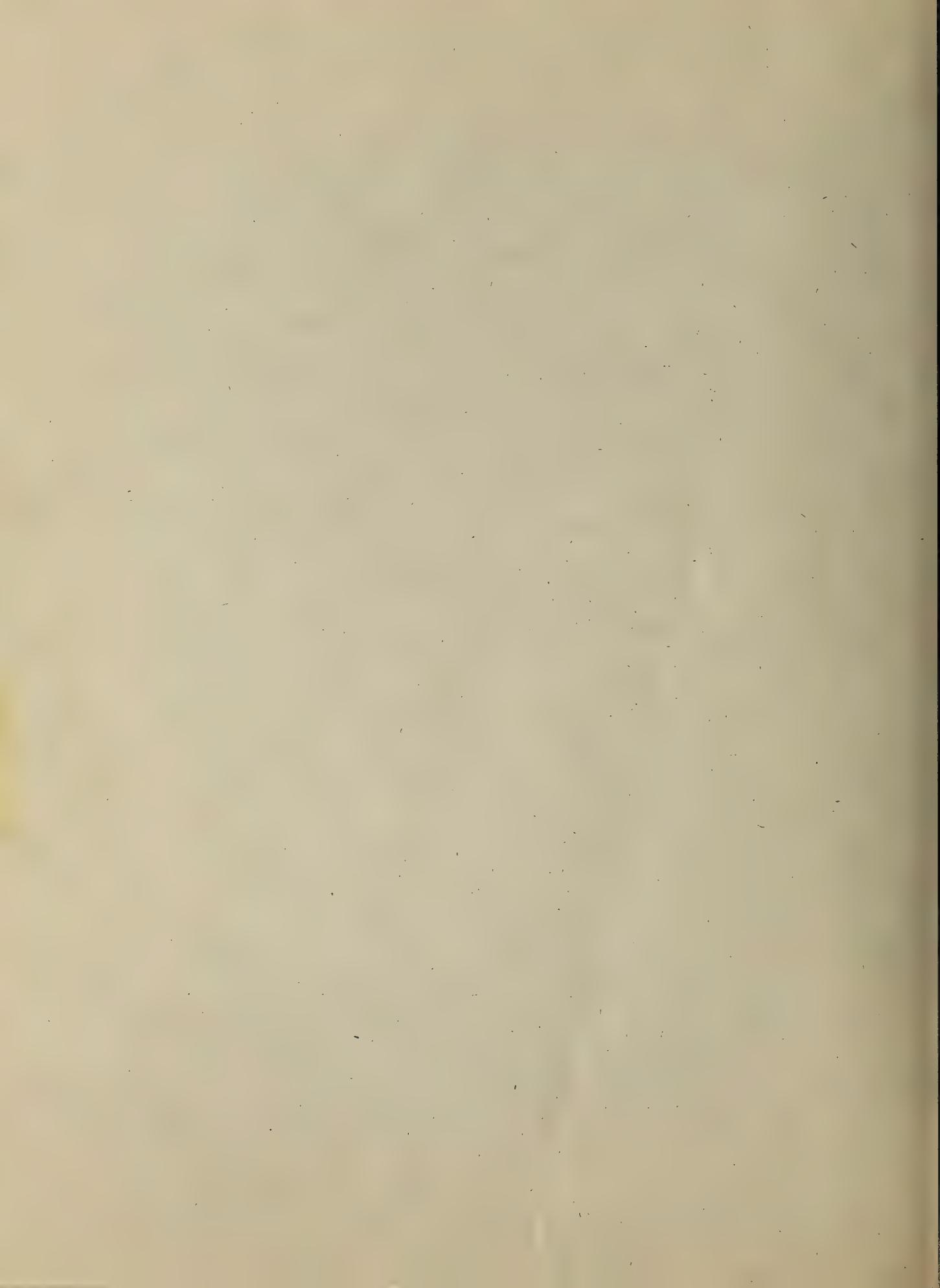
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