ISSN 0738-9388

Volume: 47 THE FESTIVUS ISSUE 2

Observations Regarding the Biology of *Pteropurpura trialata*

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ABSTRACT The Three-Wing Murex, *Pteropurpura trialata,* is a moderate sized predator that specializes in feeding on the vermetid snail *Serpulorbis squamigerus.* Reproduction occurs from February to August, but peak activity is April through June. Adult growth is not continuous but occurs in brief spurts most commonly when the water is cool between December and April. Shells from San Diego are notably different in both shape and size from those to the north in Los Angeles, California. The population in Orange County between San Diego and Los Angeles is intermediate for these characteristics. Distribution, abundance, habitat, feeding, reproduction, color forms and sub-adults are reviewed in this paper.

INTRODUCTION

The common name of *Pteropurpura trialata* (Sowerby, 1841) is the Three-Wing Murex. The three large varices, which form the wings are one characteristic common to all members in the genus *Pteropurpura;* the shape of the varices is unique to each species. Four species of *Pteropurpura* occur in Southern California; *P. trialata, P. macroptera* (Deshayes, 1838), *P. vokesae* (Emerson, 1964), and *P. festiva* (Hinds, 1844). McLean (1978) provides excellent photos of the ventral surface for each of these four species. Three additional species of *Pteropurpura* occur further south in Baja California, Mexico, these include, *P. centrifuga* (Hinds, 1844), *P. erinaceoides* (Valenciennes, 1832) and *P. leeanus* (Berry, 1959). The seven species from California and Baja California, Mexico represent approximately half the members of the genus. The pattern of the radula and operculum place *Pteropurpura* in the Muricidae subfamily Ocenebrinae (D'Attilio & Myers, 1983). Radwin & D'Attilio (1976) illustrate and discuss the shell morphology of all seven species. Until the recent past, species from the Californias have also been placed in the following genera: *Pterynotus*, *Calcitrapessa*, and *Ocenebra*.

Of these seven species, only the biology of *P. festiva* has been published by Tuskes & Tuskes (2009) who reviewed growth, reproduction, feeding, prey selection, resource partitioning, and habitat preference of that species. Although there are some similarities, the biology of *P. trialata* is notably different than that of *P. festiva* which will be compared in the discussion. Of the four species found in California, *P. trialata* is the largest and occurs from the intertidal zone to approximately 25 meters depth. No significant biological information other than the primary prey species of the adult has been published (Williams, 1978).

METHODS

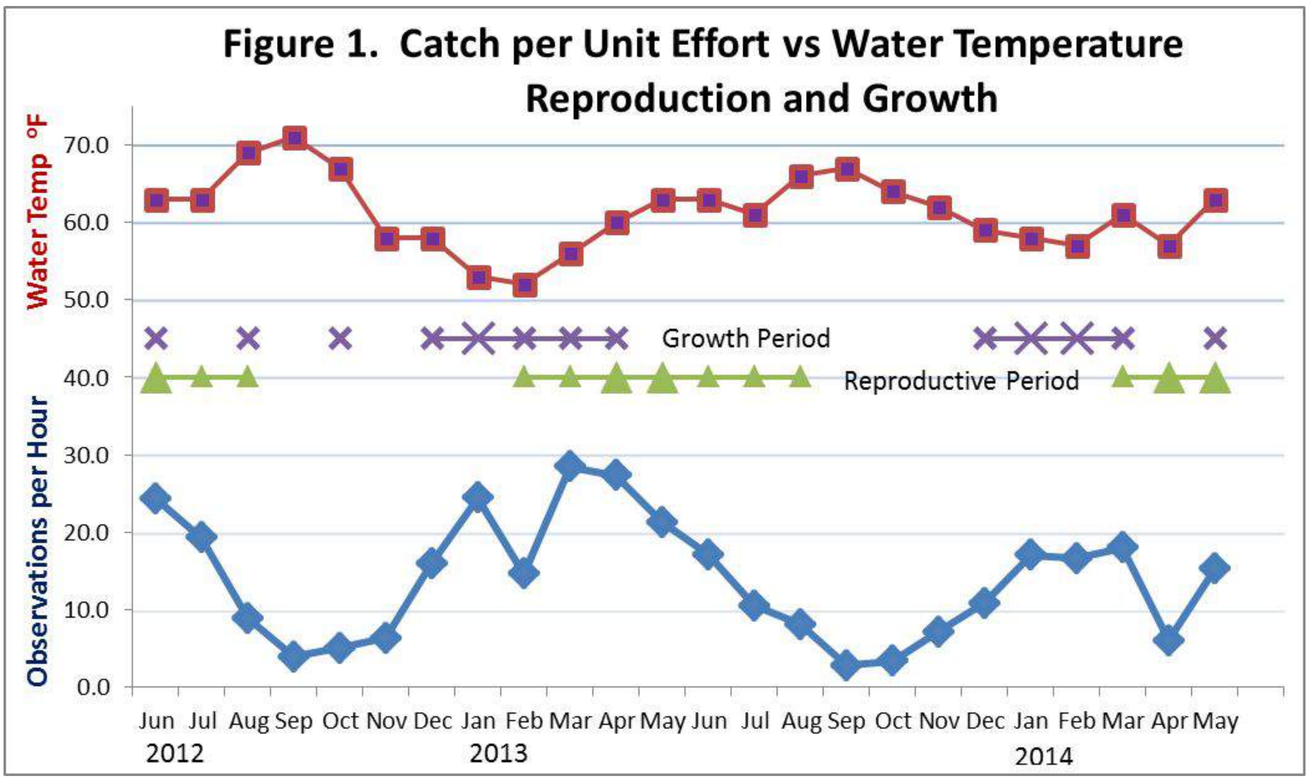
In addition to general observation over many years, a study area on the Mission Bay jetty was selected that measured 130 m in length and 10 m in width. The depth range was intertidal to five meters. The study area was surveyed using SCUBA every month for two consecutive years. Photos were taken, water temperature and conditions recorded, and each snail was scored as to activity and condition of the shell. Fouling organisms begin settling on the shells within a month after a new growth was completed. Categories for condition include (1) new growth in progress (2) new growth; no fouling on newest growth (3) clean; pattern of shell partially visible (4) old; heavy fouling but apex and siphon intact (5) very old; heavy fouling and the siphon and/or apex eroded. Clusters of egg capsules were photographed allowing for an accurate count. Egg capsules were collected in order to determine their size, the number of embryos/capsule and their developmental time at 70^0 F. Other information recorded monthly included number of egg clusters observed, prey species, and reproductive activity. Each survey required 70 to 90 minutes underwater. The data was adjusted to observations per hour in order to standardize the catch (observations) per unit effort.

A mark recapture study was attempted. Each shell was measured prior to release with the expectation that if recaptured at a later date, then the rate of growth could be determined. In addition, the shells of mature but dead *P. trialata* were collected to examine fouling rates. These shells were cleaned, dried, and then 10 shells were glued with silicon sealer to each of six small jetty rocks (<30 lb). Each rock was marked "Research do not disturb" and then placed in the habitat. At six month intervals two shells from each rock (randomly selected prior to the dive) would be removed by cutting the binding sealer. The shells would be transported in water, and then all of the fouling material in two 1 cm^2 areas between varices removed, dried and then weighed. The resulting graph of weight/time was expected to produce a chart that could be used to estimate how long mature shells continued to live and reproduce after growth had stopped. Mature shells could then be collected, and released after 2 cm^2 area of fouling material was collected. After drying, the weight would be compared to the chart and a rough but adequate estimate of age after shell maturity may be generated.

DISCUSSION

Distribution and Habitat. *Pteropurpura trialata* is most numerous from San Diego to Los Angeles, California. The northern limit of the range is currently believed to be Point Conception, which is approximately 45 miles west and slightly north of Santa Barbara, California. Point Conception is the boundary between the cooler Oregonian marine faunal province and the warmer Californian Province to the south. *Pteropurpura trialata* has been mistakenly illustrated as *Ceratostoma foliata* (Gmelin, 1791) on a number of occasions (Gotshall, 1994, McGinitie & McGinitie, 1949), and probably the source of the erroneous assumption by Morris *et al*. (1990) that *P. trialata* occurs in Northern California. McLean (1976) gave the southern record as Cedros Island, Baja California, Mexico. Hertz & Hertz (1984) reported a long list of typical Southern California gastropods found in the area of Punta Asuncion, Baja California Sur, Mexico, including live *P. trialata*. The southern range of *P. trialata* in Baja California is most likely further south than Asuncion, perhaps to the area of Magdalena Bay. Jackson (2001) published a range extension for the cowry *Neobernaya spadicea* from an off shore location just north of Magdalena Bay in Baja California Sur, Mexico. *Neobernaya spadicea* is a common companion species of *P. trialata* in water less than 15 m in depth. There were no southern records in the Scripps Institution of Oceanography collection (per. comm. Hairm Cha, Curator SIO). In addition to the computerized data base of the Los Angeles County Museum of Natural History, the collections at both the Santa Barbara and San Diego Natural History Museums and that of the California Academy of Science were visited. Keen (1971) does not list this species from the Panamic region. Adults are associated with rocky habitat and are most commonly observed from the intertidal zone to a depth of 15-20 m, although some occur deeper. North (1976) suggests they occur to depths of approximately 30 m or more, but the species he illustrated was not *P. trialata*, but rather *P. macroptera* which typically occurs deeper than *P. trialata*. There are no records of deep water specimens having been found in the extensive off shore sampling conducted by the City of San Diego EMTS Laboratory Ocean Monitoring Program (per. comm. Wendy Enright), and McLean & Gosliner (1996) did not include the species in the benthic survey of the Santa Maria Basin.

Abundance. Figure 1 shows the relative abundance of adults based on a catch per unit effort as described in the methods. With minor variation the same cycle is repeated annually. As water temperatures cool in November and December the number of adults observed in the same unit of time steadily increases. During 2013 and 2014 the water temperature reached its minimum in February. Peak adult occurrence is between January and April. As the water warms adults are less commonly observed; and each September during the warmest water, adult occurrence was at its low point. During November through April 2013/2014 winter water temperatures were as much as 6^0F warmer than the same period in 2012/2013, perhaps contributing to few adult observations when compared to the previous winter. Adults are occasionally found on sand close to rocks but they do not typically travel across open sand patches. It is possible that these individuals may have lost their footing on the rock. Night diving on numerous occasions does not suggest a shift in adult activity during darkness, thus the seasonal reduction in observations is most likely from adults moving deep into hidden spaces when not actively feeding.



McLean (1978) implies *P. trialata* is primarily an intertidal species. On the Mission Bay jetty, perhaps one percent of the population may be accessible during minus tides. Based on the shape of *P. trialata,* they are not adapted to live in environments routinely impacted by waves. The rhythmic flow of water from a swell is notably different than the force of waves hitting rocks in the intertidal zone. In Southern California, gastropods that live in the intertidal zone with notable wave action present a low smooth profile such as limpets, or a rounded shell that presents less drag, such as *Mexacanthina lugubris* (Sowerby, 1821), *Acanthina paucilirata* (Sterns, 1971), *A. punctulata* (Sowerby, 1825), *Acanthinucella spirata* (Blainville, 1832), *Roperia poulsoni* (Carpenter, 1864), *Ceratostoma nuttalli* (Conrad, 1837), and juvenile *Pteropurpura festiva*. Negus (1993) found *P. trialata* on rocks intertidally in the calm waters of Agua Hedionda Lagoon. On the Mission Bay jetty *P. trialata* is most abundant at depths from two to nine meters. Some individuals can be found in the lower intertidal zone, especially where there is no wave action on rocky habitat within the bay.

Adult Prey Species. The primary prey species for mature *P. trialata* is the vermetid snail *Serpulorbis squamigerus* (Carpenter, 1857). The common name for *S. squamigerus* is the Worm Snail, and is based on the unusual worm-like shape of their shell. They attach their shells to rocks or other *S. squamigerus* and can form dense colonies. Once these snails settle, they cannot move. As a result, the food must come to them. *Serpulorbis* are particulate feeders and tend to settle in areas with stronger currents; hence their higher than usual density along entry channels and subsequent reports of *P. trialata* being common at entries to bays. Tidal flows through channels produce higher water velocity than in the inner bays or the open ocean. *Serpulorbis* occur off shore and in inner bays but their abundance in these areas is greatly reduced and they may be found singly rather than dense clusters.

In captivity, mature *P. trialata* consume a *S. squamigerus* in three to four days. They did not drill the tube of the snails, but rather extended their mouth down the aperture opening of the shell. In captivity, we observed on occasion that they would break away up to 8 mm from the lip of the *Serpulorbis*, presumably to reach deeper into the tube to access the animal. After feeding for three to four days the snail moves off and may wander or hold up in a recess for a week before feeding again. Williams (1976) reported that in captivity they drilled into the side of the *Serpulobris* tube and consumed the snail. Clearly they have multiple modes of attack.

Growth and Size. When the water begins to cool from December through February the frequency of shells exhibiting new growth is highest. After that, it tapers off as the water warms (Figure 1) and the activity shifts to reproduction. During the actual growth cycle, when a new varices is added the snails are usually reclusive. Although some individuals occasionally display new shell growth during the summer, it is infrequent. McGinitie & McGinitie (1949) illustrate a *P. trialata* that while in captivity added a new inter-node and varices in 3 days. They remarked about the rapidity of growth and amount of calcium carbonate required; unfortunately, the caption in the book is mislabeled as *Ceratostoma foliata*. Mature snails do not put on a new growth each year. Shells that are heavily fouled often show extensive erosion on the apex, and even an inability to maintain the siphon structure. In captivity snails with complete shells typically replace the siphon within a few weeks, even when not in the growth phase. The animals

ISSN 0738-9388

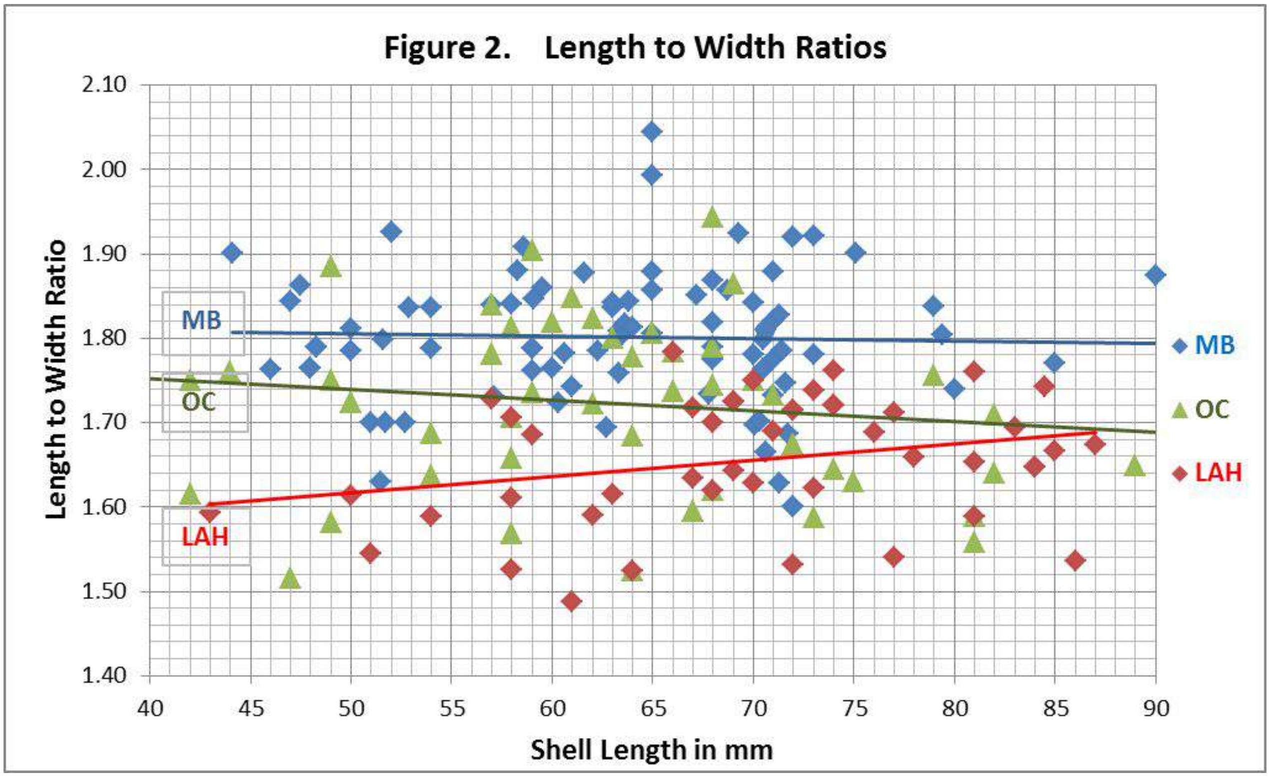
with eroded shells seldom repair siphons in captivity. These snails are still observed reproducing in the spring but we suspect that they are terminal adults, perhaps 2-3 years after their final growth period, and will not survive another year.

In 2012, three months prior to the start of the study, 158 live *P. trialata* were measured on a section of the Mission Bay (MB) jetty. The sample represented all individuals observed regardless of size. The average length was 62.4 mm, the median was 63.3 mm with a range from 44.1 to 74.7 mm. Shells in the 44-55 mm range added approximately 6.6 mm of length during the previous new growth; larger shells averaged an increase of 7.3 mm. Having surveyed the entire length of both the North and South jetty, shells greater than 75 mm are uncommon and only a few shells between 80 and 90 mm were observed.

Measurements of live individuals in naturally occurring populations may be difficult to compare to specimens in private collections and museums, as collectors typically do not randomly sample the population, but rather often focus on the largest or most attractive specimens. Data from Orange County (OC) and Los Angeles Harbor (LAH) jetty are based on measurements from private collections and museums. The average length of shells from OC was 61 mm (n = 60) while material from LAH averaged 70 mm in length (n = 45). Having dove the LAH jetty on a number of occasions, I found few *P. trialata* but they were larger than those found further south. To address the probable disparity between museum records and populations that were sampled randomly, the 15 largest specimens for MB, OC, and LAH from collections were compared. Collected material from MB averaged 77.8 mm and OC averaged 77.1 mm. The 15 largest specimens from LAH averaged 83.6 mm and were statistically larger ($p > 0.025$) than those from MB or OC. The largest specimen measured is in the SBMNH collection and is 105 mm in length and was collected off Santa Barbara Island. The species is far less common in Santa Barbara County than further south. Only 14 museum specimens were located which collectively averaged 65.7 mm with a standard deviation ("STDV") of 9.3.

Adult Variation. There is notable variation in both color patterns and the shape of the shells. A paper by Rick Negus (1993) illustrates a wide range of color forms and discussed a dwarf population of adult *P. trialata* found in Agua Hedionda Lagoon, San Diego Co., CA. In Mission Bay, San Diego, the ratio of normally marked shells to the alba (totally white) forms is approximately 20:1. While alive, white shells typically have far fewer fouling organisms growing on them than shells with the typical brown patterns. The least common color form in MB is a white shell with 2-3 light brown bands and an orange aperture; that phenotype occurs at a frequency of perhaps 400:1. Among the Eastern Pacific *Pteropurpura,* a unique characteristic of *P. trialata* is that the banding on the shell is disrupted by the white varices. In other species such as *P. macroptera* form tremperi, *P. festiva, P. centrifuga*, and *P. erinaceoides,* the banding, when present, continues onto the varices.

Most shells from Santa Barbara, San Diego and many from Orange County are characterized by a slightly elongated spire and shorter varices, giving the shell a slender elongated shape (Figure 2 & 3b) when compared to material from Los Angeles Harbor**.** A 78 mm shell from LAH is 5 mm wider than a 90 mm shell from MB. The length to width ratio from LAH is 1.64. Specimens from OC, located between MB and LAH, had a ratio of 1.76. In MB the length to width ratio was 1.8. The best fit line for the



MB is nearly parallel to the x-axis indicating that length to width ratios changes very little as the mature shells continue to grow. As shells from LAH become larger, they appear slightly more elongated perhaps due to the length of the siphon. There were an insufficient number of shells from the area of Ensenada, Baja California, Mexico for a comparison to be meaningful. A third characteristic is the shape of the varices. Nearly all LAH shells have deeply scalloped varices (Figure 3a). In MB perhaps 50% have little or no scalloping, 40% have some scalloping (Figure 3b) and 10% have scalloping that approaches that of the LAH population. Collectors anecdotally associate smaller and less scalloped varices with rougher water conditions. A comparison in shell morphology between the inside and outside of the LAH jetty might prove or disprove the rough water hypothesis of collectors. Although shells from the LAH are easily distinguished from most MB specimens, there is a cline in these characters with the OC material being somewhat intermediate to LAH and MB. The cause for this cline in shell shape has not been determined..

Reproduction. Reproductive clusters of *P. trialata* were observed on rocks starting in January or February. Clusters of egg capsules are found from February to August, but the highest frequency each year was when the water starts to warm from April to June (Figure 1); the timing puts the planktonic larvae in some of our warmest water. Females tend to deposit their cluster of egg capsules on vertical or near vertical rock surfaces with usually a minimal amount of red and brown algae present. Based on capsules deposited in captivity, development from the embryos to emergence from the capsule requires 19-21 days when held at 70°F. Development time at 60 to 65 °F may be considerably longer. Determining developmental time *in situ* was not practical as the

ISSN 0738-9388

initial age of the capsules when found would not be known.

Twenty clusters of eggs were photographed and counted and two egg capsules each were collected from ten clusters. The average number of egg capsules per cluster was 59.8 (STDV of 14.9) and a range from a low of 34 to a high of 82 capsules/cluster (See Table 1). Capsules are yellow and have a short petiole that connects the capsule to the base matrix attached to the rock (See Figure 4a). Capsule length, including petiole, is from 10 to 13 mm, the width is approximately 6 mm and it is about 1.5 mm in thickness (See Figure 4b). The embryos/developing larvae are in a thick clear mucus-like material. Of the 20 capsules, two each from ten clusters, the number of embryos ranged from 255 to a high of 679 and averaged 484.5 (STDV of 127.7) embryos/capsule (See Table 1). Based on an average of 59.8 capsules/cluster and 484.5 embryos/capsule the average number of embryos/cluster is 28,973. It is not known if females are capable of depositing more than one cluster per season. Based on the biomass of the cluster it is unlikely that a second cluster of similar size could be produced. Ninety-two percent of the females observed depositing egg clusters were scored as old to very old, and only eight percent showed signs of recent new growth.

Embryos measure approximately 0.23 mm and are circular. As they develop they enlarge and elongate slightly prior to shell development. The capsules turn a dull brown prior to the larvae emerging. The planktonic larvae exit with a microscopic shell through an opening at the tip of the capsule. Females do not brood the egg capsules and leave the area after depositing them.

Capsules Per Cluster	Capsules Per Cluster	Embryos Per Capsule	Embryos Per Capsule
34	57	1 - 595	6 - 255
39	64	1 - 599	6 - 273
40	71	2 - 570	7 - 408
43	71	2 - 619	7 - 428
45	72	3 - 565	8 - 616
48	76	3 - 597	8 - 679
51	80	4 - 454	9 - 613
54	80	4 - 425	9 - 624
55	81	5 - 421	10 - 333
55	82	5 - 432	10 - 383
Average 59.8 capsules per cluster		Average 484.5 embryos per capsule	

Table 1. Number of Egg Capsules/Cluster and Number of Embryos/ Capsule.

Juveniles and Sub-adults. The location of juveniles and their development is unknown. We observe juvenile *Roperia poulsoni* (Carpenter, 1864), *Pteropurpura festiva* (Hinds, 1844), and *Maxwellia gemma* (Sowerby, 1878) from 8 to 15 mm in length, in the same habitat as adult *P. trialata* but no juvenile *P. trilalata*. Night diving, and looking under rocks intertidally has not produced juveniles. We have also not found juveniles on the Dana Point or LA Harbor jetties. If juveniles were present, those that die may become the home of hermit crabs. Multiple dives to collect hermit crabs on the MB jetty have also failed to produce a juvenile shell of *P. trialata*. Conversations with divers/collectors have not turned up juveniles. Juvenile shells are absent from the collections in Southern California museums. The smallest sub adult examined measured 29 mm. From the protoconch the juvenile shell had 25 small rudimentary ridges prior to the first of five enlarging varices; at that size, the shell shape, sculpture and color is that of an adult *P. trialata*. The specimen was taken under a flat rock at 55' N.W. of Bird Rock, Orange County, Ca, by an unknown collector and given to Paul Kanner. A second small sub adult was

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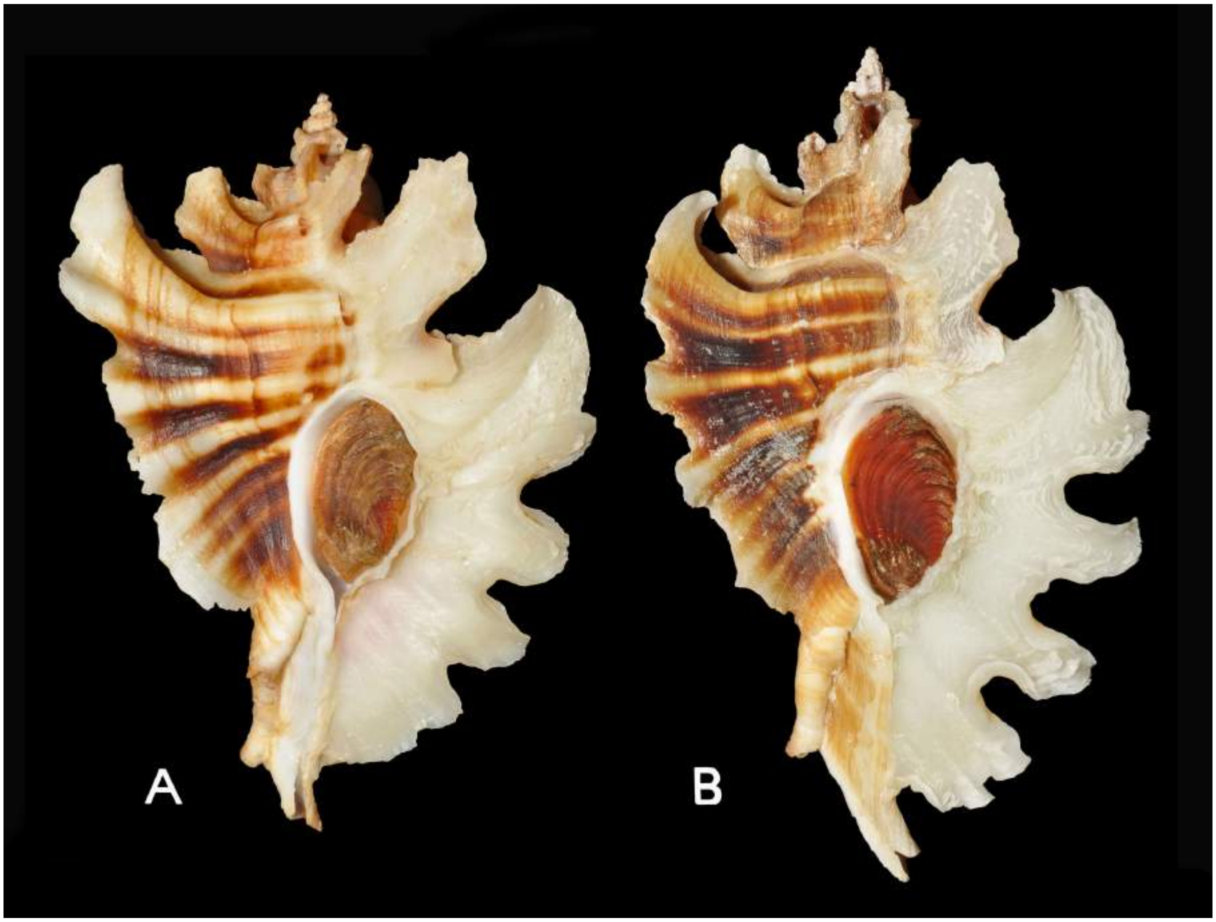

Figure 3. mature *P. trialata.* **A.** from Los Angeles Harbor. **B.** from Mission Bay. Note the difference in the length and orientation of the varices in relation to the apex.

found dead on the LA Harbor jetty by Larry Catarius and measured 30.9 mm. Prior to the development of expanded varices the juvenile shell might look similar to some species of *Ocenebra*. Juveniles and subadults must outnumber adults by multiple orders of magnitude, and therefore their general absence from the adult environment suggests they develop elsewhere, and as they mature move into the reproductive population and shift to a new prey species. Poorman (1982) published interesting comments regarding the different habitat of juveniles and adults near San Carlos, Mexico. Adult *Cassis centiquadrata* (Valenciennes, 1832) were found in shallow water and intertidally, but in deep water (60 m) only a few smaller adults were found but juveniles were common. He also noted that *Fusinus dupetitthouarsi* (Kiener, 1840) as small as 10 mm were dredged at 100 m but adults were taken in shallower water and in the intertidal zone.

Similarities and differences between the biology of *P. trialata* and *P. festiva*.

In Mission Bay, female *P. trialata* tend to deposit clusters of egg capsules in isolation and only occasionally close to clusters from another female. *Pteropurpura festiva* often form dense clusters of females all of which are depositing their egg capsules en mass. Both species reproduce as the water begins to warm and neither species tend their egg clusters. Juvenile *P. festiva* are most commonly found on rocks with sub adults and small adults. Sub adults and small adults feed on limpets, barnacles, and other snails. The largest specimens (50 to 60+ mm) are often on sand, feeding on clams and occasionally bubble snails. Juvenile *P. trialata* do not appear to have been found and sub adults smaller than 40 mm are uncommon, suggesting that these stages must occur in a different habitat and perhaps different depth range. Mature *P. festiva* feed on a variety of gastropods, bivalves, and occasionally scavenge dead crustaceans. Mature *P. trialata* are specialized feeders targeting one species of gastropods, perhaps exclusively.

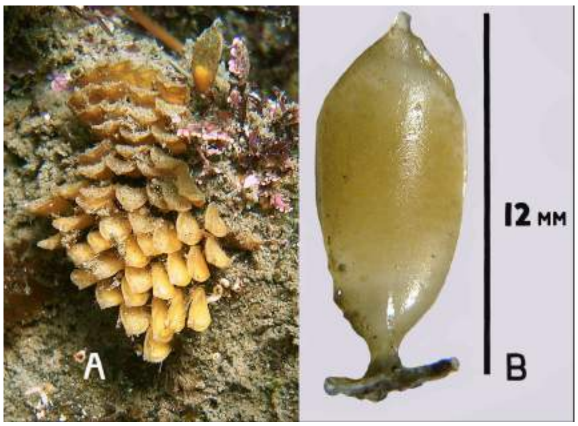

Figure 4. Egg capsules of *P. trrialata*. **A.** typical cluster of capsules on a vertical rock surface. **B.** Individual egg capsule.

No Results. The mark recapture effort produced no results as bryozoans quickly overgrow the shell obscuring information, making it impossible to obtain data. The efforts of the fouling study were equally unproductive. Within the first month all shells were obscured by green algae, by the second month they were colonized by more complex brown algae which proved to be the immature stages of the giant kelp *Macrocystis pyrifera* (C. Agardh, 1820). By the third month the rocks and shells were being covered by *Sargassum* sp. and *Macrocystis*. This succession of algae species is not observed on shells of living *P. trialata*. The rocks were retrieved and cleaned of algae and placed near the base of the jetty just above the sand at 5 m. Within three days the shells had been attacked and crushed by bat rays and only 5 remained undamaged. These negative results may benefit the design of others efforts.

ACKNOWLEDGMENTS

We would like to thank the staff at San Diego, Santa Barbara, and Los Angeles County Museums of Natural History, and the California Academy of Science for allowing visits to their collection or having placed specimen data on-line, the San Diego Life Guard Service for permission to dive certain locations, and Paul Kanner and Larry Catarius for making material available.

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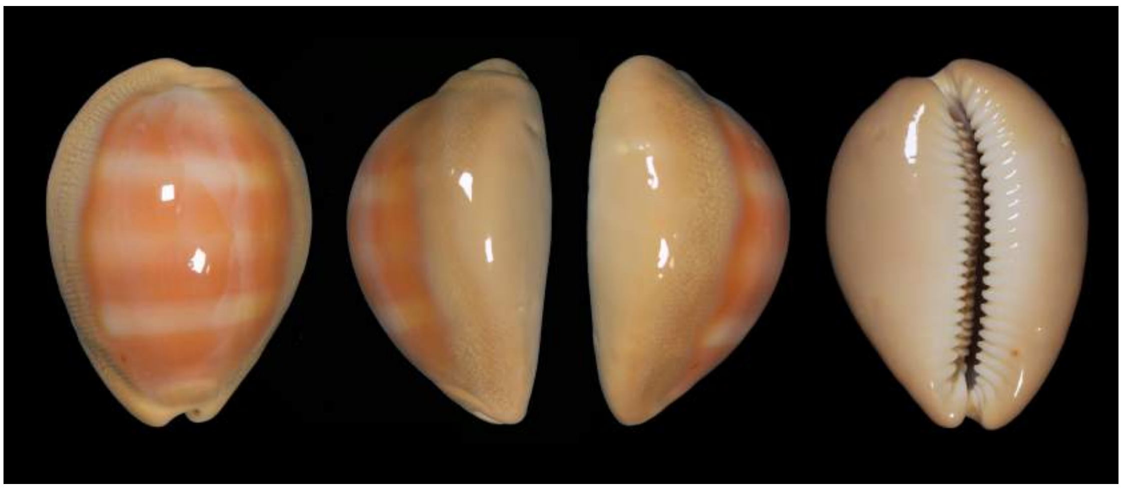

Taxonomic note - new species: *Lyncina alicae* Lum, 2013 (Image of Paratype No. 1, by David Lum)

This gorgeous and rare Hawaiian endemic cowrie is compared to *L. schilderorum*, *L. sulcidentata*, and *L. kuroharai*. It has been referred to in the past as a hybrid of *L. schilderorum* and *L. sulcidentata*; however, it is distinct from them and shows a greater consistency of conchological characteristics than either *L. schilderorum* or *L. sulcidentata*. *L. aliceae* has short, sharply-cut columellar and labral teeth, similar to those of *L. kuroharai* of the Western Pacific, and a cream colored aperture on a tan base. In comparison, *L. schilderorum* has a mostly white base, a bright white aperture, and very fine columellar and labral teeth restricted to the aperture; and *L. sulcidentata* has very long stout teeth, with the labral teeth reaching up to half way across the labrum, and a light tan colored aperture and base. Finally, *L. aliceae* has light tan flecks over a dark tan background on the margins which creates a chatoyant effect with a mild irregular vertical line pattern akin to *L. sulcidentata*, whereas *L. schilderorum* has very distinct and regularly spaced fine vertical lines along the right margin.(Lum, David 2013. A new species of *Lyncina* from Hawaii (Mollusca: Cypraeidae). *Beautifulcowries Magazine* 4: 4-11.)