

# **THE OVULIDAE (MOLLUSCA: GASTROPODA) OF SINGAPORE**



**Hoong Wei Wong**

Raffles Museum of Biodiversity Research  
National University of Singapore  
Singapore  
**2011**



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## CONTENTS

1.	<a href="#">Introduction</a> .....	1
2.	<a href="#">Material And Methods</a> .....	2
3.	<a href="#">Systematic Account</a> .....	3
	a. <a href="#">Prionovolviniae</a> .....	3
	b. <a href="#">Ovulinae</a> .....	15
	c. <a href="#">Aclyvolvinae</a> .....	20
4.	<a href="#">Discussion</a> .....	21
5.	<a href="#">Acknowledgements</a> .....	22
6.	<a href="#">Illustrations</a> .....	23
	a. <a href="#">Shells</a> .....	23
	b. <a href="#">Living Animals</a> .....	41
7.	<a href="#">Alphabetical Checklist of the Ovulidae Recorded from Singapore</a> .....	50
8.	<a href="#">Literature Cited</a> .....	55
9.	<a href="#">Citation of This Book</a> .....	58
10.	<a href="#">Index</a> .....	58

## INTRODUCTION

Closely related to true cowries of the family Cypraeidae, shells of the family Ovulidae can be differentiated by columella and outer lip dentition, which are often weaker or completely lacking in ovulids. Like the true cowries, they have a retractable mantle often decorated with colour and finger-like papillae that can be drawn over the entire shell. The mantles of these animals sometimes mimic the colours and textures of their hosts as a natural form of camouflage. Together with the families Pediculariidae and Eocypraeidae, they are affectionately known as “Allied Cowries”, and live in association with coelenterates, which includes hard corals, soft corals, gorgonians, and hydrozoans. Some species were found to live as predators of Anthozoa, with the others living commensally and inflicting no wounds on their host (Cumming, 1997; Fehse, 2007a; Lorenz & Fehse, 2009).

The taxonomy of the family Ovulidae has been revised several times (e.g., Cate, 1973; Fehse, 2001; Lorenz & Fehse, 2009), often based on shell characters. Schiaparelli (2005) investigated the phylogeny of the family based on the 16S rRNA gene and other ecological data such as host specificity and morphological adaptations to propose some unexpected taxonomic groupings. Based on these findings and published studies of the radulae, shell and animal morphology (e.g., Azuma & Cate, 1971; Azuma, 1974), Fehse (2007a) reorganised the higher systematics at the family and subfamily levels. The recent work by Lorenz & Fehse (2009) summarised the current knowledge of the Ovulidae, and in the process revised the taxonomy of a number of species and genera.

There appears to be a decent number of species recorded locally in published literature, but most of these works mention taxa as part of a checklist without illustrations or descriptions. Studies by Lim (1969a, 1969b), Chuang (1973), and Purchon & Purchon (1981) recorded about ten species. The monumental work by Cate (1973) included Singapore in the distribution of at least six species. Goh & Chou (1994a) and Goh et al. (1999) recorded six species in their checklist of gorgonian associates in Singapore. Among the many specimens and photographs of living animals illustrated by Lorenz & Fehse (2009) were seven species from Singapore, a number of which were recorded for the first time. A compilation of these records and more by Tan & Woo (2010) mentioned 23 species from 14 genera, of which five species were new records based on examination of specimens in collections or compelling photographic records.

An investigation into the diversity of these animals in Singapore proved to be frustrating as few locally collected specimens are available for comparison in public institutions, and hence, access to a handful of private shell collections proved valuable to this study. With the exception of a few exceptionally low spring tides each year, several species are seldom encountered in the intertidal areas, limiting the privilege of collecting specimens or observing them in their natural habitat to those who dive regularly. Where effort was made to diligently sift through beach drift and debris washed up on shore, the fragile shells of the ovulids were often broken, faded, or badly worn, making it almost impossible to identify the species.

An attempt is made here to consolidate published literature, sightings, and collected specimens to expand the checklist of the locally occurring species of the family Ovulidae, and serve as an identification guide to some of the species in Singapore. This preliminary study hopes to serve as a baseline to encourage further investigations into the ecology and diversity of these animals.

## **MATERIAL AND METHODS**

Abbreviations of public and private repositories used in the text are as follows: ZRC, Zoological Reference Collection, Raffles Museum of Biodiversity Research, National University of Singapore; BBC, B. Boo Collection; CSY, S.Y. Chan Collection; WHW, H. W. Wong Collection; TKC, T. Kee Collection; TSK, S. K. Tan Collection. Abbreviations used to indicate sampled localities commonly used in this article are as follows: CBP, Changi Beach Park; ECP, East Coast Park.

The southern and eastern coastlines of mainland Singapore were surveyed over a 4-year period from Jun.2006 to Aug.2010. Activities at the locations included sifting through beach drift and shell sand, inspecting bycatch and debris brought up by fishing gear and combing the intertidal areas during low tides for empty shells and live animals. Photographs of ovulids taken locally by SCUBA divers and other marine enthusiasts were examined. A diver was tasked to collect specimens from waters off Pulau Hantu which were not immediately identifiable from photographs of living animals in situ. Previously collected specimens deposited in the ZRC were inspected, and requests were made to inspect and photograph specimens held in a number of private collections made in the last two decades or so, which proved to be an extremely useful avenue to gain a better insight into the diversity of this family. All figured specimens were deposited into the ZRC unless otherwise indicated. Shells in the possession of the author will be deposited into the ZRC at a later time after further examination. The different species were identified based on descriptions and illustrations of shells and live animals in literature (e.g., Lorenz & Fehse, 2009), and by personal communication with local and foreign enthusiasts and malacologists.

Species were classified as new records based on historical data in Lim (1969a, 1969b), Cate (1973), Chuang (1973), Purchon & Purchon (1981), Way & Purchon (1981), Trew (1987), Chou et al. (1994), Goh & Chou (1994a), Goh et al. (1999), Fehse (2001, 2002a), Wong (2008), Lorenz & Fehse (2009), and Tan & Woo (2010). A description of the shell is provided for each species to distinguish it from other locally occurring ovulids, and the terminology used to describe the parts of the shell follows that of Lorenz & Fehse (2009: 11). Based on observations of animals in situ or in photographs, descriptions of the external-morphology and notes on other ecological observations are also included. A representation of the locally collected material examined is illustrated in Figs. 1–18, and measurements given indicate the length of the shell from the anterior terminal tip to the posterior terminal tip. Where available, photographs of the living animal are also included (Figs. 19–27). Ecological observations and taxonomic and nomenclatural issues are addressed under ‘Remarks’, but no attempt was made here to provide an exhaustive list of synonyms. The nomenclature and classification used follows that in Lorenz & Fehse (2009). Subgeneric placements

have not been adopted here. Voucher specimens of species sampled locally were deposited in the ZRC (ZRC.MOL.3010–3056).

A list of Ovulidae recorded from Singapore accompanied by their respective references is presented in Table 1. Important notes relating to the status of the species in Singapore and the catalogue numbers of any material held in the ZRC are included under the ‘Remarks’ column. Species indicated with an asterisk (\*) denote unverifiable occurrence in Singapore based on this study. Species indicated with a hex (#) denote a doubtful taxonomic status of the species according to the recent revision by Lorenz & Fehse (2009).

## SYSTEMATIC ACCOUNT

### Family Ovulidae Fleming, 1828

#### Subfamily Prionovolvinæ Fehse, 2007

##### *Globovula sphaera* Cate, 1973

(Fig. 2a–h)

**Material examined.** — 1 specimen (SL 18.5 mm) (BBC), empty shell, Changi, Oct.2005; 2 specimens (15.0 mm, 15.8 mm) (CSY), fishing nets from 25 fathoms, Tanjung Pinang, Bintan Island, Indonesia, Sep.1997.

**Shell description.** — The shell is solid and distinctively globular in shape, less inflated toward the anterior. The posterior canal is short, solid, and the posterior terminal is rounded and opened to the left. The funiculum is poorly developed and represented by an oblique, rounded ridge. The labrum is thick and rounded, and very weakly crenulated. The aperture is narrow throughout. The ventrum is calloused and smooth in appearance. The terminal ridge is prominent. The anterior terminal is solid and rounded. The entire shell exterior is white and appears smooth and glossy.

**Remarks.** — The shell of species is unmistakable and only confused with *Globovula cavanaghi* (Iredale, 1931), which has a consistently smaller size, and exhibits a wider range of coloration from white, to yellow, to rose. The latter is known most commonly from Australian waters. *Globovula sphaera* has not been found alive in Singapore. Two specimens examined in this study (Fig. 2e–h) were caught in fishing nets off Bintan Island, Indonesia, southeast of Singapore.

##### *Prionovolva brevis* (G. B. Sowerby I, 1828)

(Figs. 2a–l, 19c–e)

**Material examined.** — 2 specimens (13.7 mm, 13.6 mm) (ZRC.MOL.3010), beach worn shells among debris at high tide line, ECP, H. W. Wong coll., 17 Aug.2008; 1 specimen (13.5 mm) (ZRC.MOL.3011) empty shell among beach debris, Changi Beach, H. W. Wong coll., 18 Aug.2008; 1 specimen (23.2 mm) (WHW), empty shells among debris at high tide line, Changi East, Oct.2005.

**Shell description.** — The shell is solid and oval in shape, narrowing slightly toward the anterior. The posterior terminal is rounded, and the posterior canal opens to the left. The funiculum is a prominently raised but rounded longitudinal ridge. The labrum is flattened and denticulated more prominently at the central portion where a number of teeth extend to the periphery. The aperture is wide. The ventrum is calloused and a prominent longitudinal ridge runs from the funiculum to the basal ridge at the anterior. The terminal ridge is prominent, curving inwards. The anterior terminal

is pointed but rounded. The dorsum is sometimes weakly striated toward the terminals, and smooth otherwise. Several weak, transverse angulations can sometimes be observed. The dorsum coloration varies from white to purplish pink, and two white transverse bands are sometimes observed. The base is generally white.

**External morphology.** — The mantle is translucent pink, and covered by an irregular reddish pink network. The short, white papillae are placed within the lighter coloured areas of the mantle. The tentacles are red, and the foot is flesh. The edge of the pale siphon is marked reddish pink. A red stripe starts from the base of the white tentacle and runs past the eye. The tail end of the foot sports a bold transverse reddish pink stripe.

**Remarks.** — Fehse (2000) concluded that *Prionovolva pudica* is a synonym of *Prionovolva brevis*, and *Prionovolva wilsoniana*, although considered by many authors (e.g., Liltved, 1989; Wagner & Briano, 1997; Dharma, 2005) to be a junior synonym of *Prionovolva brevis*, is a separate species. According to Fehse (2000), shells of *Prionovolva brevis* can be distinguished from the closely related *Prionovolva wilsoniana* Cate, 1973 by the latter having a less calloused base, a less thickened outer lip that is more oblique towards the aperture at the anterior, a weaker fossula, a less developed inner adaxial carinal edge, and a stronger dorsal coloration. The radulae of the two species appear to be distinct (Fehse, 2000 after Azuma, 1970, 1975, 1989). Inspection of shells and photographic evidence seem to indicate that both species occur in Singapore, but insufficient shells in good condition are available to confirm this. Hence, the more senior name is chosen here to represent the local population till more specimens are available for inspection. Dharma (2005) reported *Prionovolva brevis* from Batam Island, Indonesia, not far south of Singapore. In Singapore, *Prionovolva brevis* was photographed living on *Dendronephthya* species in intertidal regions at Beting Bronok (Fig. 19d) and Tuas (Fig. 19c), to shallow SCUBA depths of about 10 m off Pulau Hantu (Fig. 19e). Based on photographs taken by divers and enthusiasts, they appear to be host specific in Singapore but more sightings will be needed confirm this.

### ***Prionovolva nivea* Cate, 1974**

(Fig. 1m–t)

**Material examined.** — 1 specimen (7.2 mm) (ZRC.MOL.3012), beach worn shell among debris at high tide line, ECP, H. W. Wong coll., 17 Aug.2008; 2 specimens (8.7 mm, 9.6 mm) (WHW), empty shell among beach debris, ECP, Jun.2006.

**Shell description.** — The shell is elliptical in shape, narrowing anteriorly, somewhat resembling a more elongated *Prionovolva brevis*. The posterior terminal is rounded and the posterior canal opens to the left. The funiculum is an oblique, weakly raised and rounded ridge. The labrum is denticulated, only slightly stronger at the central portion. The aperture is narrower posteriorly, widening slightly toward the anterior. The ventrum is smooth and rounded. The inner adaxial carinal ridge and fossula are indistinct. The terminal ridge is prominent and curving inwards. The anterior terminal is rounded. The dorsum and base are smooth, lacking any striation or transverse angulations. The shell is generally white.

**Remarks.** — The shell of this species appears similar to *Prionovolva brevis* and *Prionovolva wilsoniana*. It can be differentiated from the latter two by being more elongate and having a lack of any transverse dorsal striation or angulations, a thinner shell which sometimes appears translucent, a more prominent fossula, a less developed funiculum and basal axial ridge connecting the funiculum and the terminal ridge, and a more convex outer labrum when viewed laterally (Fehse, 2000). The radula of *Prionovolva nivea* appears to be distinct from the two closely related species (Fehse, 2000, after Azuma, 1994). *Prionovolva nivea* has not been found alive in Singapore. Faded shells examined were from East Coast Park and St. John's Island.



***Margovula pyriformis* (G. B. Sowerby I, 1828)**

(Fig. 2i–t)

**Material examined.** — 1 specimen (7.3 mm) (ZRC.MOL.3014), empty shell, ECP, H. W. Wong coll., Jun.2009; 1 specimen (21.5 mm) (TSK), empty shell, ECP, Nov.1997; 1 specimen (14.5 mm) (TSK), empty shell, Changi, 23 Oct.2005; 2 specimens (16.9mm, 14.8 mm) (WHW), empty shell, CBP, 2007.

**Shell description.** — The shell is distinctively pyriform in shape; the posterior is inflated and the anterior attenuates sharply. The posterior terminal is pointed and protruding, and the posterior canal opens to the left. The funiculum is a prominently raised, smooth, oblique ridge. The labrum is flattened with distinct but irregular labral denticulation. The aperture is narrow. The ventrum is smooth and rounded. A distinct axial ridge is restricted to the fossular region and weak otherwise. The terminal ridge is prominent and almost linear. The anterior canal is elongated. The dorsal sculpture is highly variable and can be entirely or partially covered with incised, widely spaced striation to entirely smooth, with all intermediates known to exist (D. Fehse, pers. comm.). The colour of the shell varies from cream to red or dark brown.

**Remarks.** — This species is distinguished from other related species (e.g., *Margovula bimaculata*) by its distinctive inflated shape and its elongate extremities. A number of smaller, beach worn specimens examined in this study are likely a different species, possibly *Margovula bimaculata* (A. Adams, 1854) or *Margovula tinctilis* Cate, 1973. They differ from *Margovula pyriformis* by having a more ovate and less distinct pyriform shape, a wider aperture, and a smaller size. However, since dorsal coloration is an important characteristic for correct identification and distinguishing between these species of *Margovula*, they can only be tentatively identified until fresh specimens are available for inspection. These three closely related species of *Margovula* live in association with soft corals, and they have yet to be found alive in Singapore.

***Margovula marginata* (G. B. Sowerby I, 1828)**

(Fig. 3a–t)

**Material examined.** — 1 specimen (22.0 mm) (ZRC.MOL.3013), broken shell among beach debris, National Service Resort and Country Club, ECP, H. W. Wong coll., 13 Dec.2008; 2 specimens (20.1 mm, 23.6 mm) (TSK), empty shells among beach debris, ECP, Sep.1997; 5 specimens (8.1–14.0 mm) (TSK), empty shells among beach debris, Changi, 23 Oct.2005; 2 specimens (15.5 mm, 23.6 mm) (WHW), empty shell among beach debris, ECP, 2009.

**Shell description.** — The shell is inflated oval, tapering slightly towards the anterior. The posterior terminal varies from pointed to blunt, and the posterior canal opens to the left. The funiculum is an oblique, raised ridge that is mildly and irregularly crenulated. The labrum is irregularly denticulated, appearing as irregular crenulations anteriorly. The aperture is narrow, wider toward the anterior. The ventrum is smooth and rounded, or only showing weak traces of the dorsal striation. The fossula is shallow. The terminal ridge is large and prominent. The anterior terminal varies from being an oblique point to blunt and round. The dorsum is covered with weak transverse striations and angulations. The shell is white to cream, often with a thin gold line just above the marginal sutures. Faint brown blotches occur occasionally on the dorsum.

**Remarks.** — Lorenz & Fehse (2009) described the closely related *Margovula crawfordcatei* and distinguished it from *Margovula marginata* by being the more inflated shell outline, less labral denticulation, the presence of two transverse brown lines on the dorsum, and a more curved posterior extremity in the former. *Margovula translineata* (Cate, 1973) is less inflated and more pyriform in shape, and has a crenulated funiculum. *Margovula marginata* is known to live in

association with soft corals such as *Dendronephthya* species. It has yet to be found alive in Singapore.

***Diminovula alabaster* (Reeve, 1865)**

(Figs. 4a–t, 19f–h)

**Material examined.** — 2 specimens (7.8 mm, 8.8mm) (ZRC.MOL.3016), empty shells among beach debris, National Sailing Centre, ECP, H. W. Wong coll., 17 Aug.2008; 1 specimen (11.1 mm) (ZRC.MOL.3015), on *Dendronephthya* species exposed at low tide, Singapore Armed Forces Ferry Terminal, CBP, 13 Aug.2010; 1 specimen (10.9 mm) (ZRC.MOL.3017), on *Dendronephthya* species exposed at low tide, southern coastline, Pulau Ubin, H. W. Wong coll., 14 Aug.2010.

**Shell description.** — The shell is generally ovate or elongated ovate. The posterior terminal is thick, rounded and elongated. The prominent funiculum is often weakly and unevenly crenulated. The labrum is finely denticulated. The aperture is narrow. The ventrum is smooth, calloused, and glossy, with younger specimens showing slight trace of the dorsal striation. The anterior canal is solid and the anterior terminal tip is elongated and rounded. Shell colour was most commonly milky white, although yellow, pink, and pale grey variations were sometimes observed. A distinct golden line encircles the shell above the margin and often disappears on the left side. The dorsum is covered with fine, incised, transverse striation, and usually bears three pairs of brown spots, but these were rather weak or not present on a few specimens.

**External morphology.** — The mantle is generally transparent, with small to medium sized, randomly placed, irregular round spots, which are either pink or grey in colour, and outlined by a thin darker line. The papillae, which are small, spaced-out, and wart-like, do not occur within these coloured spots. The foot is transparent, littered with pink to black dashes and lines. The siphon and tentacles seem to be of the same colour as the mantle spots. The tentacles are white at the tips.

**Remarks.** — The material examined revealed many variations in shape, size, labral dentition and colourations, and it is likely that further investigation will find these to represent more than one species. However, the taxonomic status of many related members in this group (e.g., *Diminovula aurantiomacula*, *Diminovula kosugei*, *Diminovula whitworthi*) are currently tentative (Lorenz & Fehse, 2009), making a definite species assignment of each and every variation difficult. For example, Fig. 4q–t illustrates a specimen resembling *Diminovula whitworthi* Cate, 1973, which can be differentiated from *Diminovula alabaster* by having more diffused spotting on the dorsum resembling bands, a wider aperture with more distinct labral denticulation, and less rostrate extremities. Fig. 4m–p illustrates a specimen resembling *Diminovula aurantiomacula* Cate & Azuma in Cate, 1973, which is differentiated from *Diminovula alabaster* by a weaker carinal ridge, a wider aperture, a shorter posterior terminal projection and more distinct courser teeth. *Diminovula alabaster* and its allies were commonly found living on a variety of *Dendronephthya* species in intertidal regions to shallow SCUBA depths of about 10 m.

***Prosimnia semperi* (Weinkauff, 1881)**

(Fig. 20a)

**Material examined.** — None.

**Shell description.** — The shell is nearly cylindrical, tapering toward each terminal. There is usually a prominent transverse dorsal keel about a quarter of the shell length from the rear. The funiculum forms the left wall of the posterior terminal canal. The aperture is narrow, and the labrum is flattened and narrow, with fine, irregular crenulations, occasionally with regularly spaced denticulations pointing outwards. The terminal canals are very narrow. The posterior terminal tip is

blunt, and the anterior terminal tip is almost pointed. The dorsum is covered with an irregularly granulose texture. The shell coloration is variable from maroon to white.

**External morphology.** — The mantle is transparent revealing the colour of the shell, with numerous tiny darker, closely spaced spots that are often not observed unless closely examined. The papillae, are few, large, oval in shape when partially retracted and well spaced apart. They often bear resemblance to the polyps of its host in terms of colour and appearance.

**Remarks.** — The shell of this species resembles that of *Prosimnia draconis* Cate, 1973, but the taxonomic status of the latter is uncertain and requires further study (Lorenz & Fehse, 2009). *Prosimnia draconis* is best distinguished from this species by a more prominent and somewhat elevated transverse dorsal keel that is usually crenulated. This new record is based on the photograph of a living animal taken off Pulau Sudong at an approximate depth of five metres in Dec.2009 (Fig. 20a) as no locally collected specimens were found in this study. Shell illustrations can be found in Lorenz & Fehse (2009).

***Sandalia cf. triticea* (Lamarck, 1810)**

(Fig. 8j–l)

**Material examined.** — 1 specimen (6.4 mm) (TSK), empty shell among beach debris, St. John's Island, 12 Apr.2008.

**Shell description.** — The shell is ovately rhomboid, but known to be variable in outline. The posterior terminal tip is bluntly pointed. The funiculum is bulging, triangular, and projecting. The labrum is calloused, flattened slightly, and is irregularly crenulated and denticulated. The ventrum is smooth and rounded, and develops into a strongly calloused anterior terminal ridge that is often linear in the longitudinal direction. The anterior terminal tip and obliquely pointed to blunt. The dorsum is striated more strongly near the terminals and weakening toward the middle. The shell is known to exhibit a variety of colours such as pale grey, red or purple.

**Remarks.** — *Sandalia meyeriana* (Cate, 1973) differs from *Sandalia triticea* by having a thinner shell with a uniformly paler coloration, a more undulate fossula margin, and a narrower aperture (Lorenz & Fehse, 2009). This species has not been found alive in Singapore. It is tentatively identified here as *Sandalia cf. triticea* due to the fact no recent specimens are available for inspection.

***Crenavolva striatula* (G. B. Sowerby I, 1828)**

(Figs. 5a–l, 20b–d)

**Material examined.** — 2 specimens (8.9 mm, 8.6 mm) (ZRC.MOL.3018), beach worn specimens, Bedok Jetty, ECP, H. W. Wong coll., Jun.2010; 3 specimens (9.3 mm, 8.9 mm, 7.2 mm) (WHW), living animals on gorgonians among debris in tangled fishing gear, Bedok Jetty, ECP, Jun.2006.

**Shell Description.** — The shell is rhomboid in shape. The funiculum is a small crenulated bulge that develops into the left wall of the posterior terminal canal. The labrum is calloused, flattened, and crenulated more strongly toward the posterior half, occasionally developing into weak outward pointing denticles at the posterior terminal. The anterior terminal tip is obliquely squared. The dorsum is covered with closely spaced incised transverse striation, and the shell is orange to red in colour with three distinct transverse paler regions that extend to the labrum.

**External Morphology.** — The mantle is transparent, such that the colour of the shell and the three pale transverse bands are observable. Covering the mantle all over are evenly distributed tiny spots,

which are darker red or white. The papillae are large, few, and spaced out, and always observed to be of a darker red coloration. The tentacles are contrastingly pale at the tips to about a third of the length. The tail end of the foot sports a broad, dark orange longitudinal stripe.

**Remarks.** — Along with *Crenavolva marmorata* Fehse, 2007 and *Crenavolva janae* Lorenz & Fehse, 2009, these three species are similar in that they have three distinct paler patches or transverse bands that extend to the labrum. *Crenavolva marmorata* is distinguished from this species by having a more elongated shell shape and paler yellowish coloration, and *Crenavolva janae* is distinguished by a more ovate shell shape and more distinct pale blotching on the dorsum. A lone record of *Crenavolva striatula* in Singapore was published in a checklist of the molluscan collection at the National Museum of Wales (Trew, 1987). Faded beach worn specimens were found in shell debris deposited at the high tide mark. Living animals were rarely found on gorgonians exposed during very low tides at ECP, and only recently photographed at SCUBA depths off Pulau Hantu. The living animals can be distinguished from other locally occurring members of the genus by the colour of their papillae, which are always white in *Crenavolva guidoi*, *Crenavolva leopardus* and *Crenavolva traillii*.

***Crenavolva aureola* (Fehse, 2002)**

(Fig. 5m–t)

**Material examined.** — 5 specimens (6.3 mm, 6.5 mm, 6.7 mm, 6.8 mm, 8.0) (ZRC.MOL.3026) beach worn specimens, ECP, H. W. Wong coll., Dec.2009; 2 specimens (SL 5.7 mm, 7.3 mm) (TSK), empty shell among beach debris, St. John's Island, 12 Apr.2008.

**Shell description.** — The shell is spindle-shaped, inflated in the middle, occasionally with a transverse dorsal keel between the middle and posterior third of the shell. The posterior terminal is often obliquely pointed. The funiculum develops into the left wall of the posterior canal and is irregularly crenulated. The labrum is thickened, flattened, and denticulated more prominently in the posterior half. The anterior terminal ridge is solid and prominent, and linear in the longitudinal direction. The transverse striation is coarse and distinct over the entire dorsum. The colour of the shell is usually uniform shades of dark red.

**Remarks.** — Although no living specimens were found in this study, beach worn specimens from ECP and St. John's Island examined here were distinguished from other locally occurring species of the genus (e.g., *Crenavolva leopardus*, *Crenavolva traillii*) by the inflated spindle shape and coarser striation. A specimen of *Crenavolva aureola* collected from sites "South Singapore" is illustrated in Lorenz & Fehse (2009).

***Crenavolva leopardus* Fehse, 2002**

(Figs. 6a–x, 20e–h)

**Material examined.** — 2 specimens (9.5 mm, 8.5 mm) (ZRC.MOL.3022), on gorgonians exposed at low tide, National Sailing Centre, ECP, H. W. Wong coll., 16 Oct.2008; 1 specimen (9.1 mm) (ZRC.MOL.3019), hand picked off gorgonian at 11-m depth when diving, South Jetty, Pulau Hantu, C. H. Toh coll., 28 Mar.2010; 3 specimens (7.6 mm, 8.0 mm, 8.7 mm) (ZRC.MOL.3021), on gorgonians exposed at low tide, Changi Creek, H. W. Wong coll., 13 Aug.2010; 3 specimens (9.9 mm; 9.8 mm; 9.2 mm) (ZRC.MOL.3020), on gorgonians exposed at low tide, southern coastline, Pulau Ubin, H. W. Wong coll., 14 Aug.2010.

**Shell description.** — The shell is rectangularly ovate in shape. The posterior terminal tip is pointed and usually strongly indented such that the left rear terminal edge projected beyond that of the right side. The funiculum is short for the genus, and tapers to the rear to form a pointed left wall of the

posterior terminal canal. The labrum is thickened and flattened, and is crenulated and denticulated irregularly in the posterior half. The fossula is very slightly concave, and the inner carinal ridge is reddish cream. The anterior terminal ridge is prominent and longitudinally linear. The anterior terminal is rectangular or weakly indented. Fine, transverse striation is observed over the entire dorsum. The shell coloration is variable, with yellow, orange, red and mauve occurring commonly in Singapore. There is usually a distinct paler coloured transverse mid dorsal band.

**External morphology.** — The mantle, foot and tentacles are red to orange translucent. The mantle is covered with many small dark-red spots. The papillae are white and longer on the mid-dorsum area. The siphon is dark orange to brown. The tentacles are contrastingly pale at the tips to about a third of the length. The tail end of the foot sports a broad, darker coloured longitudinal stripe. See Fehse (2002) for further details on the external morphology of the animal.

**Remarks.** — Fehse (2002) explained that the holotype of this species illustrated in Cate (1973) was misidentified as a hypotype of *Crenavolva renovata* (Iredale, 1930), which Fehse reassigned to the genus *Cuspivolva* Cate, 1973. Fehse (2002a) mentioned that the type locality is “Caramata Passage (01°14' N; 103°55' E) near Singapore”. *Crenavolva leopardus* was commonly found living on a variety of gorgonian species alongside populations of *Crenavolva traillii* and *Cuspivolva queenslandica* in intertidal regions on the mainland shores of CBP and ECP, to shallow SCUBA depths of about 10 m in the southern islands.

***Crenavolva traillii* (A. Adams, 1855)**

(Figs. 7a–t, 21a–e)

**Material examined.** — 2 specimens (9.5 mm, 12.7 mm) (ZRC.MOL.3023), on gorgonians exposed at low tide, Changi Beach Club, H. W. Wong coll., 16 Jun.2009; 2 specimens (11.4 mm, 11.4 mm) (ZRC.MOL.3025), on gorgonians exposed at low tide, Bedok Canal, ECP, H. W. Wong coll., 15 Jun.2010; 3 specimens (15.5 mm, 11.9 mm, 10.9 mm) (ZRC.MOL.3024), on gorgonians exposed at low tide, southern coastline, Pulau Ubin, H. W. Wong coll., 14 Aug.2010.

**Shell description.** — The shell is rectangularly ovate in shape. The posterior terminal is rectangular. The funiculum is long, tapering into the left wall of the posterior canal. The labrum is crenulated and denticulated irregularly, more so in the posterior half. The ventrum is smooth and glossy, sometimes showing traces of the dorsal striation. The anterior terminal ridge is prominent and longitudinally linear. The anterior terminal is somewhat rectangular or obliquely rectangular. Fine, transverse striation is observed over the entire dorsum. The shell coloration is variable, with yellow, orange, red and mauve occurring commonly in Singapore. A distinct paler coloured transverse mid dorsal band is rare.

**External morphology.** — The soft parts resemble that of *Crenavolva leopardus* closely. The mantle, foot and tentacles are red to orange translucent. The mantle is covered with many small dark-red spots. The papillae are white and longer on the mid-dorsum area. The siphon is dark orange to brown. The tentacles are contrastingly pale at the tips to about a third of the length. The tail end of the foot sports a broad, darker coloured longitudinal stripe.

**Remarks.** — This species can be differentiated from *Crenavolva leopardus* by usually lacking the pale transverse dorsal band, an often less distinct transverse dorsal keel, a longer funiculum, and a more rectangular, less indented posterior terminal. Specimens identified as *Crenavolva* (*Crenavolva*) cf. *striatula traillii* (A. Adams, 1855) (ZRC.1995.54) by Goh et al. (1999) were not found in the ZRC and appear to have been lost, and the identification of these specimens could not be verified. Although Cate (1973) described this species as a subspecies of *Crenavolva striatula* (G. B. Sowerby I, 1828), both species are easily distinguished by distinct colour patterns and shell

characters (Fehse, 2002a). Both species have been recorded from Singapore waters (Goh et al., 1999; Trew, 1987; refer to Table 1), and since no illustrations or descriptions of the specimens are available in the published records, it cannot be determined if the identification of the specimens were in anyway influenced by the confusion initiated by Cate (1973) unless the specimens are inspected. Specimens of *Crenavolva traillii* collected from sites “South Singapore” are illustrated in Lorenz & Fehse (2009). *Crenavolva traillii* was found living on a variety of gorgonian species alongside populations of *Crenavolva leopardus* and *Cuspidolva queenslandica* in intertidal regions on the mainland shores of CBP, ECP and Pulau Ubin. It appeared to be the least common species among the three.

***Crenavolva cf. guidoi* Fehse, 2002**

(Figs. 8a–d, 21f–h)

**Material examined** — 1 specimen (5.9 mm) (ZRC.MOL.3027), on sea whip at 11 m depth, North Jetty, Pulau Hantu, C. H. Toh coll., 28 Mar.2010; 3 specimens (5.7 mm, 5.9 mm, 6.0 mm) (ZRC.MOL.3028), beach worn specimens, ECP, H. W. Wong coll., Dec.2009.

**Shell Description** — The shell is small and rectangularly ovate in shape, somewhat resembling an elongated *Crenavolva traillii*. The posterior terminal tip is only weakly indented. The funiculum tapers into the left wall of the anal canal. The labrum is flattened, and mildly crenulated in the posterior third. Fine, transverse striation is observed over the entire dorsum. The shell colouration is varies from uniformly dark red-brown, red to yellow with a whitish labrum and more intensely coloured tips.

**External Morphology** — The mantle and foot appear the be translucent white, and the similarly coloured papillae are large, globule in shape, and well spaced apart. The siphon, rear tip of the foot, and middle third of the tentacles are coloured dark reddish brown.

**Remarks** – This species resembles *Crenavolva traillii* but can be distinguished by its smaller size, finer dorsal striation, and fewer dentitions on the labrum (Fehse, 2002a; Lorenz & Fehse, 2009). In addition, they are differentiated from *Crenavolva leopardus* of similar size by the absence of the paler mid dorsal transverse band commonly found on shells of the latter. The specimens examined in this study were identified based on these shell characters. However, it was noticed that the specimens examined had shells that were consistently bright white with orange tinged terminals, which might suggest that they might be a separate species. They are herein identified as *Crenavolva cf. guidoi*. A specimen of *Crenavolva guidoi* collected from sites “South Singapore” is illustrated in Lorenz & Fehse (2009).

***Crenavolva matsumiyai* Azuma, 1974**

(Fig. 7u–x)

**Material examined.** — 1 specimen (SL 9.0 mm) (WHW), CBP, 2006.

**Shell description.** — The shell is elongated rhomboid in shape, often with transverse dorsal keel about a third of its length from the posterior. The funiculum, posterior terminal tip and canal walls often appear crenulated. The labrum is flattened and appears constricted between the anterior and the mid line, and has strongly developed denticulations posteriorly such that some project past the periphery of the labrum. The posterior and anterior terminal tips are only slightly indented, and the terminal canals are often pointed upwards, more so at the posterior. The dorsum is covered with transverse striation, and the entire shell is usually coloured bright red to orange, although paler variations are known to exist.

**Remarks.** — The reddish coloration, elegantly curved labrum, rostrate terminals, and strong posterior labral denticulation make this a rather unmistakable species. Although the lone specimen examined was collected on gorgonian species exposed in the intertidal mud flats of Changi, it is otherwise found almost exclusively at SCUBA depths of about 35 m or more in the Philippines (F. Lorenz, pers. comm.). Known only from Japan just ten years ago (Fehse, 2002a), this species has since been found throughout the Indo-Pacific (Lorenz & Fehse, 2009).

***Primovula cf. tropica* F. A. Schilder, 1931**  
(Fig. 8m–p)

**Material examined.** — 1 specimen (SL 6.3 mm) (TSK), empty shell among debris at high tide line, St. John's Island, 12 Apr.2008.

**Shell description.** — The shell has a spindle shape inflated at the middle, and roundly shouldered at about the posterior third. The posterior terminal is bluntly pointed. The funiculum is small, triangular, prominent and crenulated. The labrum is rounded and covered with fine denticulation. The aperture is narrow throughout. The anterior terminal is obliquely rectangular. The entire dorsum is covered with regular incised striation. The shell is known to exhibit reddish or pinkish colorations, with terminals more intensively coloured.

**Remarks.** — Lorenz & Fehse (2009) commented that not much is known about this species, and despite being unmistakably unique from other members of the genus in shell features, specimens appear to be rare and poorly studied. This species is almost exclusively known from the western Indian Ocean. The shell examined in this study is tentatively assigned to this species based on the absence of darker coloured dorsal transverse bands and transverse striations that are well developed over the entire dorsum, distinguishing it from other members of the genus *Primovula*. However, since it differs from *Primovula tropica* illustrated in Cate (1973) and Lorenz & Fehse (2009) by having a distinctively pointed posterior terminal, more specimens will be required to identify it confidently. It is uncertain if specimens identified by Goh et al. (1999) as *Crenavolva (Crenavolva) cf. rosewateri* Cate, 1973 are actually this species as the ZRC material (ZRC.1995.57–58) appears to have been lost.

***Primovula roseomaculata* (Schepman, 1909)**  
(Fig. 8q–x)

**Material examined.** — 2 specimens (4.3 mm, 5.2 mm) (ZRC.MOL.3029), beach worn shell among beach debris, ECP, H. W. Wong coll., Jun.2010.

**Shell description.** — The shell is pyriform in shape and somewhat inflated toward the posterior. The funiculum is prominent, crenulated, triangular in shape, and bulging. The labrum is crenulated and covered with numerous fine denticulations throughout. The aperture is narrow, and the inner adaxial carinal ridge is well developed. The posterior terminal canal is protruding, and both terminal tips appear blunt and rectangular. The dorsum is entirely covered with fine striations. The shell colour is known to be white to pink, with darker coloured dorsal semi circular markings.

**Remarks.** — *Primovula fulguris* (Azuma & Cate, 1971) appears rather similar in shell appearance, and might be an extreme variation of this species (Lorenz & Fehse, 2009). The lone record of this species in Singapore was published in a checklist of the molluscan collection at the National Museum of Wales (Trew, 1987). No living animals have been found recently.

***Cuspidolva ostheimeriae* Cate, 1973**

(Figs. 10a–d, 22e–h)

**Material examined.** — 1 specimen (7.1 mm) (ZRC.MOL.3030), on gorgonians exposed at low tide, CBP, H. W. Wong coll., Jul.2010.

**Shell description.** — The shell is rhomboidal, somewhat inflated and roundly shouldered just behind the mid line. The funiculum is large, triangular and projecting. The labrum is flattened and regularly crenulated. The aperture is narrow throughout. The posterior terminal tip is rounded but pointed and the anterior terminal tip is obliquely rectangular. The dorsum is entirely covered with incised transverse striation. The shell is pink to red, with two or three paler transverse dorsal bands.

**External morphology.** — The appearance of the soft parts appears similar to that of *Cuspidolva singularis*. The mantle is generally transparent, covered with numerous, small, closely and evenly spaced dark brown and white spots all over. The papillae are small and white. The foot is light cream, and the tentacles have a broad darker orange-grey band near the middle. The siphon tips are darker coloured as well.

**Remarks.** — This species is closely related to *Cuspidolva howlandae* (Cate, 1974) as can be seen from the similar diamond or rhomboidal shape, but can be differentiated by the former having a weaker transverse dorsal keel, having a larger funiculum, and by its banded coloration. *Cuspidolva singularis* is also similar but can be distinguished by more elongated shape and a white to yellow coloration. The living animal was found on gorgonian species exposed during low tide.

***Cuspidolva singularis* (Cate, 1973)**

(Figs. 10e–x, 22a–d)

**Material examined.** — 3 specimens (4.9 mm, 7.3 mm, 8.5 mm) (ZRC.MOL.3032), beach worn shells, CBP, H. W. Wong coll., 18 Aug.2008; 1 specimen (7.3 mm) (ZRC.MOL.3031), on gorgonians exposed at low tide, CBP, H. W. Wong coll., 13 Jul.2010; 2 specimens (8.3 mm, 6.5 mm) (ZRC.MOL.3033), on gorgonians exposed at low tide, ECP, H. W. Wong coll., 16 Jun.2010; 2 specimens (8.0 mm, 9.1 mm) (ZRC.MOL.3034), on gorgonians exposed at low tide, Pulau Ubin, H. W. Wong coll., 15 Jul.2010; 7 specimens (SL 4.4–6.1 mm) (TSK), empty shells among beach debris at high tide line, St. John's Island, 12 Apr.2009; 2 specimens (SL 5.3 mm, 5.4 mm) (TSK), empty shells among beach debris, Changi, 23 Oct.2005.

**Shell description.** — The shell is rhomboidal, somewhat inflated and roundly shouldered at the posterior third. The posterior terminal tip is sharp and pointed. The funiculum is large, triangular and projecting. The labrum is flattened and weakly crenulated, with denticulation more developed in the posterior half such that some teeth project past the periphery of the labrum. The anterior terminal tip is obliquely rectangular. The dorsum is completely covered with well developed incised transverse striations. The shell is lemon yellow to translucent white, sometimes with two or three paler bands. The terminals are orange.

**External morphology.** — The mantle is generally transparent, covered with numerous, small, closely and evenly spaced dark brown and white spots all over. The papillae are small and white. The foot is light cream, and the tentacles have a broad darker orange-grey band near the middle. The siphon tips are darker coloured as well.

**Remarks.** — Further investigation into the occurrence of this group in Singapore might reveal more than a single species, as suggested by the variations in shell characters exhibited by the specimens examined. This species resembles *Cuspidolva bellica* (Cate, 1973), and is differentiated by the latter



having more colour variations, weaker dorsal striation, the shape of its funiculum, and by the labrum being more strongly denticulate throughout instead of only in the posterior half (Lorenz & Fehse, 2009). Fig. 10u–x is an example of small shell possessing the large bulging funiculum characteristic of that of *Cuspidolva indica* (Reeve, 1865), a taxon whose status was considered doubtful by Lorenz & Fehse (2009) as its original description was based on an eroded specimen. The living animals of *Cuspidolva singularis* were observed on gorgonian species exposed during low tides. They appeared to be host specific. Beach worn shells of this species were found at Changi, ECP, and St. John's Island.

***Cuspidolva formosa* (G. B. Sowerby II in Adams & Reeve, 1848)**  
(Figs. 11a–t, 23a–b)

**Material examined.** — 1 specimen (9.3 mm) (ZRC.MOL.3035), beach worn shell, ECP, H. W. Wong coll., Jun.2009; 3 specimens (10.0 mm, 10.7 mm, 11.1 mm) (ZRC.MOL.3036), on gorgonians exposed at low tide, CBP, H. W. Wong coll., 13 Jul.2010; 2 specimens (10.0 mm, 10.1 mm) (WHW), rotting specimens among abandoned fishing gear, ECP, Jun.2006.

**Shell description.** — The shell is elongated rhomboidal. The funiculum is large, but often not projecting. The left wall of the posterior canal is solid and thickened, curving slightly to the right where the posterior canal opens. The posterior terminal tip is pointed, and the anterior terminal tip is obliquely rectangular or weakly indented. The labrum is thick and flattened, and denticulated more prominently in the posterior half with teeth occasionally extending past the posterior outer labral margin. The ventrum is smooth, rounded and glossy. The dorsum is covered with transverse, incised striation, and is usually white or yellow with irregular blotches of orange or violet. The terminal tips are darker orange.

**External morphology.** — Among the individuals observed in situ, the pattern and coloration of the mantle appears to be consistent with little variation, and is distinct from any of the other locally occurring ovulids. The mantle is transparent with large, round blotches of black regularly spaced apart covering the entire shell. The tentacles are pale with a dark broad, transverse band at the middle. The foot is pale and entirely covered with tiny black spots.

**Remarks.** — The shell characters and coloration of this species are usually sufficient to distinguish it from other members of the family. The examined specimens are less elongated, broader, and more rounded at the terminals than typical shells, and represent a form occasionally found in the Philippines (F. Lorenz, pers. comm.). However, the shells from Singapore are consistently coloured with pale yellow instead of the more typical violet. The living animals were observed on gorgonian species in shallow water exposed during low tides, and they appeared to be host specific at Changi Beach Park where they were found.

***Cuspidolva queenslandica* (Cate, 1974)**  
(Figs. 12a–x, 23d–h)

**Material examined.** — 2 specimens (8.3 mm, 11.8 mm) (ZRC.MOL.2840), isopropyl alcohol dried, ECP, H. W. Wong coll., 13 Jun.2006; 2 specimens (7.0 mm; 8.4 mm) (ZRC.MOL.3037), isopropyl alcohol dried, CBP, H. W. Wong coll., 16 Oct.2008; 2 specimens (8.3 mm, 8.8 mm) (ZRC.MOL.3039), on gorgonians exposed at low tide, ECP, H. W. Wong coll., Jun.2010; 1 specimen (10.8 mm) (ZRC.MOL.3038), on gorgonians exposed at low tide, Pulau Ubin, H. W. Wong coll., 15 Jul.2010.

**Shell description.** — The shell is cylindrical to ovately rhomboidal in shape. The funiculum is large, and rounded. The posterior terminal tip is usually rounded and less commonly pointed, and

the anterior terminal tip is obliquely rectangular or weakly indented. The labrum is thickened and flattened, and crenulated irregularly in the posterior half. The labral denticulation is usually weak, although some specimens possess a few prominent teeth in on the posterior. The dorsum is covered with transverse, incised striation, and the shell is usually uniformly coloured a dark brownish red, although some specimens exhibited lighter colours of orange or red.

**External morphology.** — Wong (2008) reported that the mantle of the living animal is translucent and covered with small, closely spaced maroon dots. The papillae are large, spaced out and are always white. The white colouration extends to the areas around the papillae giving a mottled appearance to the mantle. The siphon, tentacles, head, body and foot are maroon to purple, although a few were observed to have an orange foot. Tentacles are always white at the tips.

**Remarks.** — This species was first recorded in Singapore by Wong (2008) as *Cymbovula segaliana* Cate, 1974, but Lorenz & Fehse (2009) found specimens from Singapore to be conchologically similar to *Cuspidovula queenslandica*. Although easily recognisable by the shell shape and coloration, the form of the posterior terminal and the degree of posterior labral dentition tends to vary considerably. Fig. 12i–l is an example of a specimen with terminal processes resembling *Cuspidovula formosa*. It is locally common on gorgonian species in shallow water along the east coast of Singapore, and has been observed less commonly on the north east coastlines of Pasir Ris, Changi and Pulau Ubin. This species was found almost always on the same orange or mauve, thinly branched sea fan species.

***Dentiovula dorsuosa* (Hinds, 1844)**

(Fig. 8a–h)

**Material examined.** — 1 specimen (8.2 mm) (ZRC.MOL.3040), faded empty shell among debris at high tide line, ECP, H. W. Wong coll., Dec.2009.

**Shell description.** — The shell is ovately rhomboidal, shouldered at the posterior third. The terminal tips are rectangular or only weakly indented. The funiculum is small and crenulated. The labrum is rounded posteriorly, flattening out anteriorly, and finely denticulated throughout with teeth occasionally extending past the posterior outer labral margin. The aperture is narrow. The entire dorsum is covered is fine, incised transverse striation. Shell colour is variable from white, to yellow, to rose or violet. Occassionally, a yellow line encircles the shell above the margin and often disappears on the left side, and three transverse yellow lines might be found on the mid dorsal hump and toward each terminal.

**Remarks.** — This shell of this species resembles that of *Dentiovula marie* (F. A. Schilder, 1941). The latter is distinguished by having a smaller size, being less calloused, having a more distinctively curved posterior aperture, having less labral teeth, having finer dorsal transverse striation, and more branching papillae on its mantle (Lorenz & Fehse, 2009). The living animal has not been found since Cate (1973) reported it from Singapore.

***Dentiovula rutherfordiana* (Cate, 1973)**

(Fig. 9a–d)

**Material examined.** — 1 specimen (SL 11.0 mm) (CSY), beach worn specimen among debris, ECP, Mar.1994.

**Shell description.** — The shell is rhomboidal in shape. There is a distinct transverse dorsal keel at its broadest point about a third of the shell length from the posterior. The funiculum is small but calloused and slightly projecting. The labrum is broadly flattened and weakly crenulated. The

aperture is narrow. The entire dorsum is covered with fine, incised transverse striation. The shell is generally white, although pinkish specimens have been found in the Philippines. Occasionally, a thin yellow line encircles the shell margin.

**Remarks.** — Red coloured shells with slightly finer striation from the Philippines are currently assigned to *Dentiovula horai* (Cardin, 1994), but since occasional white specimens from the same location are almost indistinguishable from *Dentiovula rutherfordiana*, further investigation should be done to determine if they are indeed variations of the same species. This species can be differentiated from *Dentiovula dorsuosa* by its distinct transverse dorsal keel, weak labral denticulations, and its calloused and projecting funiculum. The specimen illustrated in Fig. 9a–d is beach worn, but its shell features clearly distinguish it from any other species found locally. Apart from the unique shell shape, it is identified as *Dentiovula rutherfordiana* on the basis of the presence of a thin golden line encircling the shell which is known to occasionally occur in this species.

### ***Dentiovula* species**

(Fig. 9e–x)

**Material examined.** — 1 specimen (7.5 mm) (ZRC.MOL.3041), empty shell among debris at high tide line, Area C, ECP, H. W. Wong coll. Jun.2009; 2 specimens (8.1 mm, 7.5 mm) (WHW), empty shells among debris at high tide line, Area C, ECP, H. W. Wong coll., 2009; 2 specimens (SL 7.6 mm, 8.8 mm) (TSK), empty shells among debris at high tide line, Changi East, 23 Oct.2005.

**Shell description.** — The shell is elongated rhomboidal in shape. The anterior terminal is rounded, and posterior terminal is narrow, protruding, and bluntly rounded. There is a rounded transverse dorsal keel at its broadest point about a third of the shell length from the posterior. The funiculum is large, triangular, and bulging. The labrum is broadly flattened and strongly crenulated especially in the rear half. The aperture is narrow. The entire dorsum is covered with fine, incised transverse striation.

**Remarks.** — The five specimens examined are a likely a new species (F. Lorenz pers. comm.) as can be seen by their consistent conchological features. They are smaller and more ovate, lacking the distinct dorsal keel of typical *Dentiovula rutherfordiana*, superficially resembling the holotype of *Cuspidovula narinosa* (Cate, 1973), which Lorenz & Fehse (2009) consider to be of doubtful taxonomic status. According to Fehse (2011), the local specimens differ from *Cuspidovula narinosa* by the more distinctly crenulated labrum in the former. In addition, they both are distinguished from the recently described *Dentiovula lorenzi* (Fehse, 2011), among other shell characters, by the latter having more regularly spaced striation. As the shells from Singapore are much too worn to be identified, and do not seem to resemble any other known species with certainty, they are herein identified as *Dentiovula* species.

## **Subfamily Ovulinae Fleming, 1828**

### ***Volva volva* (Linnaeus, 1758)**

(Fig. 18u–x)

**Material examined.** — 2 specimens (56.2 mm, 73.6 mm) (ZRC.MOL.3042), shell fragments among debris at high tide line, ECP, H. W. Wong coll., 31 Oct.2008; 1 specimen (80.0 mm) (ZRC.MOL.3043), beach worn empty shell, CBP, H. W. Wong coll., 2009; 1 specimen (SL 25.0 mm) (CSY), juvenile, empty shell, ECP, Apr.1994; 1 specimen (SL 68.0) (WHW), empty shell among beach debris, Changi East, 2006.

**Shell description.** — The shell is large with two equally long, straight, elongated terminal canals which have incised transverse striation, sometimes curving upwards gently. The centre of the shell is ovate and inflated. The shell is generally white or cream. The fossula and funiculum are lacking. The outer lip is thickened but not toothed, and the dorsum is either smooth.

**Remarks.** — About four other species share the unique shell shape with *Volva volva*; *Volva cumulata* Iredale, 1931 has a more inflated body whorl and calloused labrum; *Volva striata* (Lamarck, 1810) and *Volva habei* Oyama, 1961 have transverse dorsal striation covering the dorsum; *Volva kilburni* Cate, 1975 is more fragile and separated from other members of the genus based on animal morphology and by radula differences. *Amphiperas volva* mentioned in a checklist by Chou et al. (1994) probably refers to *Volva volva*. This animal has not been observed alive in Singapore recently. Dharma (2005) reported this species from Bintan Island, Indonesia, southeast of Singapore.

***Pellasiimnia angasi* (Reeve, 1865)**

(Figs.17a–p, 24a–f)

**Material examined.** — 1 specimen (24.5 mm) (ZRC.1975.3.6.26), off Pulau Tekong, Jun.1924; 1 specimen (19.4 mm) (ZRC.MOL.3044), empty shell, CBP, H. W. Wong coll., 14 Nov.2008; 1 specimen (20.0 mm) (ZRC.MOL.3045), empty shell, ECP, H. W. Wong coll., Dec.2009; 3 specimens (SL 19.9 mm, 20.2 mm, 21.0 mm) (WHW), fishing bycatch, ECP, 2007.

**Shell description.** — The shell of this species is elongate in shape, with terminals drawn out only moderately. The length of the terminal canals varies among specimens. There is no funiculum. The shell is glossy and smooth, with weak striation occurring only on the anterior and posterior ends. The thickly formed outer lip terminates before the inner-lip at both ends, and is weakly angulated about a fifth of the shell-length from the anterior end. The dorsum, margins, and base are all white or cream, although pink and rose coloured specimens seem to be just as common in Singapore. The tips of the canals are sometimes tinged brownish orange.

**External morphology.** — The mantle of this species has a mantle pattern similar to *Pellasiimnia improcera*. The mantle is transparent, covered by large irregularly shaped but rounded red to orange blotches that stretch over large portions of the shell longitudinally, giving it a striped camouflage appearance. Closer examination of these red or orange blotches reveals faint, irregular, closely spaced darker pixelated patterns. In the case of *Pellasiimnia angasi*, these blotches often merge, making the mantle appear red with only white spots. The papillae are small, triangular, numerous, and always pale or white, usually occurring within the white areas on the mantle. The foot is translucent white, and the edges are outlined by a thin darker line all around. The front tip of the foot sports a handful of thin longitudinal dark coloured stripes, and there is a dark red or orange longitudinal stripe at the rear end of the foot. The tentacles are white with two broad darker bands, the one nearer the base extending toward the eye.

**Remarks.** — This species closely resembles *Pellasiimnia improcera*, but the shells of the latter can be differentiated by being generally smaller in size, a thinner outer lip, a less inflated and more slender outline, a weaker and more gradual angulation at the anterior shoulder of the outer lip, a much narrower aperture, a smoother dorsum, and darker orange terminals (Wilson, 1993; Fehse & Weise, 1993, Lorenz & Fehse, 2009). *Pellasiimnia maccoyi* (Tenison-Woods, 1878) from south and eastern Australia is similar, but it has shorter, broader terminals, and is more calloused (Lorenz & Fehse, 2009). *Pellasiimnia angasi* has been observed and photographed on different coloured *Melithaea* species in Singapore, either exposed at very low tides at East Coast Park (Fig. 24a) or at SCUBA depths off Pulau Sudong (Fig. 24b) and Changi (Fig. 24c–d). A number of specimens examined were caught in tangled fishing gear off Bedok Jetty, East Coast Park.

***Pellasmimnia improcera* (Azuma & Cate, 1971)**

(Figs. 17q–x, 24g–h)

**Material examined.** — 1 specimen (14.0 mm) (ZRC.MOL.3046), empty shell, CBP, H. W. Wong coll., 14 Nov.2008; 2 specimens (8.5 mm, 9.0 mm) (ZRC.MOL.3047), empty shells, ECP, H. W. Wong coll., Dec.2009; 1 specimen (SL 19.1 mm) (WHW), fishing bycatch, ECP, 2007; 1 specimen (SL 23.4 mm) (WHW), empty shell, CBP, 2005.

**Shell description.** — The shell of this species is lanceolate in shape, with terminals drawn out only moderately. Weak incised transverse striation occurs at the anterior and posterior ends, occasionally over the entire dorsum. The outer lip terminates before the inner-lip at both ends, and is weakly angulated about a fifth of the shell-length from the anterior end. There is no funiculum. The dorsum, margins, and base are all white or cream. The tips of the canals are tinged yellow.

**External morphology.** — See *Pellasmimnia angasi*.

**Remarks.** — This species is similar to *Pellasmimnia angasi*, but can be differentiated based on shell characters (see *Pellasmimnia angasi* for discussion on differences). In Singapore, this species was photographed on *Antipathes* species at SCUBA depths off Pulau Semakau (see Ng, 2009: 91, Fig. 4) and on *Melithaea* species at the intertidal area of East Coast Park.

***Phenacovolva rosea* (A. Adams, 1854)**

(Figs. 13a–x, 25g–h, 26d–h)

**Material examined.** — 3 specimens (30.2 mm, 31.8 mm, 33.9 mm) (ZRC.MOL.3048), on gorgonian exposed at low tide, CBP, H. W. Wong coll., Jun.2009; 2 specimens (23.0 mm, 34.5 mm) (ZRC.MOL.3049), on gorgonian exposed at low tide, Pulau Ubin, H. W. Wong coll., 15 Jul.2010; 1 specimen (25.1 mm) (ZRC.MOL.3050), on gorgonian exposed at low tide, ECP, H. W. Wong coll., 14 Jun.2010.

**Shell description.** — The shell is spindle-shaped, with the middle area slightly more inflated than the anterior and posterior, which taper gradually to form pointed terminal tips. The relative length of the canals appears to vary between specimens. The funiculum is represented by a weak node at the base of the posterior canal. The labrum is thickened, folded inwards, and smooth, abruptly bent inwards about a fifth of the shell length from the anterior. Transverse striation is absent or barely noticeable on the middle of the dorsum, but becomes more incised and prominent toward the terminals. The shell is usually coloured shades of orange or red, and sports an often distinct, thin, paler coloured transverse band at the middle. The labrum is usually paler in colour.

**External morphology.** — The mantle is translucent crimson red, densely covered with small dark red spots. The papillae are yellow, arising from white spots. The siphon is of a similar colour to that of the mantle. The tentacles are white and encircled by two broad mauve bands. Fehse (1999) compared in detail the external morphology of this species and other related members, but it is found in this study difficult to distinguish between this and the closely related *Phenacovolva nectarea*.

**Remarks.** — Some authors consider *Phenacovolva rosea* and *Phenacovolva nectarea* to be different forms of the same species, but according to Lorenz & Fehse (2009), *Phenacovolva nectarea* usually exhibits paler colours, and the lighter dorsal transverse band is often broader and less distinct, and the terminal tips are brightly coloured orange. Fig. 13u–x shows a shell with distinct, transverse striation covering the entire shell including the mid dorsal area. Lorenz &

Fehse (2009) illustrated shells of this variation, commenting that further investigations might possibly determine it to be a separate species. The animals of this variation were not immediately distinguishable. Photographs of live *Phenacovolva rosea* from Singapore were published by Lorenz & Fehse (2009). In this study, it was found on a variety of gorgonian species exposed at low tide, and the live animal has been photographed at SCUBA depths off Pulau Hantu (Fig. 26f).

***Phenacovolva nectarea* Iredale, 1930**

(Figs. 14a–t 26a–d)

**Material examined.** — 2 specimens (28.3 mm, 30.3 mm) (ZRC.MOL.3052), beached shells, Bedok Jetty, ECP, H. W. Wong coll., 9 Apr.2007; 1 specimen (27.5 mm) (ZRC.MOL.3051), tangled fishing gear, off Bedok Jetty, ECP, H. W. Wong coll., Jun.2006.

**Shell description.** — The shell of this species closely resembles *Phenacovolva rosea* in shape (see shell description of *Phenacovolva rosea*), but *Phenacovolva nectarea* usually exhibits paler colours, and the lighter dorsal transverse band is often broader and less distinct, and the terminal canals are light coloured, usually orange or yellow.

**External Morphology.** — See *Phenacovolva rosea*.

**Remarks.** — Some authors consider this species to be synonymous with *Phenacovolva rosea* (see *Phenacovolva rosea* for discussion on differences). This species was first recorded by Trew (1987) and Goh et al. (1999) in Singapore as *Phenacovolva tokioi* (Cate, 1973), considered by Lorenz & Fehse (2009) to be a junior synonym. Photographs of live *Phenacovolva nectarea* from Singapore were published by Lorenz & Fehse (2009). *Phenacovolva nectarea* was found on a variety of gorgonian species exposed at low tide, and has been photographed at SCUBA depths off Pulau Hantu and Pulau Semakau.

***Phenacovolva dancei* Cate, 1973**

(Figs. 15q–t, 25a)

**Material examined.** — 1 specimen (25.0 mm) (ZRC.1975.3.6.27), dredged at 18 fathoms (1°25'03'' N; 102°58' E), M. W. F. Tweedie coll., 11 Feb.1933.

**Shell description.** — The shell is spindle shaped, inflated centrally with terminal canals drawn out at equal lengths. The shell appears thin and translucent. The funiculum is weak and often represented by a crenulated swelling at the base of the posterior canal. The dorsum is often covered with incised transverse striations, occasionally weak at the mid dorsal area. The shell is pale orange with three indistinct, broad transverse bands. The terminal tips are orange.

**Remarks.** — This species can be differentiated from *Phenacovolva rosea* and *Phenacovolva nectarea* by the three, broad transverse pale bands across the dorsum and its relatively thinner shell. Shells of *Phenacovolva fusula* and *Phenacovolva barbieri* also often have three pale transverse bands, but the size and shape of the funiculum and the broader shell shape of these species distinguishes it from *Phenacovolva dancei*. Cate (1973) identified Singapore as the type locality of this species. It has been photographed on sea whips at SCUBA depths off Pulau Hantu (Fig. 26a). The ZRC specimen examined was labelled “*V. brevirostris*” but its elongated, spindle-shape and fragile character identifies it with *Phenacovolva dancei* instead.

***Phenacovolva brevirostris* (Schumacher, 1817)**

(Fig. 15a–t)

**Material examined.** — 1 specimen (33.0 mm) (ZRC.1975.3.6.25), dredged at 43 fathoms (3°48'10'' N; 100°14'50'' E), M. W. F. Tweedie coll., 21 Oct.1933.

**Shell description.** — The shell is spindle shaped and strongly inflated medially. The terminal canals are short and of equal length. The funiculum is a stout and prominent spiral cord. The labrum is thickened and calloused. The aperture is wide. The dorsum is smooth, and the terminals are transversely striated. The shell is rose to beige, with a wide, paler mid dorsal transverse band. Two more less distinct bands may occur on both sides of the central band. The terminals tips are orange.

**Remarks.** — This species resembles *Phenacovolva fusula*, which is broader anteriorly and has a more dorsal patterning. A number of beach worn specimens were examined in this study, and were assigned to this species based on the broad shell shape and prominent funiculum. *Phenacovolva barbieri* is different from this species as it has transverse striation covering the entire dorsum, and more distinctly coloured transverse banding. This species was included in a checklist by Chuang (1973), and Goh et al (1999) mentioned that although this species was reported in Singapore by Lim (1969a) as *Volva brevirostris*, the records were unverifiable due to the fact that the “location of the specimens is not known”. A locally collected specimen is illustrated in Lorenz & Fehse (2009).

***Phenacovolva barbieri* Lorenz & Fehse, 2009**

(Figs. 16a–t, 25b–f)

**Material examined.** — 1 specimen (20.0 mm) (ZRC.MOL.3053), beach worn specimen, ECP, H. W. Wong coll., Dec.2009; 1 specimen (24.3 mm) (ZRC.MOL.3054), on gorgonian exposed at low tide, Pulau Ubin, H. W. Wong coll., 15 Jul.2010.

**Shell Description.** — The shell is spindle-shaped and inflated medially. The funiculum is a strong spiral cord at the base of the posterior canal. The labrum is thick, calloused and rounded, often appearing to have weak denticulations. The dorsum is covered entirely with incised transverse striation. The shell is red to violet with a wide pale transverse band. Two more less distinct bands may occur on both sides of the central band. The terminals tips are orange.

**External morphology.** — The almost transparent mantle is covered with irregularly shaped, rounded black spots, with yellow, pointed papillae. The foot is flesh coloured, and the siphon and mantle posterior appear dark grey. The tentacles are encircled by two black bands.

**Remarks.** — The shell is similar to *Phenacovolva brevirostris*, but differs by having incised transverse striation covering the entire dorsum. The light and dark coloured transverse bands on the dorsum are also more strongly contrasting. This species was recorded from Singapore by Lorenz & Fehse (2009), and a photograph of what they thought might be the living animal is republished here for reference (Fig. 25e). The examined specimen in Fig. 16q–t is faded, but the dorsal striation covering the entire dorsum and heavily calloused labrum with weak denticulation assigns it to this species.

**Subfamily Aclyvolvinae Fehse, 2007**

***Aclyvolva lanceolata* (G. B. Sowerby, 1848)**

(Figs. 18a–d, 27g–h)

**Material examined.** — 1 specimen (23.0 mm) (ZRC.1975.3.7.157), dredged from 18 fathoms (1°25'03'' N; 102°58' E), M. W. F. Tweedie coll., 11 Feb.1933; 1 specimen (17.5 mm) (ZRC.1975.3.7.158), dredged, Pulau Pisang, Malaysia (01°46' N; 103°25' E), Jan.1934.

**Shell description.** — The shell is elongate and lanceolate in shape, somewhat cylindrical. There is no funiculum. The labrum is thickened and flattened without any denticulations, curving inwards at about a third of the shell length from the anterior. The posterior terminal tip is rounded and slightly pointed, and the posterior terminal sometimes appears distorted toward the right side. The anterior terminal is pointed. The dorsum is covered entirely with fine incised striation. The colour of the shell is orange red.

**Remarks.** — Shells of the genus *Aclyvolva* Cate, 1973 are distinguished from *Hiatavolva* Cate, 1973 by the rounded posterior terminal tips in the former, and can be distinguished from the genus *Kuroshiovolva* Azuma & Cate, 1971 by the latter having an almost linear aperture and squared terminals. This species is distinguished from the western Indian Ocean's *Aclyvolva nicolamassierae* Fehse, 1999, the latter having finer transverse striation, a narrower aperture, a more calloused ventrum, and paler red colorations. Purchon & Purchon (1981) mentioned that *Neosimnia lanceolatum* was “found crawling on gorgonians near Buran Darat” in dredge and trawl hauls between 1950 and 1960, but excluded from their checklist as “it has not been possible to check their identities at the British Museum (Natural History)”. Likewise, *Volva lanceolata* (Sowerby) mentioned in a checklist by Lim (1969a, 1969b) was excluded by Goh et al. (1999) as the locations of the specimens are not known. A ZRC specimen inspected in this study was dredged from the southern part of the Strait of Malacca, about 40 km west of Tuas, Singapore. The red coloured animal has been photographed by SCUBA divers off Pulau Hantu on sea fans and whips (Fig. 27g–h).

***Aclyvolva lamyi***

**(F. A. Schilder, 1932)**

(Figs. 18e–t, 27a–f)

**Material examined.** — 1 specimen (10.5 mm) (ZRC.MOL.3055), dried in ethanol, at 12-m depth on white sea whip, North Jetty, Pulau Hantu, C. H. Toh coll., 29 Nov.2009; 1 specimen (11.0 mm) (ZRC.MOL.3056), on sea whips at 10 m depth, North Jetty, Pulau Hantu, C. H. Toh coll., 28 Mar.2010.

**Shell description.** — The shell is elongate and lanceolate in shape, somewhat cylindrical. There is no funiculum. The labrum is thickened and flattened without any denticulations, and is curved inwards at about a third of the shell length from the anterior. The posterior terminal tip is rounded and slightly pointed, and the posterior terminal sometimes appears distorted toward the right side. The anterior terminal is pointed. The terminal canals of the examined shells were slightly curved upwards. The dorsum is covered entirely with fine incised striation. The colour of the shell is white.

**External morphology.** — The animals photographed in Singapore waters have a transparent mantle with large, globular, translucent white papillae scattered randomly, such that it resembles the polyps of its gorgonian host. Close examination reveals that each of the papillae is encircled by a faint orange-brown line. The foot is white with dark brown markings. The tentacles are mostly brown with white tips. A dark brown line marks the edge of the siphon and the tip of the anal canal.



**Remarks.** — *Aclyvolvula lamyi* (F. A. Schilder, 1932) is white and has a distinctly undulating labrum that sometimes appears denticulated at the anterior part (Lorenz & Fehse, 2009). This species was photographed commonly on sea whips off Pulau Hantu (Fig. 27a–c, e). Beached specimens at ECP were rarely encountered, perhaps due to its fragile nature.

## DISCUSSION

As discussed by Tan & Woo (2010), empty shells found on Singapore's beaches may not be an explicit indication of a species' presence. One example cited is small shells mixed in with sand imported for Singapore's extensive reclamation works. However, since there are a number of cases where living animals have been recorded for some species whose shells were common in reclaimed areas and initially thought unlikely to occur locally, benefit of doubt is given to discoveries of empty ovulid shells (e.g., *Globovula sphaera*, *Margovula pyriformis*, *Margovula marginata*, *Sandalia* c.f. *triticea*, and *Volva volva*) and such finds are regarded herein as sufficient proof of occurrence if the species is known to occur in Southeast Asia based on the literature.

In total, 44 species are recorded from Singapore, which is remarkable considering that massive coastal reclamation works in the 1960s left waters surrounding the island with chronic sedimentation levels (Low & Chou, 1994). The mention of *Vovla spelta* Linnaeus by Lim (1969a) is disregarded here as it is likely a junior synonym of *Neosimnia spelta* (Linnaeus, 1758), a species known only from the Mediterranean and Atlantic areas. Ten other records were not verified by this study. Of these, the recent taxonomic revision by Lorenz & Fehse (2009) found the taxonomic status of three species (*Cuspidovula renovata*, *Phenacovulva birostris*, *Testudovulva bullum*) doubtful and suggested that they were likely described based on aberrant forms of other species or material too decorticate to assign to any species. Three species (*Calpurnus verrucosus*, *Carpiscula bullata*, *Naviculavolva deflexa*) were not reported in Singapore or found in recent collections since their records by Cate (1973), and it is uncertain if habitat changes might have contributed to this apparent loss. *Calpurnus verrucosus* was recently found at Bintan Island, Riau Province, Indonesia (Fig. 19a–b), which suggests that it might still occur in Singapore waters. It is not known if the local record of *Cymbovula deflexa* mentioned in Cate (1973) was actually a white-coloured *Cuspidovula queenslandica*. After all, Cate (1974), in his description of *Cymbovula segaliana* (junior synonym of *Cuspidovula queenslandica*), mentioned that they appeared similar in shell appearance and described the holotype as being “milk white” in colour. One species (*Hiavolva depressa*) was included in a checklist by Tan & Woo (2010) based only on personal communication with malacological enthusiasts (S. K. Tan, pers. comm.), but no recent material is available for inspection and its occurrence here remains unverified. The ZRC material of two species (*Calcarovula longirostrata*, *Primovula rosewateri*) could not be located, and since there were no descriptions or illustrations of the shells in their mentioning references, their identifications remain unverified. A lone specimen from the ZRC labelled as *Amphiperas philippinarum* (Sowerby) (ZRC.1975.3.6.26) was found to be *Pellasmimnia angasi*. Likewise, the hand drawn figures of *Volva philippinaria* illustrated in Lim (1969b) resemble *Pellasmimnia angasi*. It is highly likely that the records of *Phenacovulva philippinarum* were based on similarly misidentified shells, and that this species has not, in actual fact, been found in Singapore. The seven species recorded previously but could not be verified in this study (*Calcarovula longirostrata*, *Calpurnus verrucosus*, *Carpiscula bullata*, *Hiavolva depressa*, *Naviculavolva deflexa*, *Phenacovulva philippinarum*, *Primovula rosewateri*) are known from Southeast Asia.

Few investigations have been done on ovulids in the intertidal region, likely due to the fact that only a handful of species are thought to occur in depths of two metres or less (Lorenz & Fehse, 2009). Local studies have often obtained ovulid specimens by SCUBA collecting or dredge hauls. This study found 17 species (*Crenavolva leopardus*, *Crenavolva striatula*, *Crenavolva traillii*,

*Cuspidolva formosa*, *Cuspidolva ostheimeriae*, *Crenatolva matsumiyai*, *Cuspidolva queenslandica*, *Cuspidolva singularis*, *Diminolva alabaster*, *Pellasmia angasi*, *Pellasmia improcera*, *Phenacolva barbieri*, *Phenacolva brevirostris*, *Phenacolva dancei*, *Phenacolva nectarea*, *Phenacolva rosea*, *Prionolva brevis*) alive in depths of less than a metre, some of these out of water for about an hour during extremely low spring tides. Shells of additional species not observed alive were found washed on shore among beach debris, indicating that they too might exist in shallow waters. Goh & Chou (1994b, 1996) mentioned that gorgonians seem to occur in shallower waters in Singapore compared to other reefs in the region as a result of the low water transparency surrounding the islands here, and intertidal gorgonian colonies and ovulids might well be a consequence of this.

While descriptions of a species' external morphology, such as the coloration, patterning, and appearance of its head, foot, mantle, papillae, and other soft parts have been included here to encourage the identification of living animals observed in their natural habitats or in photographs, one must remember that other than a few exceptions (e.g., *Calpurnus verrucosus*, *Ovula Ovum*), many species are known to be notoriously variable when it comes to external appearance. In addition, few studies have been done to extensively investigate the extent of variability within a species. Hence, identification to the species level based on photographs of animals in situ alone is difficult. All the records presented in this study were only included if a shell was available for inspection, with only a single exception (*Primovula semperi*).

That being said, it is highly likely that corrections, new records, and ecological observations will be added to this checklist in the near future. A number of photographs of living animals in situ shared by SCUBA divers and marine enthusiasts did not seem to correlate with any of the species included herein, and further investigation and examination of specimens yet to be found might shed light on whether these photographs represent species not yet known to occur in Singapore waters.

## ACKNOWLEDGEMENTS

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ILLUSTRATIONS

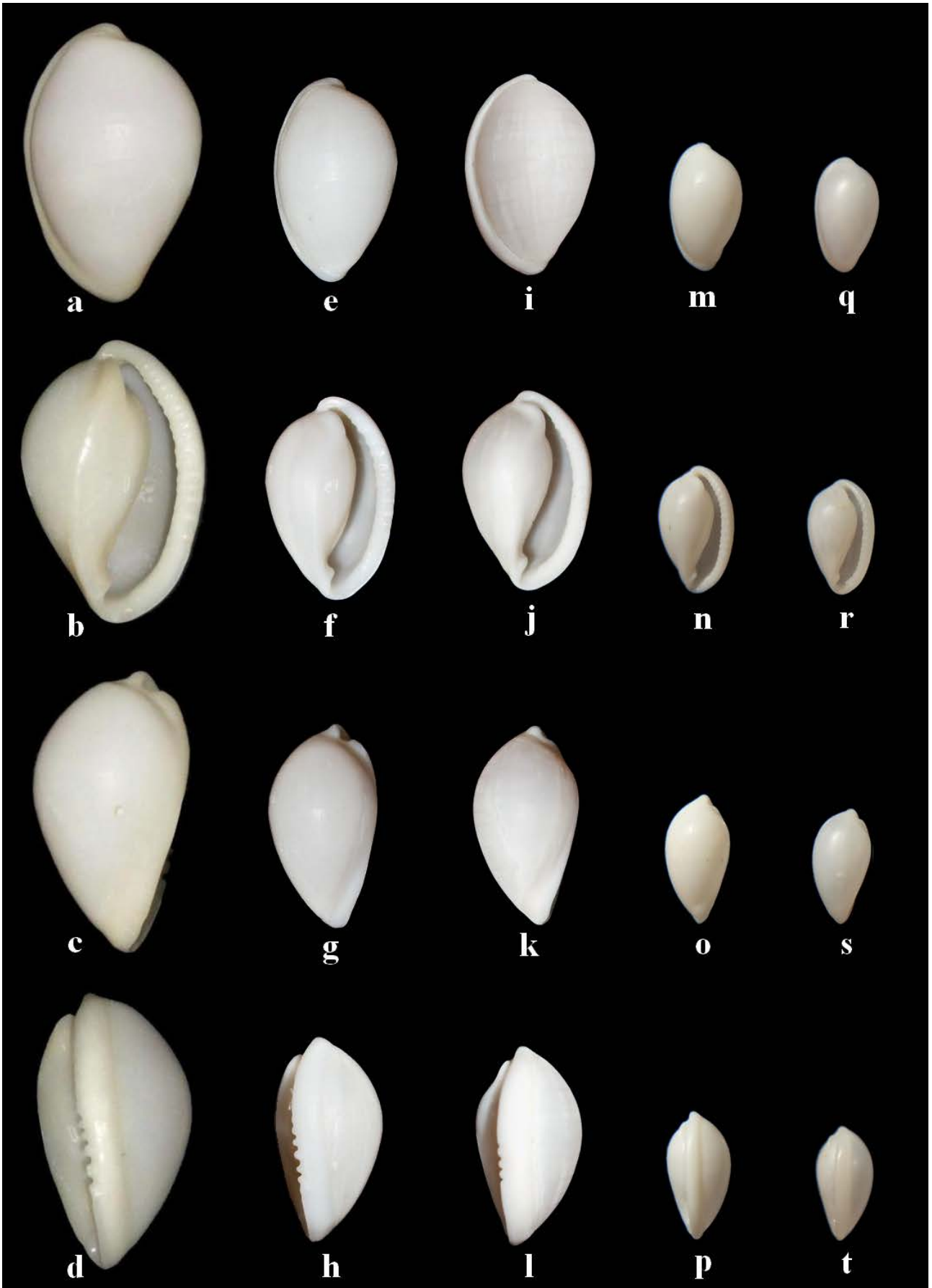


Fig. 1. *Prionovolva brevis*: a–d, 23.2 mm, Changi East (WHW); f–h, 13.7 mm, ECP; i–l, 13.6 mm, ECP. *Prionovolva nivea*: m–p, 9.6 mm, ECP (WHW); q–t, 8.7 mm, ECP (WHW).

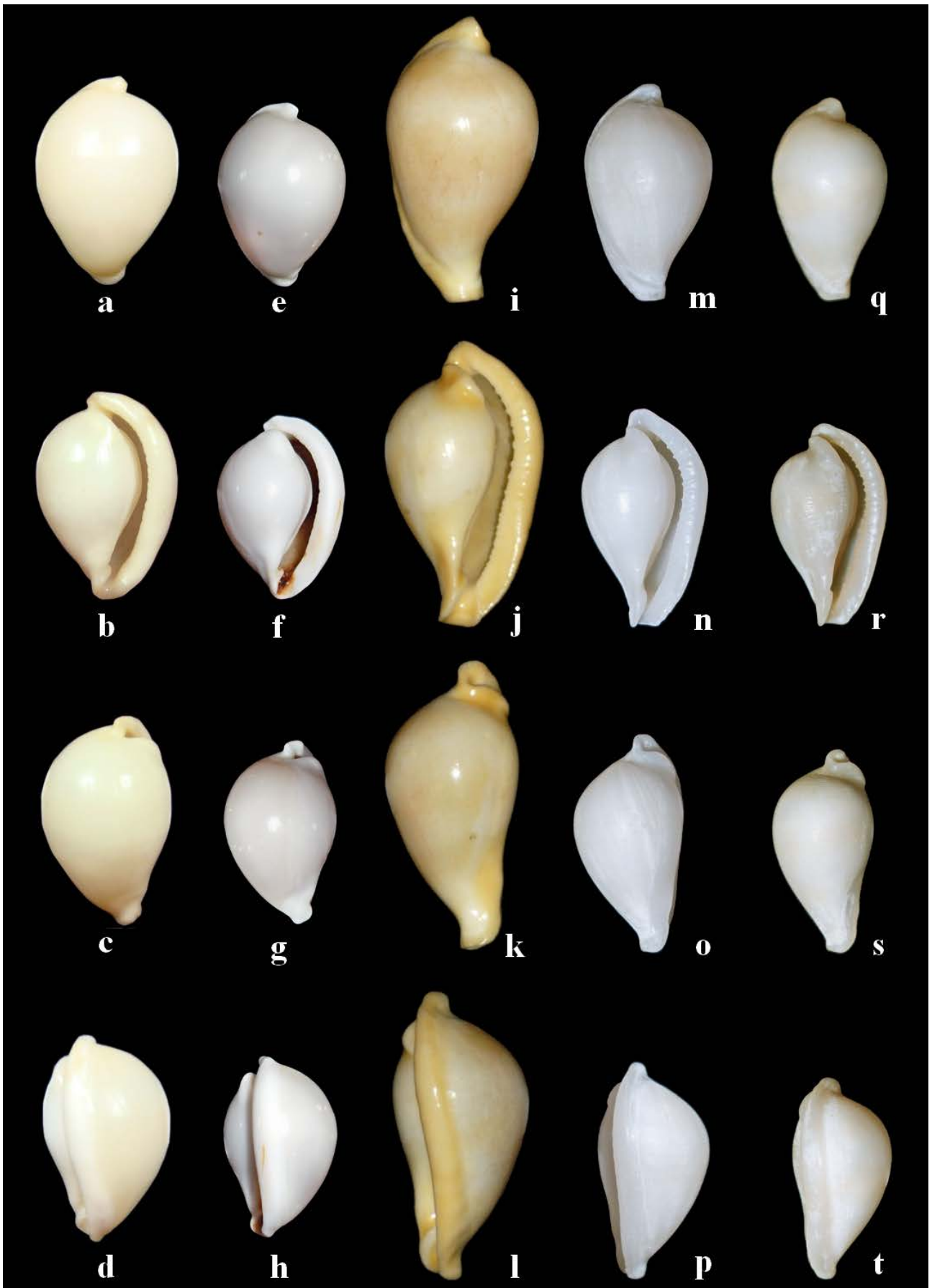


Fig. 2. *Globovula sphaera*, a–d, 18.5 mm, empty shell, Changi (BBC); e–h, 15.8 mm, in fishing nets off Bintan Island, Riau, Indonesia (CSY). *Margovula pyriformis*: i–l, 21.5 mm, ECP (TSK); m–p, 16.8 mm, beach worn shell, CBP (WHW); q–t, 14.8 mm, beach worn shell, CBP (WHW).

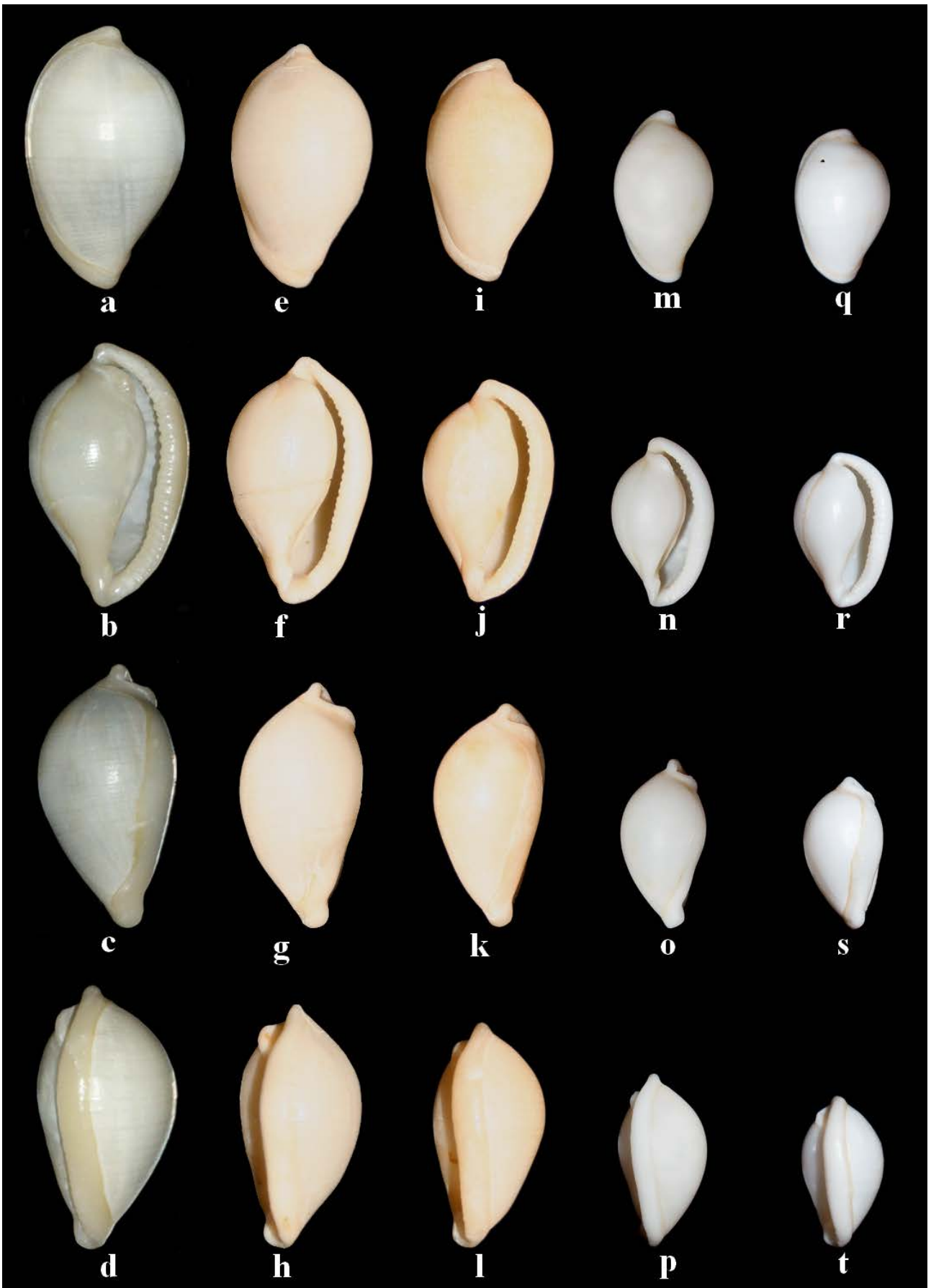


Fig. 3. *Margovula marginata*, beach worn specimens: a–d, 23.6 mm, ECP (WHW); e–h, 23.6 mm, ECP (TSK); i–l, 20.1 mm, ECP (TSK); m–p, 15.5 mm, ECP (WHW); q–t, 14.0 mm, Changi (TSK).



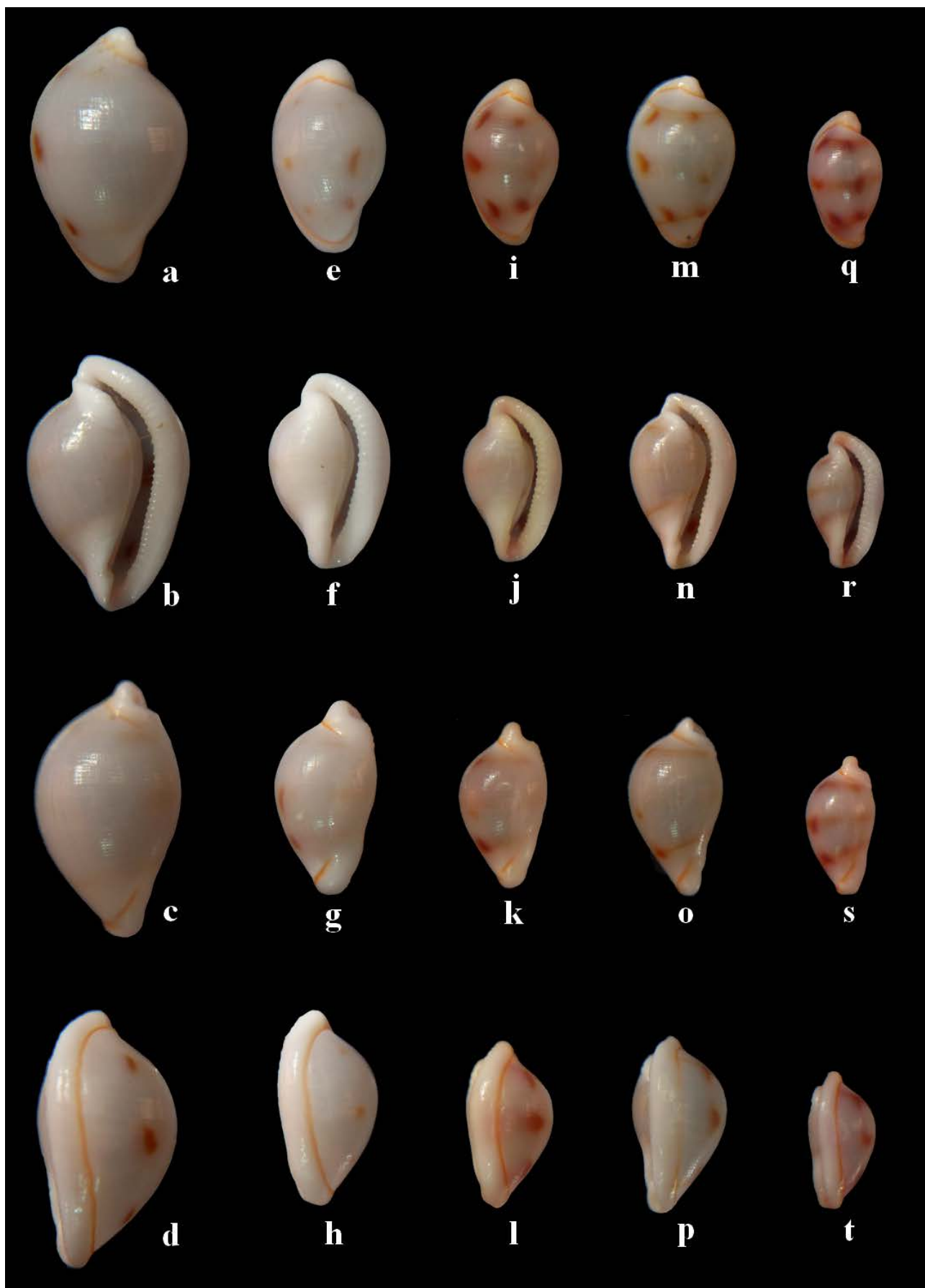


Fig. 4. *Diminovula alabaster*: a–d, 11.1 mm, CBP; e–h, 8.8 mm, ECP; i–l, 7.8 mm, ECP. *Diminovula* cf. *alabaster*: m–p, 8.6 mm, ECP; q–t, 6.3 mm, ECP (WHW).

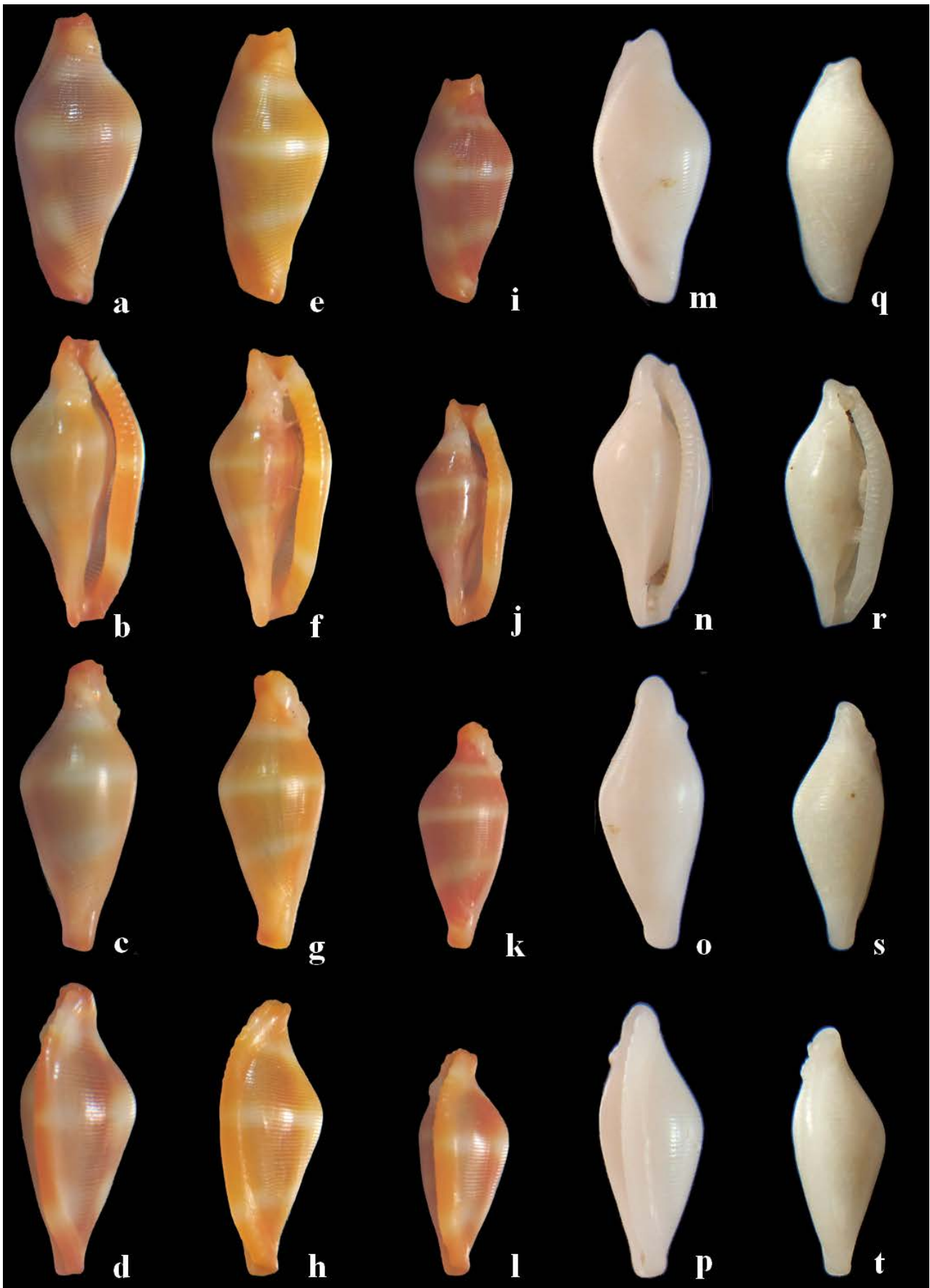


Fig. 5. *Crenavolva striatula*, on coral tangeled in fishing gear, off Bedok Jetty, ECP, Jun.2006 (WHW): a–d, 9.3mm; e–h, 8.9 mm; i–l, 7.2 mm. *Crenavolva* cf. *aureola*: m–p, 8.0 mm, beach worn shell, ECP; q–t, 7.3 mm, beach worn shell, St. John's Island (TSK).

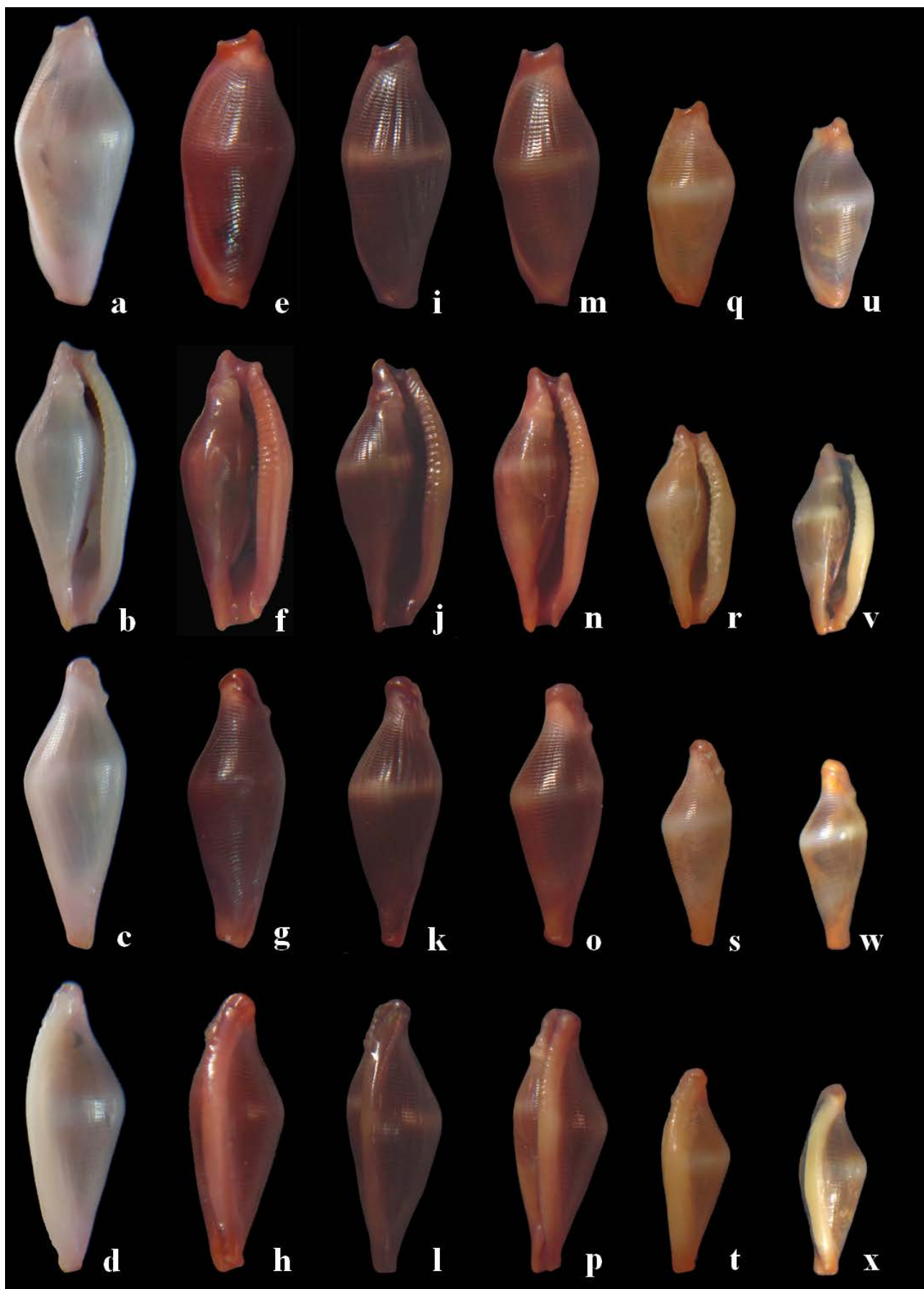


Fig. 6. *Crenavolva leopardus*: a–d, 9.8 mm; e–h, 9.5 mm, ECP; i–l, 9.2 mm, CBP; n–p, 8.9 mm, CBP; q–t, 6.9 mm; u–x, 6.5 mm, tangled fishing gear, off Bedok Jetty, ECP, 2006 (WHW).



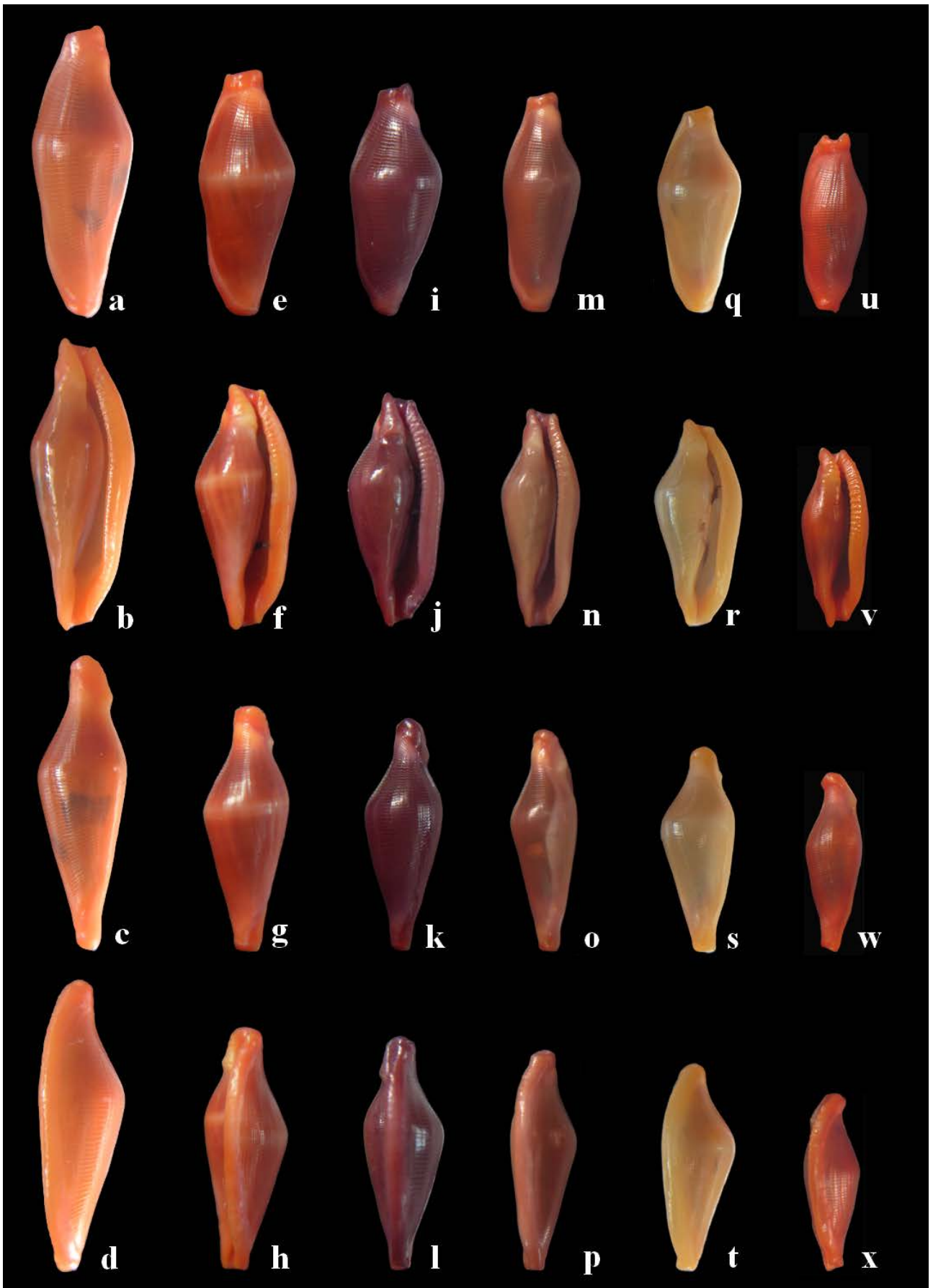


Fig. 7. *Crenavolva traillii*: a–d, 15.5 mm, Pulau Ubin; e–h, 12.7 mm, CBP; i–l, 12.1 mm, CBP; m–p, 11.4 mm, ECP; q–t, 10.9 mm, Pulau Ubin. *Crenavolva matsumiyai*: u–x, 9.0 mm, Changi (WHW).

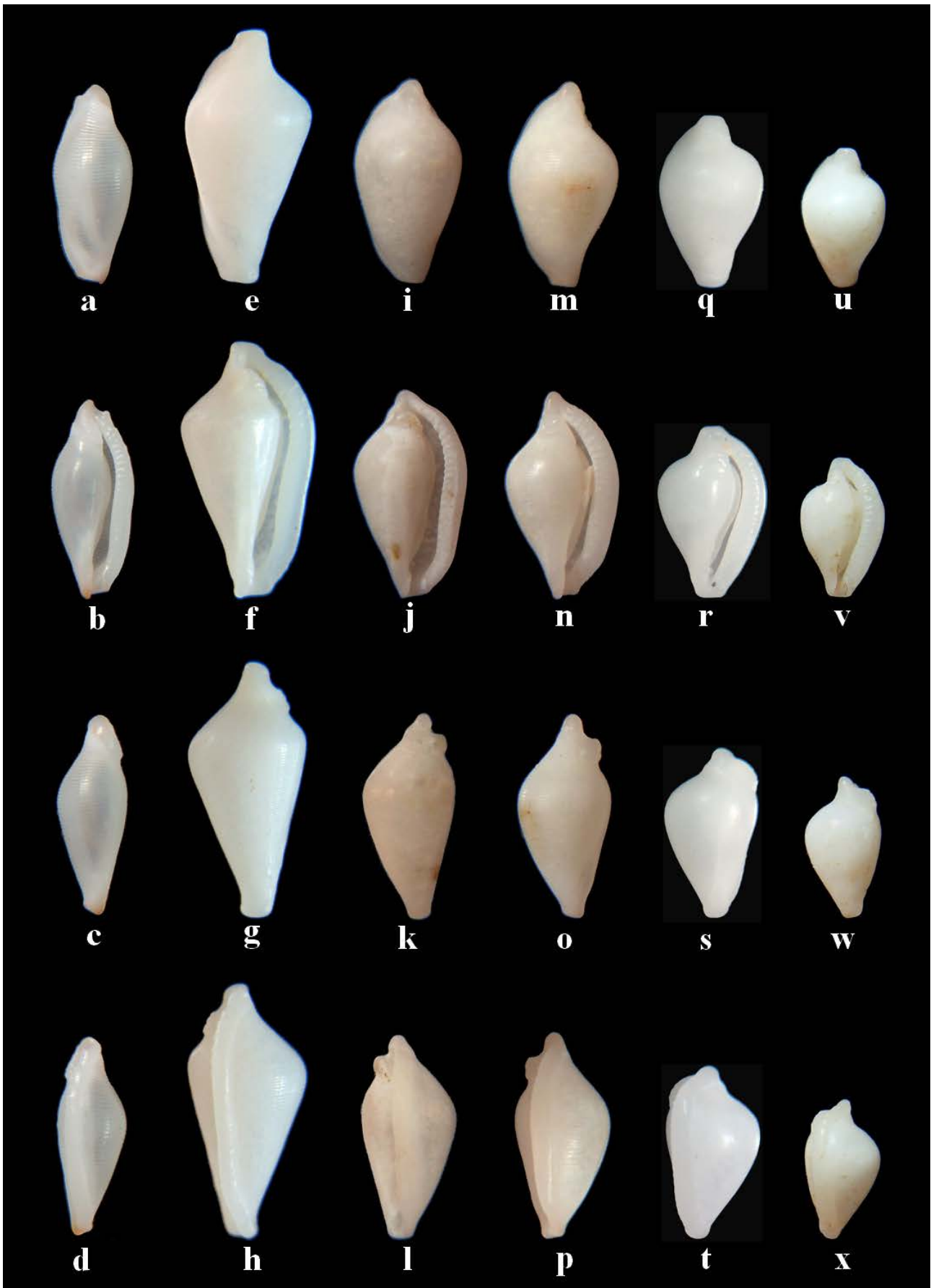


Fig. 8. *Crenavolva* cf. *guidoi*: a–d, 5.9 mm, on sea whip at 11-m depth, North Jetty, Pulau Hantu, C. H. Toh coll., 28 Mar.2010. *Dentiovula* cf. *dorsuosa*: e–h, 8.2 mm, beach worn shell, ECP. *Sandalia* cf. *triticea*: i–l, 6.4 mm, beach worn shell, St. John's Island (TSK). *Primovula* cf. *tropica*: m–p, 6.3 mm, beach worn shell, St. John's Island (TSK). *Primovula* *roseomaculata*, beach worn, ECP: q–t, 5.2 mm; u–x, 4.3 mm.

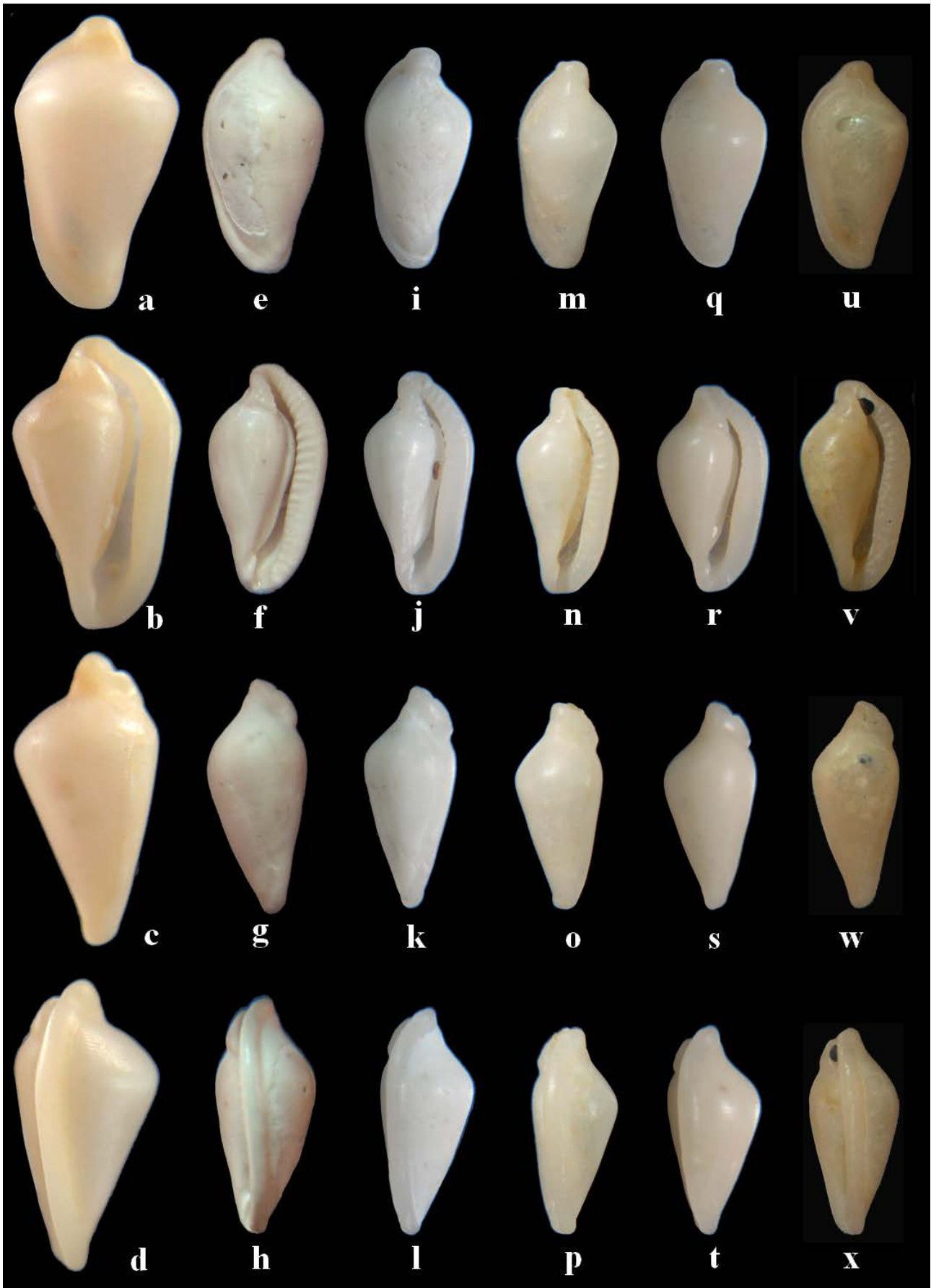


Fig. 9. *Dentiovula rutherfordiana*: a–d, 11.0 mm, beach worn shell, ECP (CSY). *Dentiovula* species, beach worn shells: e–h, 8.8 mm, Changi East (TSK); i–l, 8.1 mm, ECP (WHW); m–p, 7.5 mm, ECP (WHW); q–t, 7.5 mm, ECP; u–x, 7.6 mm, Changi East (TSK).

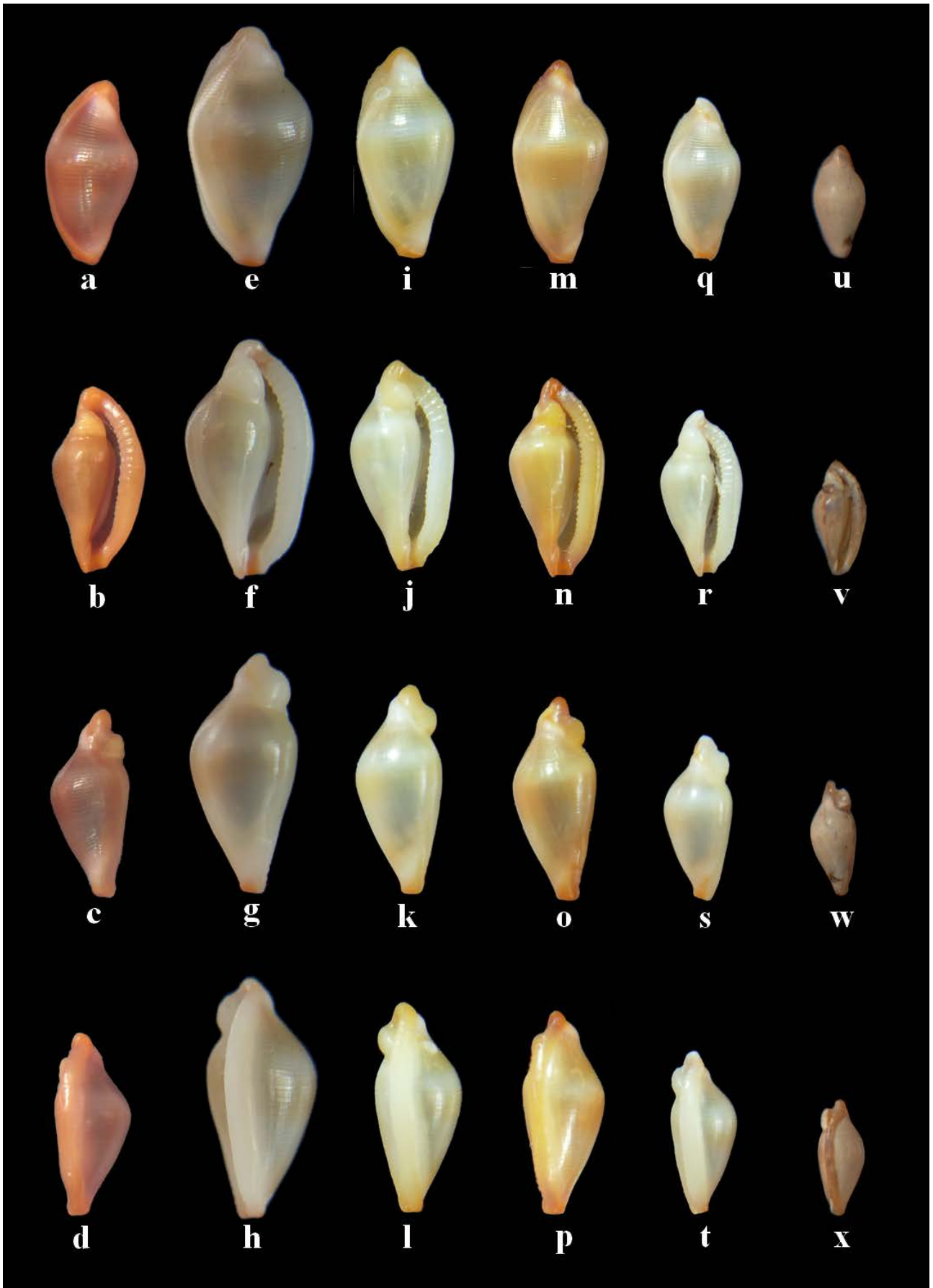


Fig. 10. *Cuspidolva* cf. *ostheimeriae*: a–d, 7.1 mm, CBP. *Cuspidolva singularis*: e–h, 9.1 mm, Pulau Ubin; i–l, 8.5 mm, CBP; m–p, 7.3 mm, CBP; q–t, 6.5 mm, ECP. *Cuspidolva* cf. *singularis*: u–x, 4.4 mm, St. John's Island (TSK).



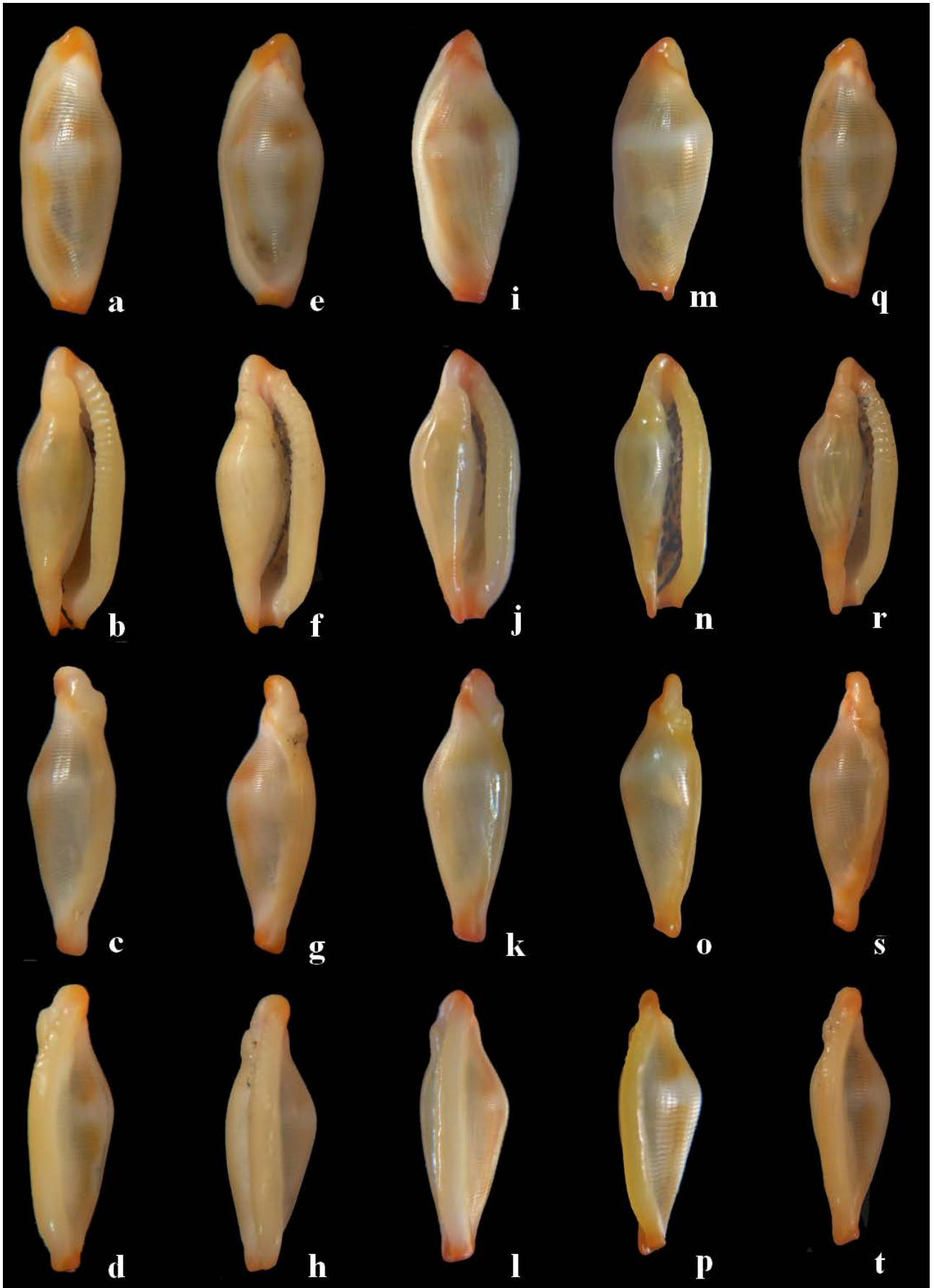


Fig. 11. *Cuspidolva formosa*, Changi: a–d, 11.1 mm; e–h, 10.7 mm; i–l, 10.4 mm. *Cuspidolva formosa*, ECP: m–p, 10.1 mm; q–t, 10.0 mm (WHW).

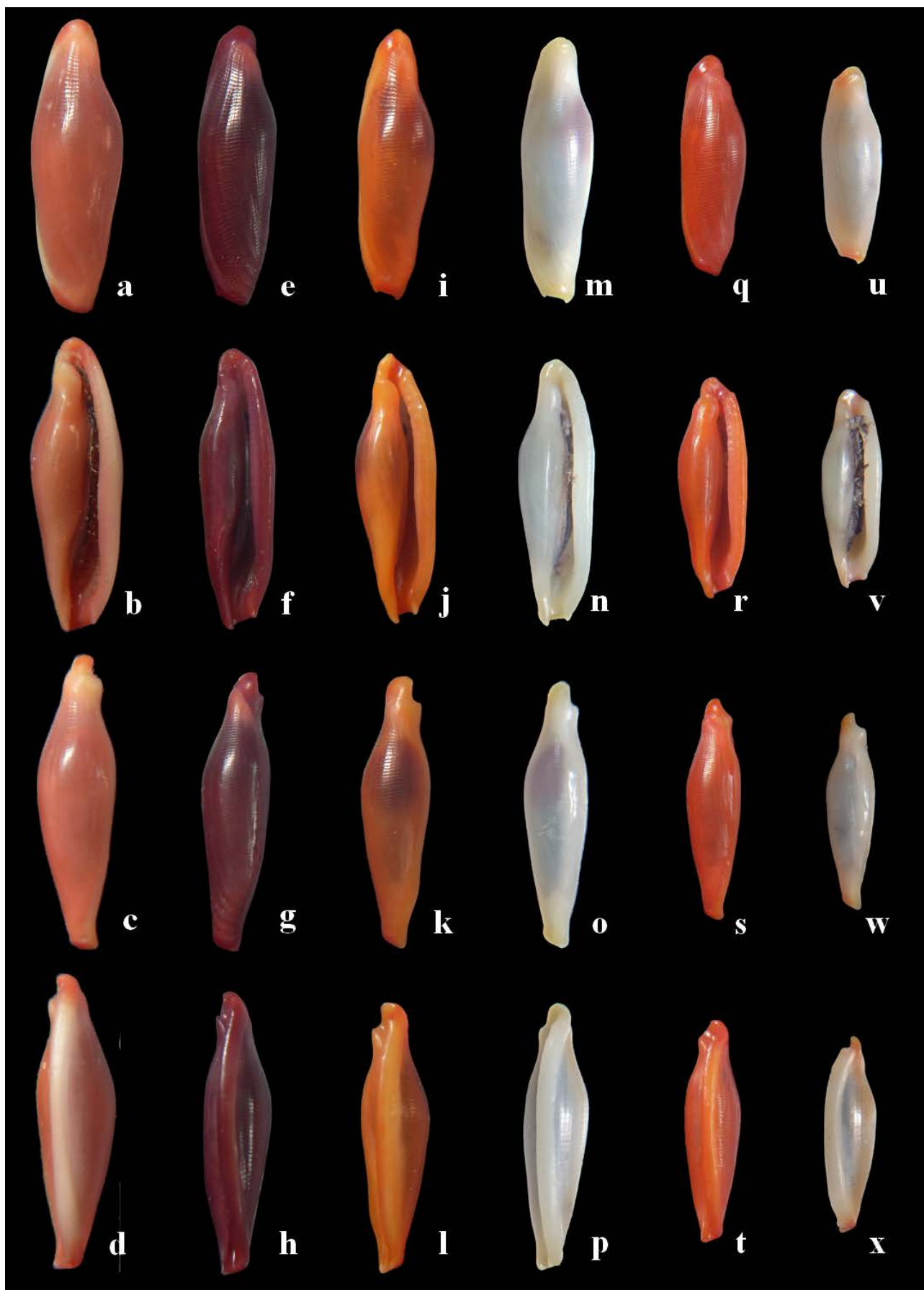


Fig. 12. *Cuspidovula queenslandica*: a–d, 11.8 mm, ECP; e–h, 11.4 mm, CBP; i–l, 11.0 mm, CBP; m–p, 10.8 mm, Pulau Ubin; q–t, 9.0 mm, CBP (WHW); u–x, 8.3 mm, ECP.

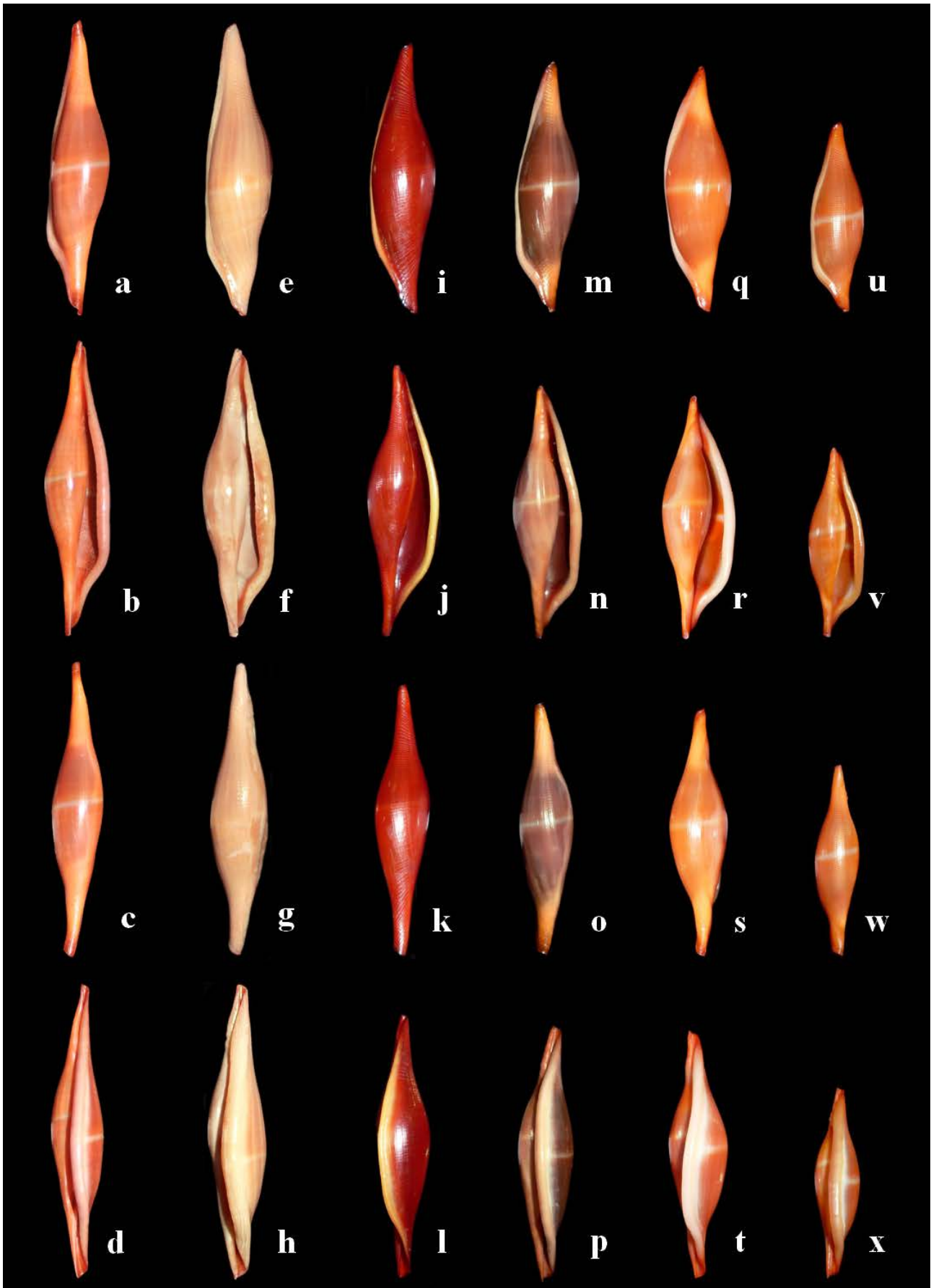


Fig. 13. *Phenacovolva rosea*: a–d, 34.5 mm, Pulau Ubin; e–h, 25.1 mm, ECP; i–l, 35.0 mm (TKC), CBP; m–p, 33.9 mm, CBP; q–t, 31.8 mm, CBP; u–x, 23.2 mm, Changi (WHW).

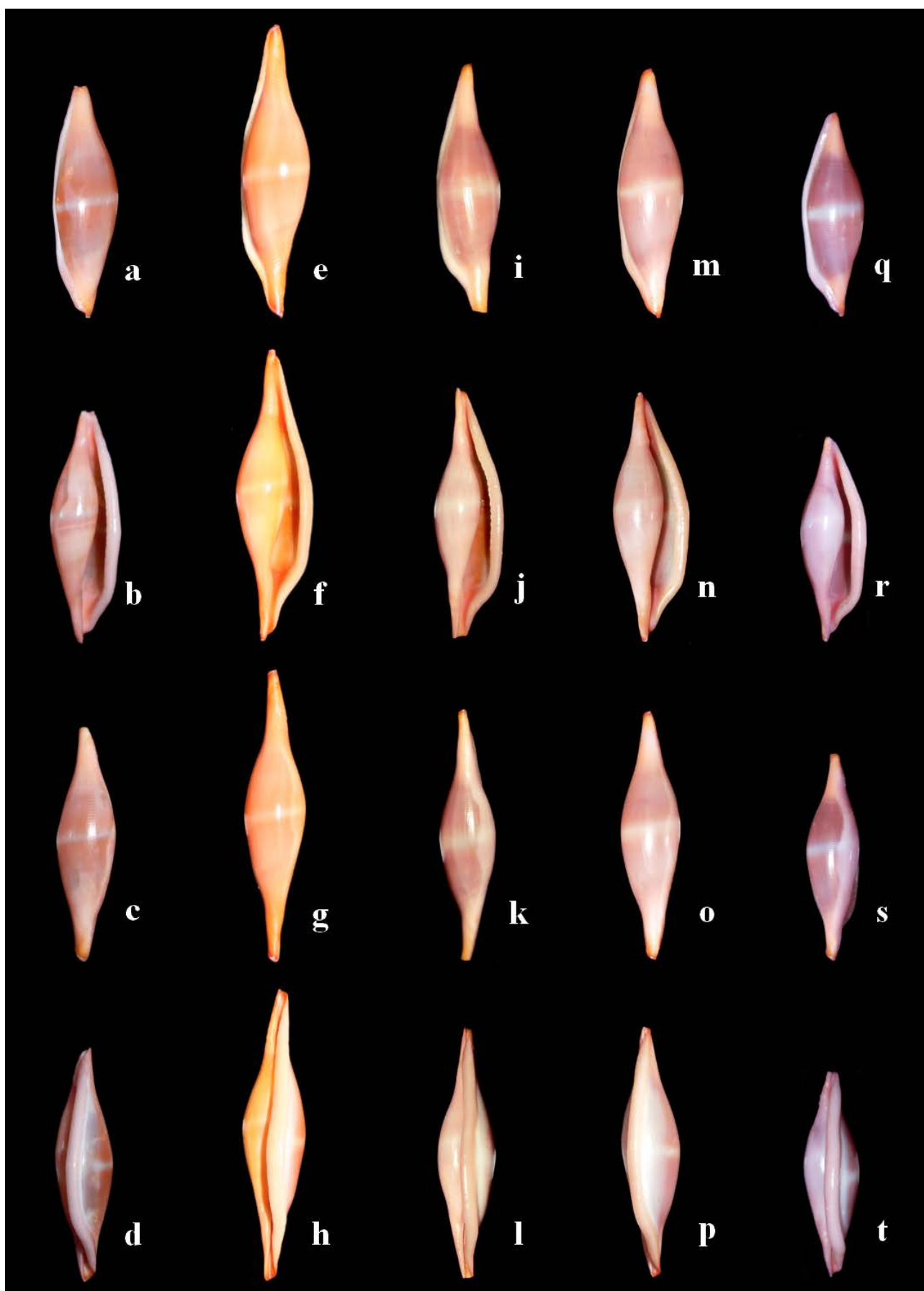


Fig. 14. *Phenacovolva nectarea*: a–d, 27.5 mm, debris in fishing gear, off Bedok Jetty, ECP; e–h, 41.5 mm, CBP (WHW); i–l, 32.3 mm, ECP; m–p, 31.5 mm, Pulau Ubin; q–t, 21.4 mm, ECP.



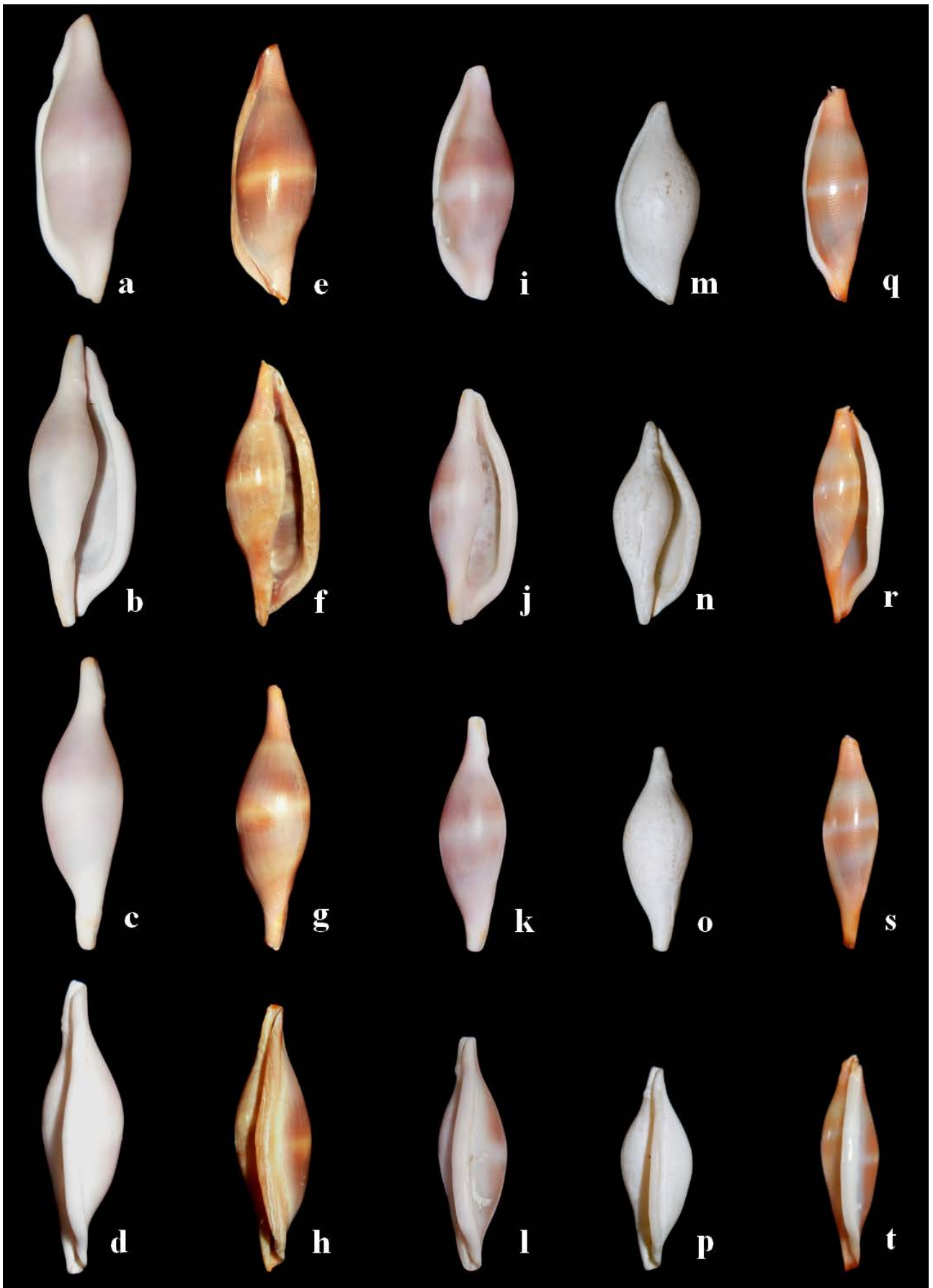


Fig. 15. *Phenacovolva brevirostris*: a–d, 27.3 mm, ECP; e–h, 24.0 mm, ECP; i–l, 22.1 mm, ECP; m–p, 18.6 mm; Changi. *Phenacovolva* cf. *dancei*: q–t, 20.1 mm, debris in fishing gear, off Bedok Jetty, ECP.

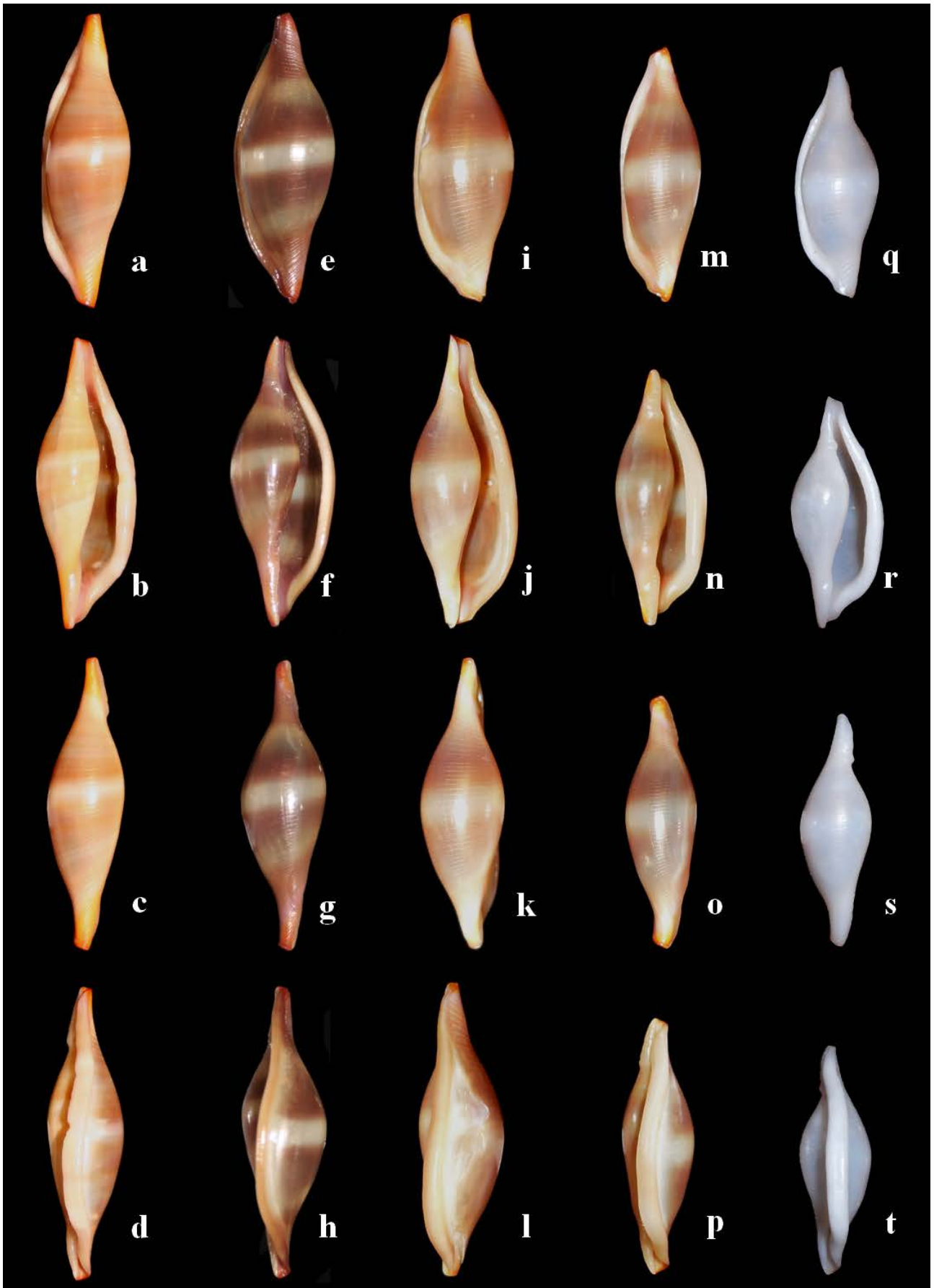


Fig. 16. *Phenacovolva barbieri*: a–d, 28.9 mm, CBP; e–h, 24.6 mm, CBP; i–l, 24.3 mm, Pulau Ubin; m–p, 21.8 mm, Pulau Ubin; q–t, 19.5 mm, Changi East.

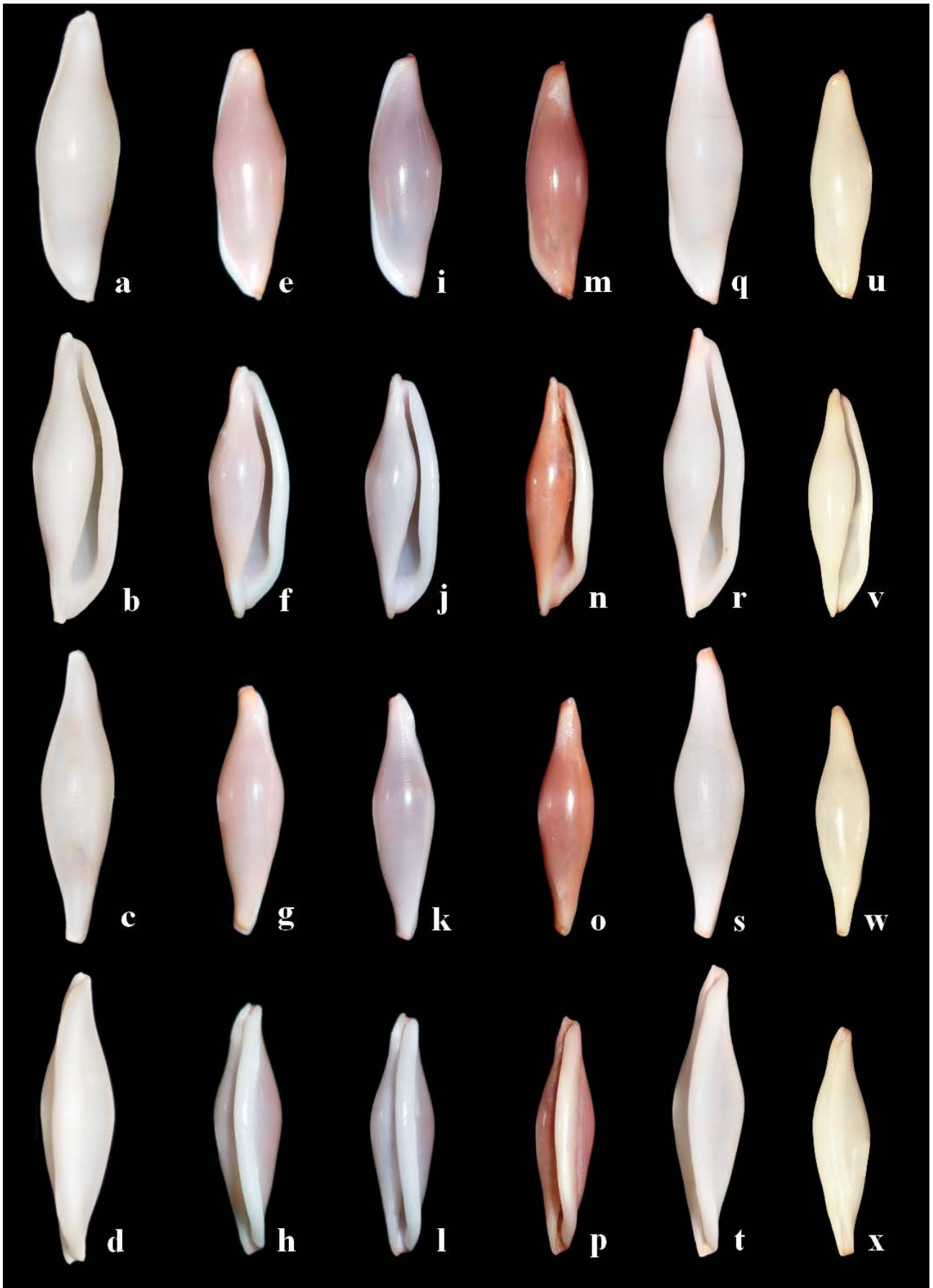


Fig. 17. *Pellasimnia angasi*: a-d, 24.5 mm, off Pulau Tekong, Jun.1924; e-h, 21.0 mm, ECP; i-l, 20.2 mm, ECP; m-p, 19.9 mm, in abandoned fishing gear, Bedok Jetty, ECP (WHW). *Pellasimnia improcera*: q-t, 23.4 mm, Changi (WHW); u-x, 19.1 mm, fishing gear, Bedok Jetty, ECP (WHW).

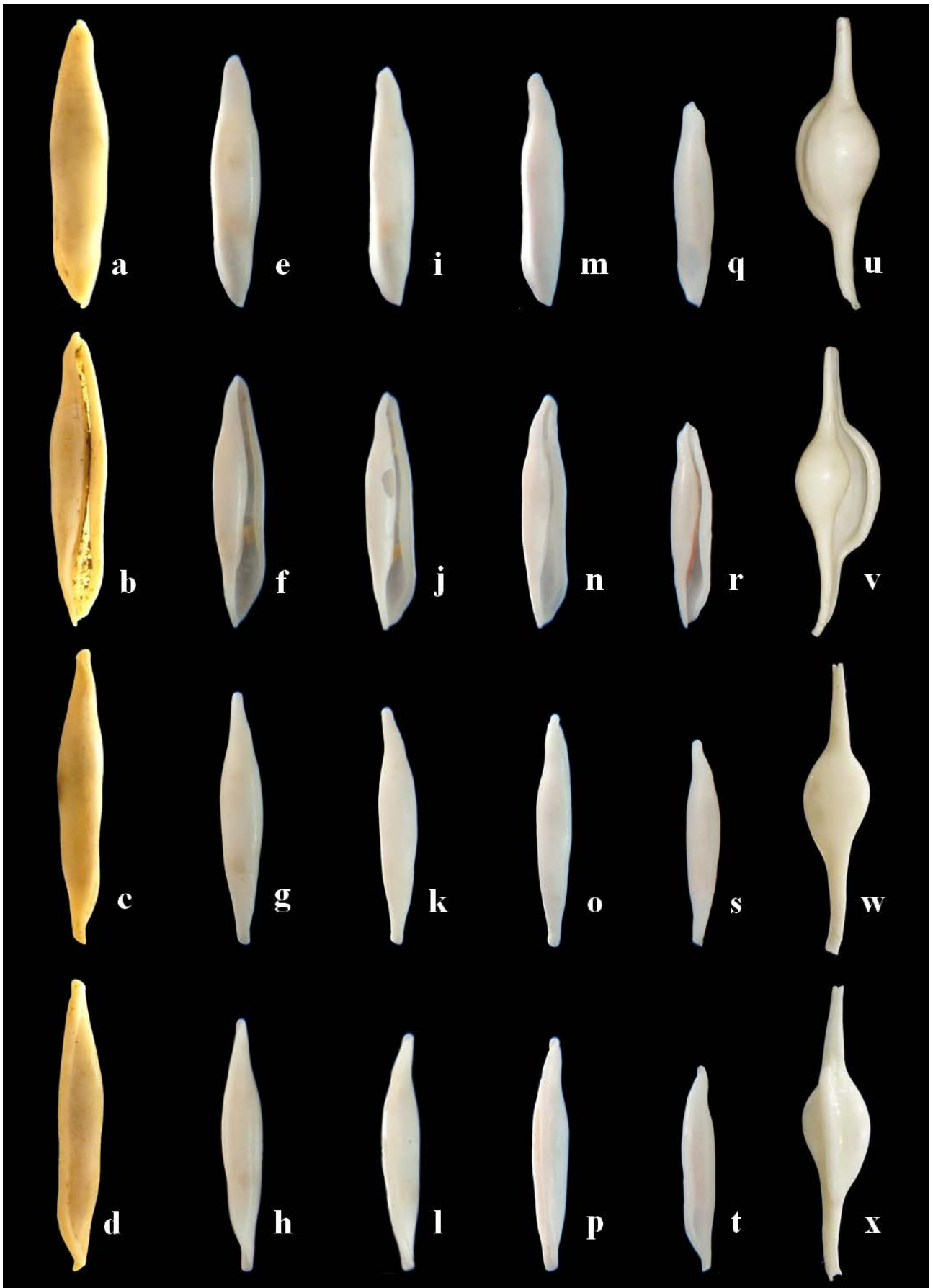


Fig.18. *Aclyvolva* cf. *lanceolata*: a–d, 23.0 mm, dredged from 18 fathoms (1°25'03'' N; 102°58' E), M. W. F. Tweedie coll., 11 Feb.1933. *Aclyvolva lamyi*, beach worn specimens, ECP: e–h, 13.5 mm; i–l, 12.7 mm; m–p, 12.5 mm. *Aclyvolva lamyi*: q–t, 11.0 mm, on sea whips at 10-m depth, North Jetty, Pulau Hantu, C. H. Toh coll., 28 Mar.2010. *Volva volva*: u–x, 68.0 mm, faded shell, Changi East (WHW).



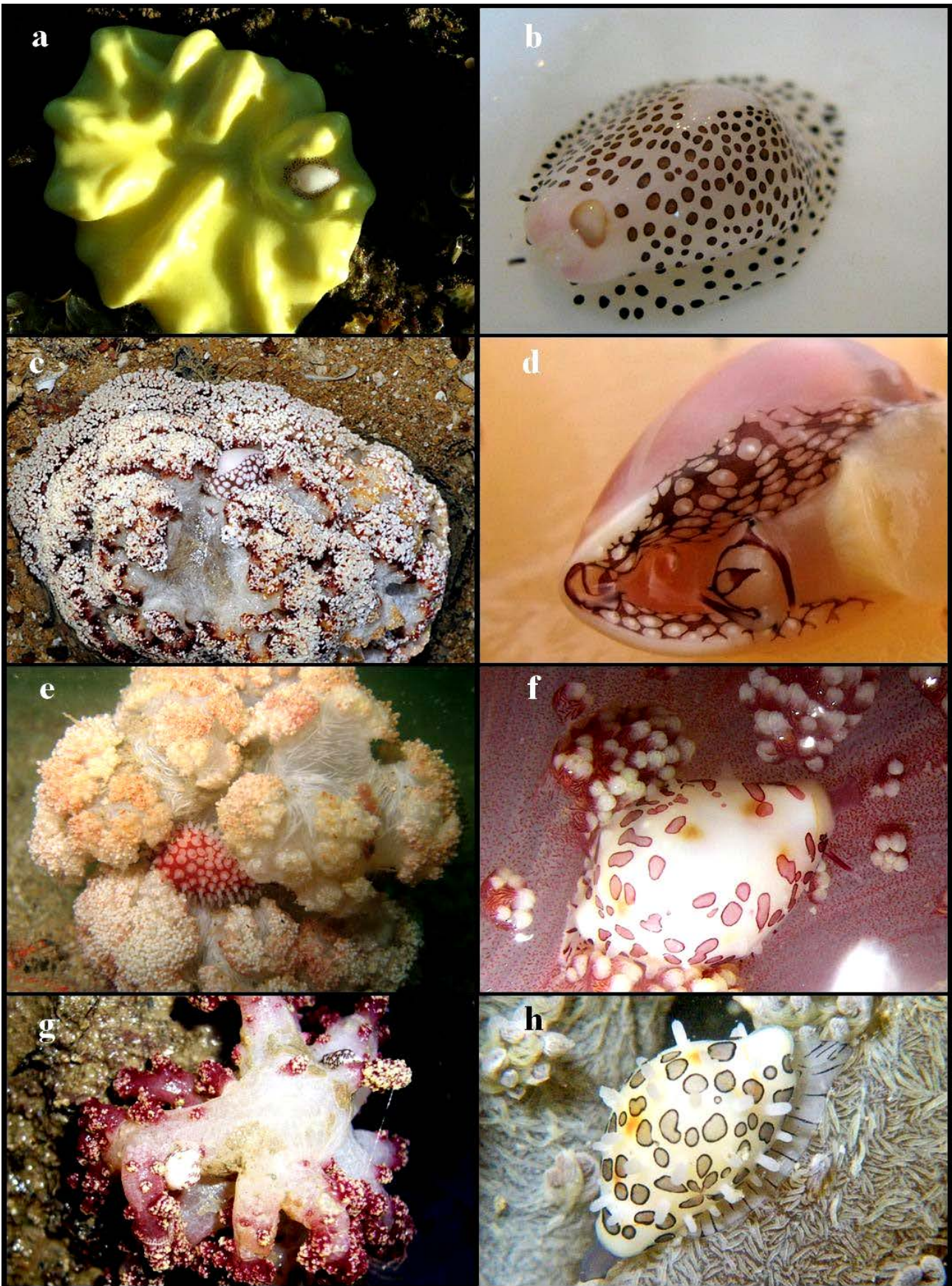


Fig. 19. a–b, *Calpurnus verrucosus*, Bintan, Sumatra, Indonesia (Photograph by: M. Chan, 2010). c–e, *Prionovolva* cf. *brevis*: c, intertidal region, Tuas (Photograph by: R. Tan, Aug.2009); d, intertidal region, Beting Bronok (Photograph by: S. C. Lim, Jun.2008); e, Pulau Hantu (Photograph by: D. Ng ([www.pulauhantu.org](http://www.pulauhantu.org)), 22 Feb.2009). f–h, *Diminovula alabaster*: f, Beting Bronok (Photograph by: C. H. Toh, Jul.2008); g, ECP, Jun.2006; h, Tanah Merah (Photograph by: K. S. Loh, Jan.2010).



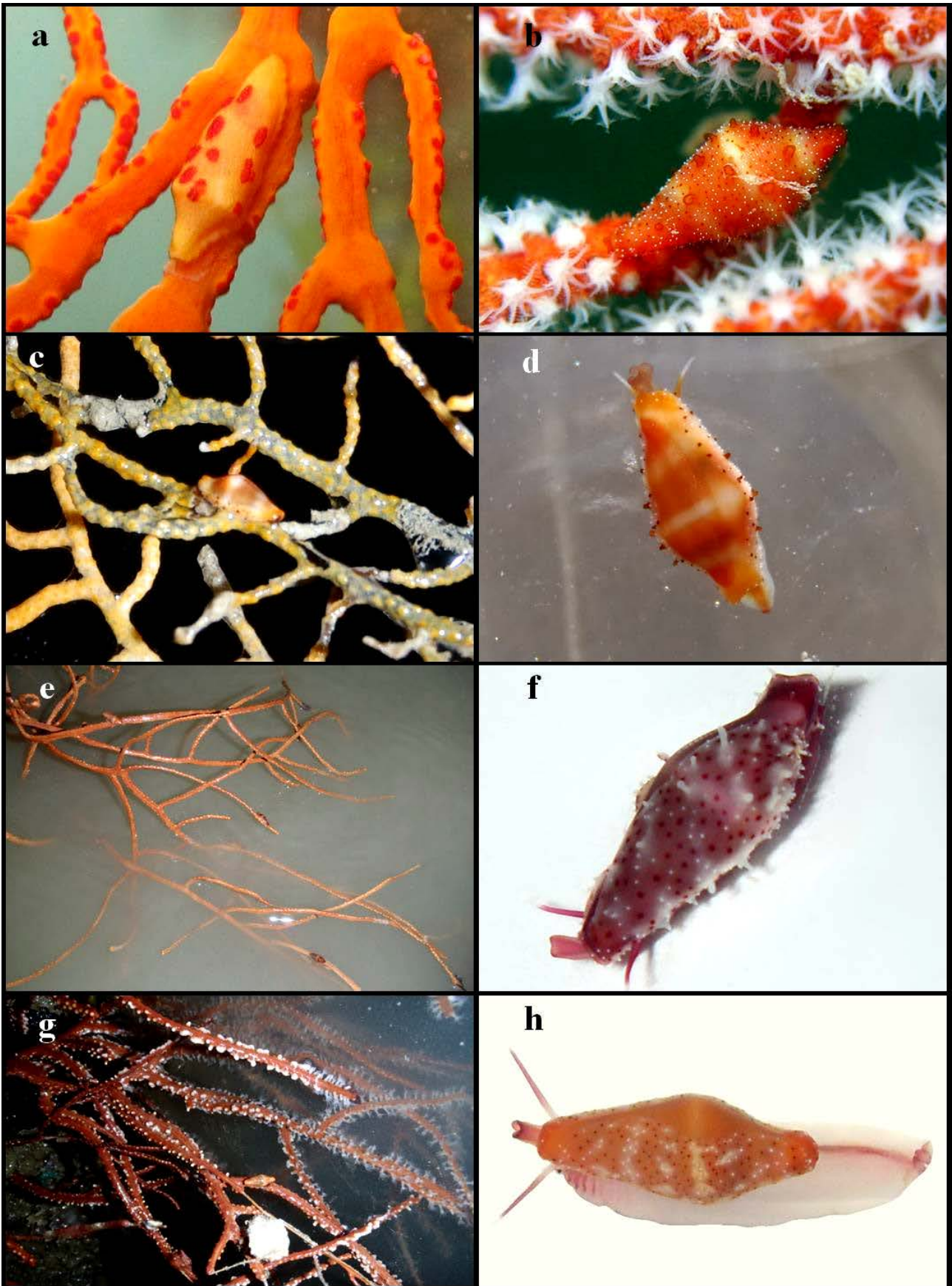


Fig. 20. a, *Prosimnia* cf. *semperi*, at 5-m depth, East Reef, Pulau Sudong (Photograph by: M. L. Neo, 27 Dec.2009). b–d, *Crenavolva striatula*: b, Pulau Hantu (Photograph by: B. Mayes, Dec.2010); c–d, tangled fishing gear off Bedok Jetty, ECP, Aug.2010. e–h, *Crenavolva leopardus*: e–f, intertidal region, Pulau Ubin, Jul.2010; g–h, Jul.2010, intertidal region, Changi Beach, Jul.2008.

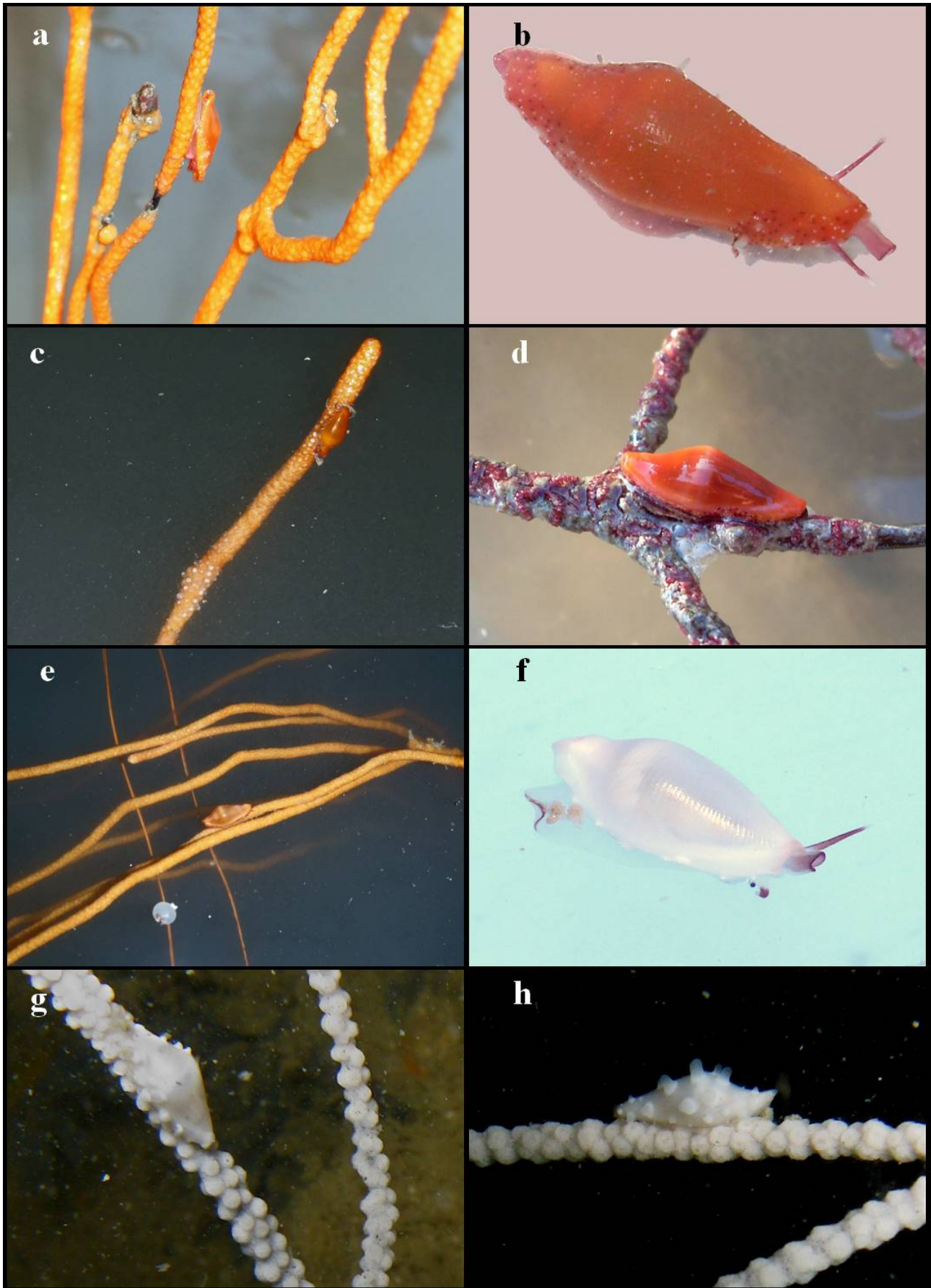


Fig. 21. a–b, *Crenavolva traillii*, Pulau Ubin, Jun.2010. c, *Crenavolva traillii*, ECP, Jun.2007. d–e, *Crenavolva traillii*, CBP, Jun.2008. f, *Crenavolva cf. guidoi*, North Jetty, Pulau Hantu (Photograph by: C. H. Toh, 28 Mar.2010). g, *Crenavolva cf. guidoi*, Pulau Hantu (Photograph by: C. H. Toh, Dec.2008). h, *Crenavolva cf. guidoi*, Pulau Hantu (Photograph by: C. H. Toh, May.2010).



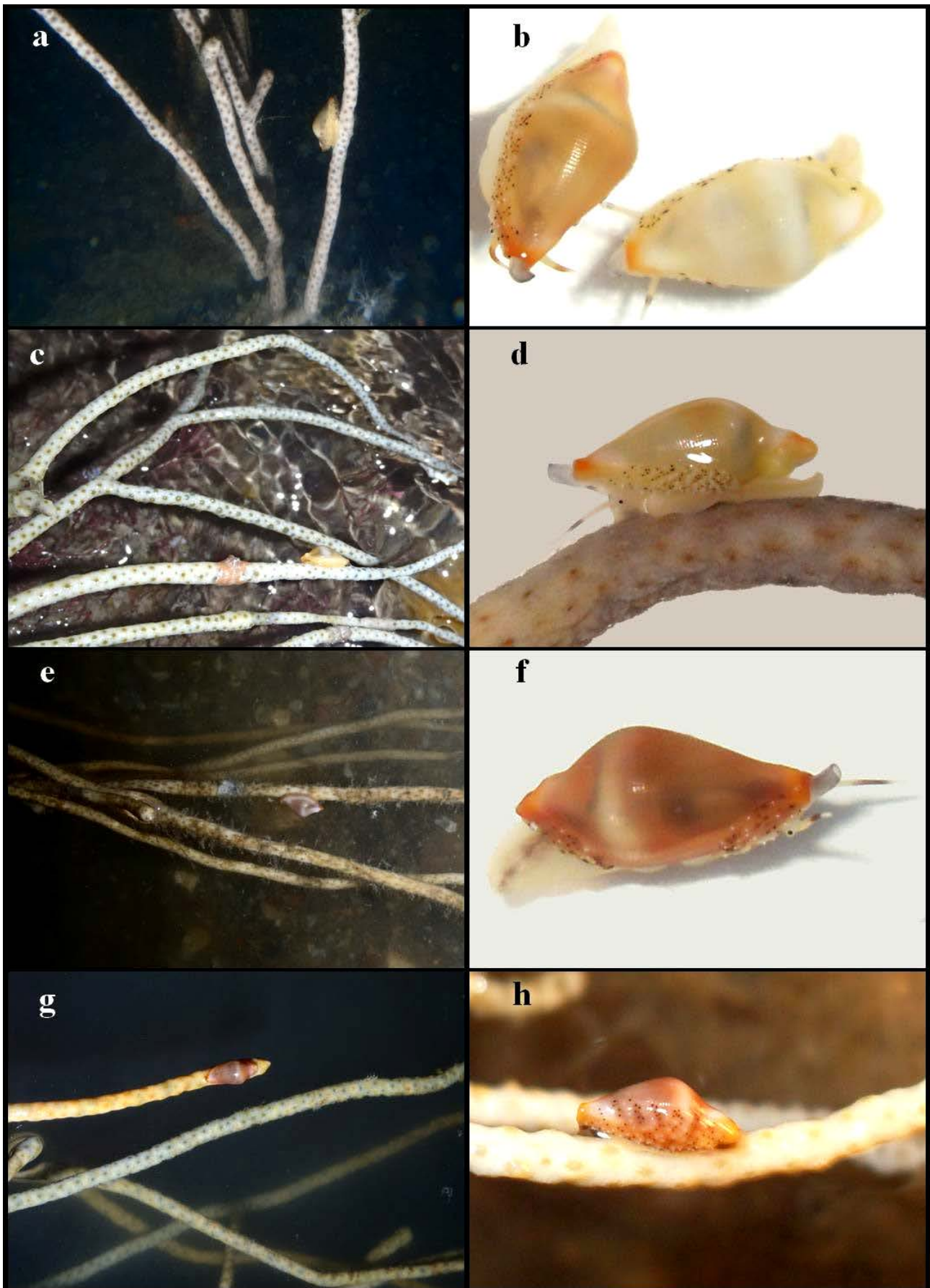


Fig. 22. a–b, *Cuspidolva singularis*, intertidal region, CBP, Jun.2009. c–d, *Cuspidolva singularis*, intertidal region, Pulau Ubin, Jul.2010. e–f, *Cuspidolva cf. ostheimeriae*, ECP, Aug.2010. g–h, *Cuspidolva cf. ostheimeriae*, CBP, Jun.2008.



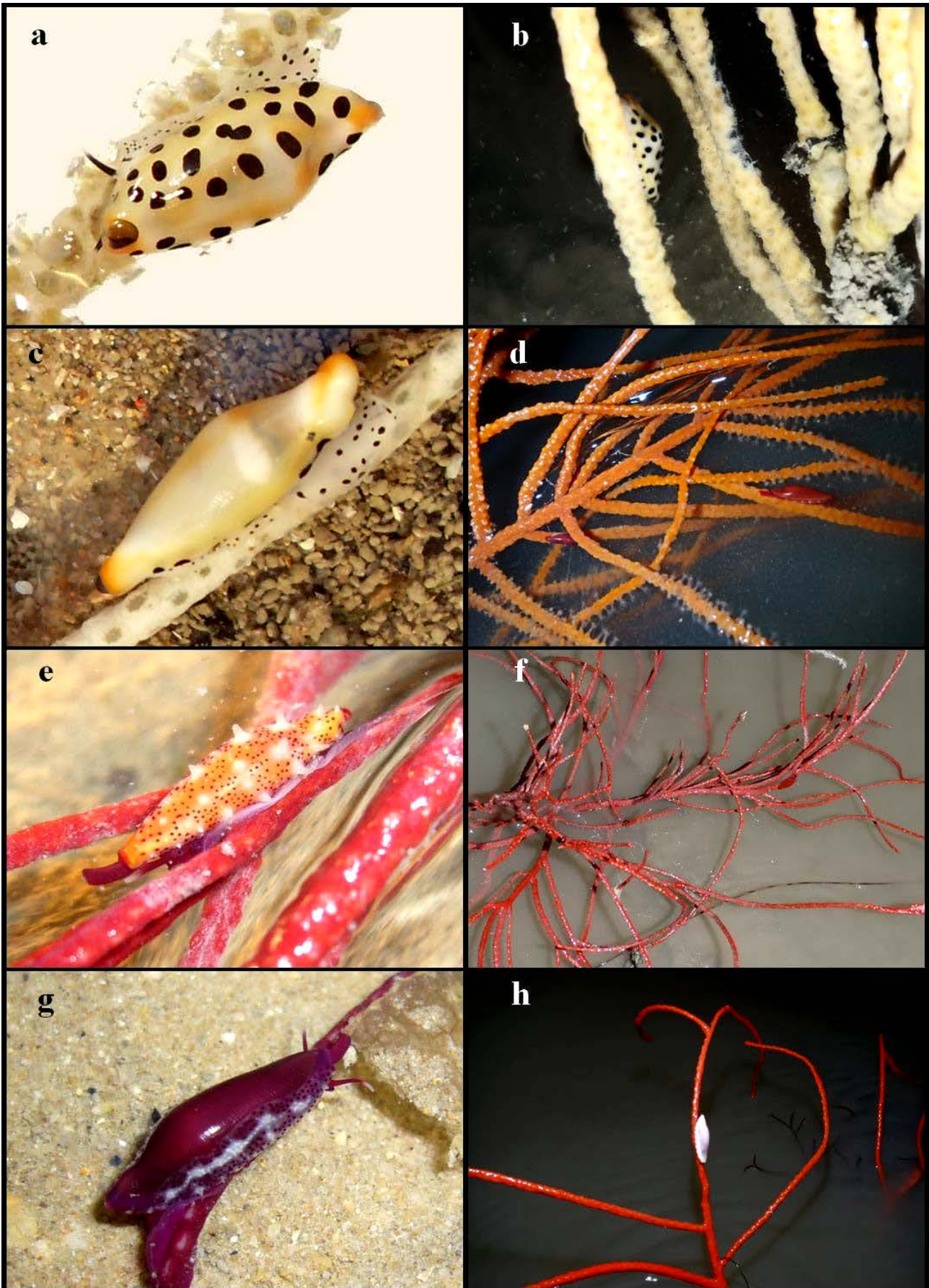


Fig. 23. a–c, *Cuspidovulva formosa*, intertidal region, Changi, Jun.2009. d, *Cuspidovulva queenslandica*, CBP, Jun.2010. e–g, *Cuspidovulva queenslandica*, intertidal region, ECP, Jun.2006. h, *Cuspidovulva queenslandica*, white form, intertidal region, Pulau Ubin, Jul.2010.



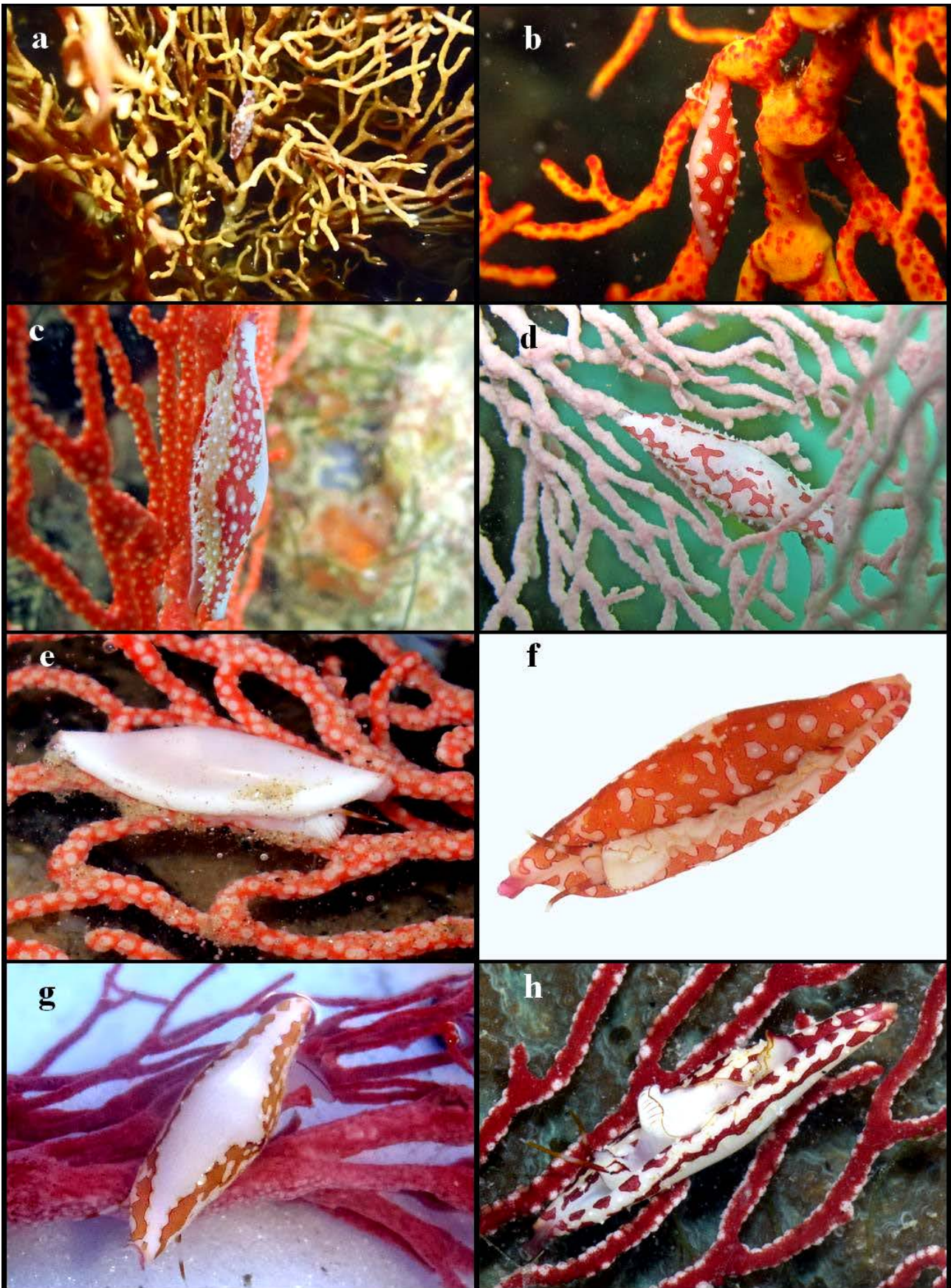


Fig. 24. a–f, *Pellasimnia angasi*: a, Bedok Jetty, ECP, Jun.2010; b, 5-m depth, East Reef, Pulau Sudong (Photograph by: M. L. Neo, 27 Dec.2009); c, off Changi Beach (Photograph by: M. L. Neo, 8 Feb.2010); d, 5-m depth, East Terumbu, Pulau Sudong (Photograph by: M. L. Neo, 27 Dec.2009); e–f, fishing gear off Bedok Jetty, ECP, 2008. g, *Pellasimnia improcera*, fishing gear off Bedok Jetty, ECP, 2008. h, *Pellasimnia* cf. *improcera*, off Pulau Ular (Photograph by: R. Tan, 23 Mar.2006).



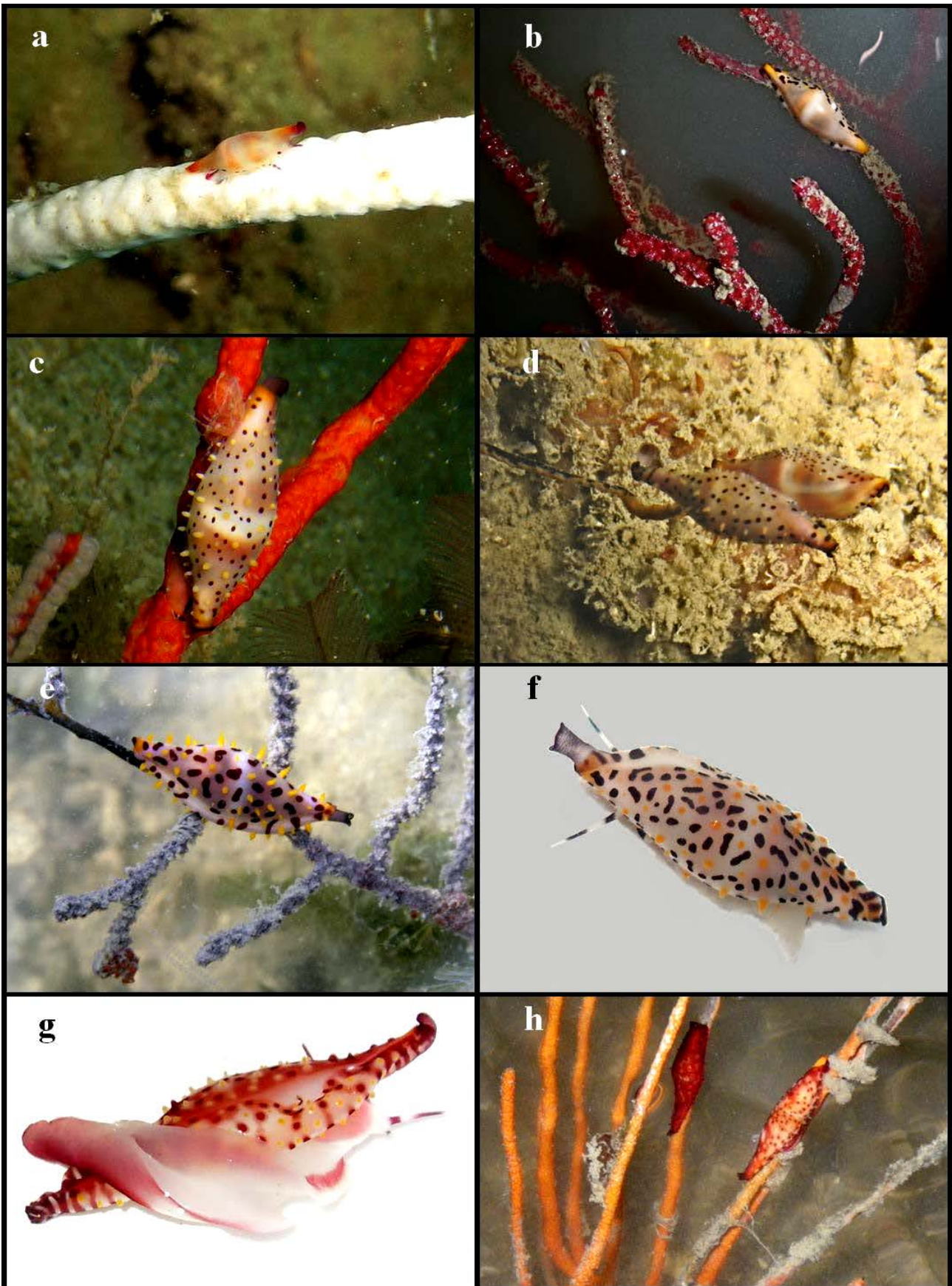


Fig. 25. a, *Phenacovolva* cf. *dancei*, Pulau Hantu (Photograph by: J. Thuaibah, 2006). b–f, *Phenacovolva barbieri*: b, intertidal, CBP, Jul.2010; c, Pulau Hantu (Photograph by: C. H. Toh, Mar.2009); d, Pulau Hantu (Photograph by: C. H. Toh, Mar.2009); e, intertidal, Beting Bronok (Photograph by: R. Tan, May.2003); f, Pulau Ubin, 2010. g, *Phenacovolva rosea*, CBP, Jun.2006. h, *Phencovolva* cf. *rosea*, Changi Beach (Photograph by: K. S. Loh, Jun.2010).





Fig. 26. a, *Phenacovolva nectarea* and *Phenacovolva* cf. *rosea*, intertidal, CBP, Jun.2010. b, *Phenacovolva nectarea* and *Phenacovolva rosea*, intertidal, CBP, Aug.2010. c–d, *Phenacovolva nectarea*: c, intertidal, Beting Bronok (Photograph by: R. Tan, Jul.2005); d, 9.3-m depth, Pulau Semakau (Photograph by: M. L. Neo, Dec.2010). e–g, *Phenacovolva rosea*: e, CBP, Aug.2010; f, Pulau Hantu (Photograph by: C. H. Toh, Mar.2008); g, ECP, May 2010. h, *Phenacovolva* cf. *rosea*, intertidal, CBP, Jul.2000.



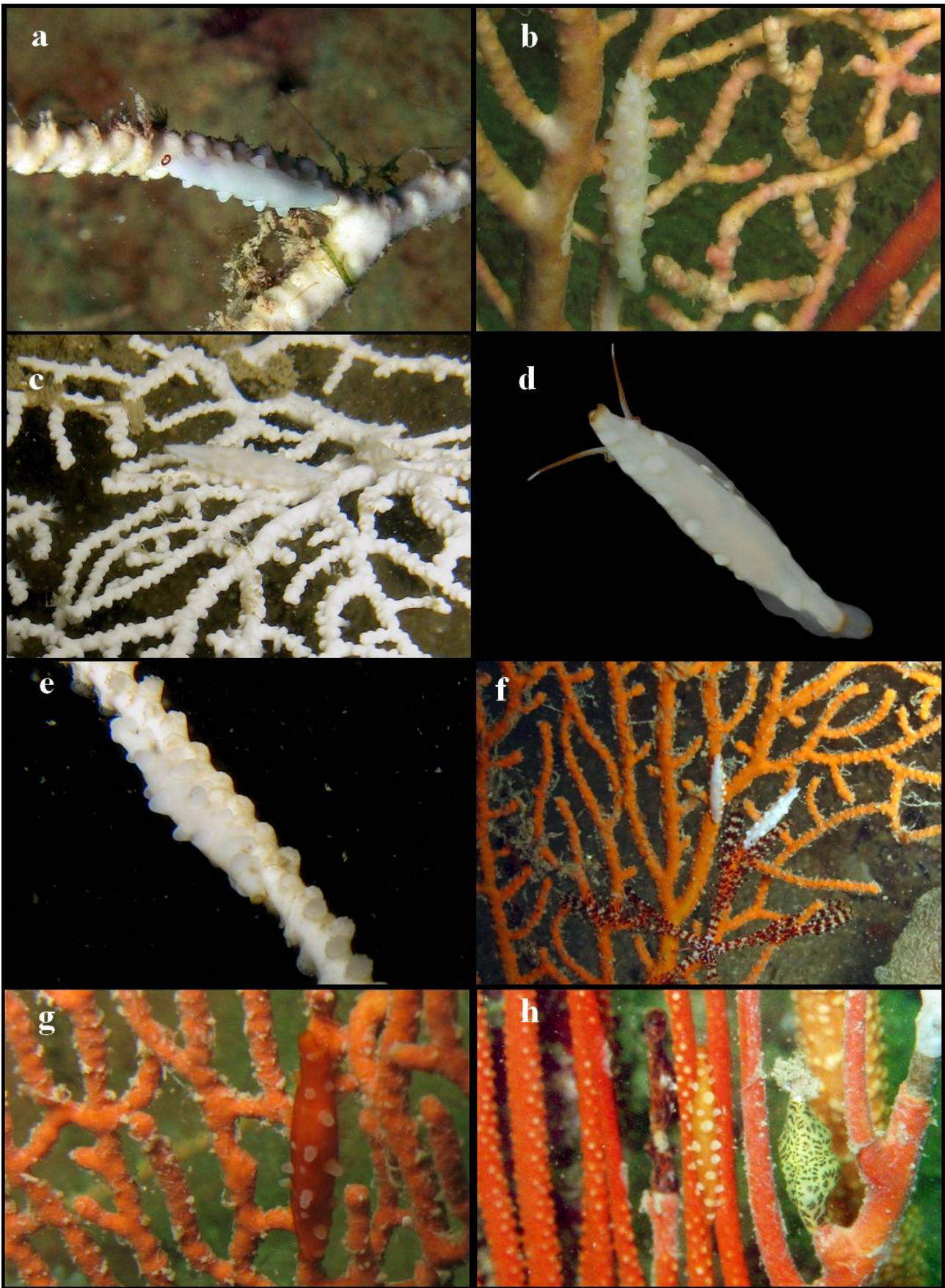


Fig. 27. a–f, *Aclyvolvula lamyi*: a, Pulau Hantu (Photograph by: J. Thuaibah, 2006); b, Pulau Hantu (Photograph by: C. H. Toh, Mar.2008); c, Pulau Hantu (Photograph by: C. H. Toh, Oct.2010); d, Pulau Hantu, Mar.2010; e, Pulau Hantu (Photograph by: C. H. Toh, Sep.2009); f, Pulau Hantu (Photograph by: M. L. Neo, Nov.2010). g–h, *Aclyvolvula cf. lanceolata*: g, Pulau Hantu (Photograph by: C. H. Toh, May.2010); h, Kusu Island (Photograph by: M. S. Khoo, 2007).

**ALPHABETICAL CHECKLIST OF OVULIDAE RECORDED FROM SINGAPORE**

Taxa in bold are treated in this study; taxa indicated with an asterisk (\*) denote unverifiable occurrence of the species in Singapore based on this study; taxa indicated with a hex (#) denote doubtful taxonomic status of the species based on published literature (e.g., Lorenz & Fehse, 2009).

<b>Taxa</b>	<b>Localities in Singapore</b>	<b>Reference(s)</b>	<b>Remarks</b>
<i>Aclyvolvula lamyi</i> (F. A. Schilder, 1932)	ECP; P. Hantu	This study	ZRC.MOL.3055–3056
<i>Aclyvolvula lanceolata</i> (G. B. Sowerby II, 1848)	Buran Darat	Purchon & Purchon, (1981)	Recorded as <i>Neosimnia lanceolatum</i>
	Not specified	Trew (1987)	
	Not specified	Goh et al. (1999) after Lim (1969a)	Recorded as <i>Volva lanceolata</i> (Sowerby)
	Not specified	Tan & Woo (2010)	
	Straits of Malacca (1.42° N, 102.97° E); P. Hantu	This study	ZRC.1975.3.7.157
<i>Calcarovula longirostrata</i> (G. B. Sowerby I, 1828)*	“reef sites south of Singapore”	Goh & Chou (1994a)	Recorded as <i>Phenacovolva longirostrata</i> (Sowerby, 1828)
<i>Calpurnus verrucosus</i> (Linnaeus, 1758)*	Not specified	Cate (1973); Tan & Woo (2010)	
<i>Carpiscula bullata</i> (G. B. Sowerby II in A. Adams & Reeve, 1848)*	“Caramata Passage, Singapore”	Cate (1973) after A. Adams & Reeve (1848); Fehse (2001)	Recorded location is type locality
	Not specified	Tan & Woo (2010)	
<i>Crenavolva aureola</i> (Fehse, 2002)	Not specified	Lorenz & Fehse (2009); Tan & Woo (2010)	
	ECP; St. John’s Island	This study	ZRC.MOL.3026
<i>Crenavolva guidoi</i> Fehse, 2002	“South Singapore”	Lorenz & Fehse (2009)	
	ECP; P. Hantu	This study	ZRC.MOL.3027–28
<i>Crenavolva leopardus</i> Fehse, 2002	Terembu Pempang Tengah	Goh et al. (1999)	Recorded as <i>Primovula</i> cf. <i>dentata</i> (Adams & Reeve, 1848); ZRC.1995.60–62
	“Caramata Passage (01°14’ N; 103°55’ E) near Singapore”	Fehse (2002)	Recorded location is type locality

The Ovulidae Of Singapore

Taxa	Localities in Singapore	Reference(s)	Remarks
	Not specified	Lorenz & Fehse (2009); Tan & Woo (2010)	
	CBP; ECP; P. Ubin; P. Hantu; St. John's Island	This study	ZRC.MOL.3019–22
<i>Crenavolva matsumiyai</i> Azuma, 1974	CBP	This study	
<i>Crenavolva striatula</i> (G. B. Sowerby I, 1828)	Not specified	Trew (1987)	
	ECP, P. Hantu	This study	ZRC.MOL.3018
<i>Crenavolva traillii</i> (A. Adams, 1855)	P. Subar Laut; Lazarus Island	Goh et al. (1999)	Recorded as <i>Crenavolva</i> ( <i>Crenavolva</i> ) cf. <i>striatula</i> <i>traillii</i> (A. Adams, 1855); ZRC.1995.54
	“South Singapore”	Lorenz & Fehse (2009)	
	Not specified	Tan & Woo (2010)	
	CBP, ECP, St. John's Island	This study	ZRC.MOL.3023–25
<i>Cuspivolva formosa</i> (G.B. Sowerby II in A. Adams & Reeve, 1848)	CBP	This study	ZRC.MOL.3035–36
<i>Cuspivolva renovata</i> (Iredale, 1930) <sup>#</sup>	“Caramata Passage (01°14' N; 103°55' E) near Singapore”	Cate, (1973); Fehse (2002a); Lorenz & Fehse (2009)	Recorded as <i>Prosimnia</i> <i>renovata</i> by Cate (1973). Lorenz & Fehse (2009) doubted the validity of its taxonomic status.
<i>Cuspivolva ostheimeræ</i> (Cate, 1973)	CBP	This study	ZRC.MOL.3030
<i>Cuspivolva queenslandica</i> (Cate, 1974)	CBP; ECP; P. Ubin	Wong (2008)	Recorded as <i>Cymbovula</i> <i>segaliana</i> Cate, 1973; ZRC.MOL.2840
	Not specified	Lorenz & Fehse (2009); Tan & Woo (2010)	
	CBP; ECP	This study	ZRC.MOL.3037–38
<i>Cuspivolva singularis</i> (Cate, 1973)	CBP; P. Ubin; St. John's Island	This study	ZRC.MOL.3031–34
<i>Dentiovula dorsuosa</i> (Hinds, 1844)	Not specified	Cate (1973)	
	Not specified	Goh et al. (1999) after Lim (1969a); Lim (1969b)	Recorded as <i>Volva</i> <i>dorsuosa</i>

Taxa	Localities in Singapore	Reference(s)	Remarks
	Not specified	Tan & Woo (2010)	
	ECP	This study	ZRC.MOL.3040
<i>Dentiovula rutherfordiana</i> (Cate, 1973)	ECP	This study	
<i>Dentiovula</i> species	Changi East; ECP	This study	ZRC.MOL.3041
<i>Diminovula alabaster</i> (Reeve, 1865)	Not specified	Cate (1973); Trew (1987); Lorenz & Fehse (2009); Tan & Woo (2010)	
	CBP; ECP; P. Ubin; St. John's Island	This study	ZRC.MOL.3015–3017
<i>Globovula sphaera</i> Cate, 1973	Changi	This study	
<i>Hiatavolva depressa</i> (G. B. Sowerby II, 1875)*	Not specified	Tan & Woo (2010)	
<i>Margovula marginata</i> (G. B. Sowerby I, 1828)	Not specified	Tan & Woo (2010)	Recorded as <i>Pseudosimnia marginata</i> (Sowerby, 1828)
	CBP; ECP	This study	ZRC.MOL.3013
<i>Margovula pyriformis</i> (G. B. Sowerby I, 1828)	Not specified	Tan & Woo (2010)	
	CBP; ECP	This study	ZRC.MOL.3014
<i>Naviculavolva deflexa</i> (G. B. Sowerby II, 1848)*	Not specified	Cate (1973)	Recorded as <i>Cymbula deflexa</i> (Sowerby II, 1848)
	Not specified	Wong (2008); Tan & Woo (2010)	Recorded as <i>Cymbovula deflexa</i> (Sowerby, 1848)
<i>Pellasmnia angasi</i> (Reeve, 1865)	P. Tekong; CBP; ECP; P. Sudong	This study	ZRC.1975.3.6.26; ZRC.MOL.3044–45
<i>Pellasmnia improcera</i> (Azuma & Cate, 1971)	Not specified	Tan & Woo (2010)	Recorded as <i>Phenacovolva improcera</i> (Azuma & Cate, 1971)
	CBP; ECP; St. John's Island; P. Semakau; P. Ular	This study	ZRC.MOL.3046–47
<i>Phenacovolva barbieri</i> Lorenz & Fehse, 2009	Beting Bronok (R. Tan, pers. comm.)	Lorenz & Fehse (2009)	Recorded as <i>Phenacovolva</i> cf. <i>barbieri</i> Lorenz & Fehse, 2009
	Not specified	Tan & Woo (2010)	Recorded as <i>Phenacovolva</i>



The Ovulidae Of Singapore

Taxa	Localities in Singapore	Reference(s)	Remarks
			cf. <i>barbieri</i> Lorenz & Fehse, 2009
	CBP; P. Ubin	This study	ZRC.MOL.3053–54
<i>Phenacovolva birostris</i> (Linnaeus, 1767) <sup>#</sup>	Not specified	Trew (1987)	Recorded as <i>Phenacovolva birostris</i> Linnaeus, 1767
	“reef sites south of Singapore”	Goh & Chou (1994a)	Lorenz & Fehse (2009) doubted the validity of its taxonomic status.
<i>Phenacovolva brevirostris</i> (Schumacher, 1817)	Not specified	Goh et al. (1999) after Lim (1969a); Chuang (1973)	Recorded as <i>Volva brevirostris</i>
	Not specified	Lorenz & Fehse (2009); Tan & Woo (2010)	
	CBP; ECP; P. Hantu	This study	ZRC.1975.3.6.25
<i>Phenacovolva dancei</i> Cate, 1973	“Singapore, Malaysia (1°14'N: 105°55'E)”	Cate (1973)	Recorded location is type locality; ZRC.1975.3.6.27
	Not specified	Trew (1987)	Recorded as <i>Turbovula dancei</i> Cate, 1973
	Not specified	Tan & Woo (2010)	
	ECP, P. Hantu	This study	
<i>Phenacovolva nectarea</i> Iredale, 1930	Not specified	Trew (1987)	Recorded as <i>Calcaria tokioi</i> Cate, 1973
	P. Semakau	Goh et al. (1999)	Recorded as <i>Phenacovolva</i> cf. <i>tokioi</i> Cate, 1973; ZRC.1995.53
	Beting Bronok (R. Tan, pers. comm.)	Lorenz & Fehse (2009)	Recorded as <i>Phenacovolva</i> cf. <i>nectarea</i>
	Not specified	Tan & Woo (2010)	
	CBP; ECP; P. Ubin; P. Hantu; P. Semakau	This study	ZRC.MOL.3051–52
<i>Phenacovolva philippinarum</i> (G. B. Sowerby II, 1848)*	Not specified	Goh et al. (1999) after Lim (1969a); Lim (1969b)	Recorded as <i>Volva philippinarum</i>
	Not specified	Chuang (1973)	Recorded as <i>Volva philippinarum</i>
	Not specified	Chou et al. (1994)	Recorded as <i>Amphiperas philippinarum</i>

<b>Taxa</b>	<b>Localities in Singapore</b>	<b>Reference(s)</b>	<b>Remarks</b>
<i>Phenacovolva rosea</i> (A. Adams, 1854)	Not specified	Lorenz & Fehse (2009); Tan & Woo (2010)	Recorded as <i>Phenacovolva</i> cf. <i>rosea</i> (A. Adams, 1854)
	CBP; ECP; P. Hantu	This study	ZRC.MOL.3048–3050
<i>Primovula roseomaculata</i> (Schepman, 1909)	Not specified	Trew (1987)	Recorded as <i>Adamantia</i> <i>roseomaculata</i> Schepman, 1909
	ECP	This study	
<i>Primovula rosewateri</i> (Cate, 1973)*	Terembu Pempang Tengah	Goh et al. (1999)	Recorded as <i>Crenavolva</i> ( <i>Crenavolva</i> ) cf. <i>rosewateri</i> Cate, 1973; ZRC.1995.57–58
	Not specified	Tan & Woo (2010)	Recorded as <i>Crenavolva</i> cf. <i>rosewateri</i> Cate, 1973.
	ECP	This study	
<i>Primovula</i> cf. <i>tropica</i> F. A. Schilder, 1931	St. John's Island	This study	
<i>Prionovolva brevis</i> (G. B. Sowerby I, 1828)	Not specified	Tan & Woo (2010)	
	CBP; ECP; Beting Bronok; P. Hantu; Tuas	This study	ZRC.MOL.3010–3011
<i>Prionovolva nivea</i> Cate, 1974	ECP; St. John's Island	This study	ZRC.MOL.3012
<i>Prosimnia semperi</i> (Weinkauff, 1881)	P. Sudong (M. L. Neo, pers. comm.)	This study	
<i>Sandalia</i> cf. <i>triticea</i> (Lamarck, 1810)	St. John's Island	This study	
<i>Testudovolva bullum</i> (G. B. Sowerby II in A. Adams & Reeve, 1848) <sup>#</sup>	Not specified	Trew (1987)	Recorded as <i>Prionovolva</i> <i>bullum</i> Adams & Reeve, 1848; Lorenz & Fehse (2009) doubted the validity of its taxonomic status.
<i>Volva volva</i> (Linnaeus, 1758)	Not specified	Chou et al. (1994)	Recorded as <i>Amphiperas</i> <i>volva</i>
	Not specified	Tan & Woo (2010)	
	Changi East; CBP; ECP	This study	ZRC.MOL.3042–3043

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## INDEX

Current names and page numbers of illustrations are in **bold**.

<i>Aclyvolva lamyi</i> .....	20, <b>40</b> , <b>49</b> , 50	<i>Margovula marginata</i> .....	5, 21 <b>23</b> , 53
<i>Aclyvolva lanceolata</i> .....	20, <b>40</b> , <b>49</b> , 50	<i>Margovula pyriformis</i> .....	5, 21, <b>24</b> , 53
<i>Calcarovula longirostrata</i> .....	21, 50	<i>Naviculavolva deflexa</i> .....	21, 53
<i>Calpurnus verrucosus</i> .....	21, <b>41</b> , 50	<i>Pellasimnia angasi</i> .....	16, 21, <b>39</b> , <b>46</b> , 53
<i>Carpiscula bullata</i> .....	21, 50	<i>Pellasimnia improcera</i> .....	17, 21, <b>39</b> , <b>46</b> , 53
<i>Crenavolva aureola</i> .....	8, <b>27</b> , 50	<i>Phenacovolva barbieri</i> .....	18, 19, 21, <b>38</b> , <b>47</b> , 53
<i>Crenavolva guidoi</i> .....	8, 10, <b>30</b> , <b>43</b> , 50	<i>Phenacovolva birostris</i> .....	21, 53
<i>Crenavolva leopardus</i> .....	8, 10, 21, <b>28</b> , <b>42</b> , 51	<i>Phenacovolva brevirostris</i> .....	18, 19, 21, <b>37</b> , 53
<i>Crenavolva matsumiyai</i> .....	10, 21, <b>29</b> , 51	<i>Phenacovolva dancei</i> .....	18, 21, <b>37</b> , <b>47</b> , 54
<i>Crenavolva striatula</i> .....	7, 8, 21, <b>27</b> , <b>42</b> , 51	<i>Phenacovolva nectarea</i> ....	17, 18, 21, <b>36</b> , <b>48</b> , 54
<i>Crenavolva traillii</i> .....	8, 9, 21, <b>29</b> , <b>43</b> , 51	<i>Phenacovolva philippinarum</i> .....	21, 54
<i>Cuspirolva formosa</i> .....	13, 21, <b>33</b> , <b>45</b> , 51	<i>Phenacovolva rosea</i> ....	17, 18, 21, <b>35</b> , <b>47</b> , <b>48</b> , 54
<i>Cuspirolva renovata</i> .....	9, 21, 51	<i>Primovula roseomaculata</i> .....	11, <b>30</b> , 55
<i>Cuspirolva ostheimeriae</i> .....	12, 21, <b>32</b> , <b>44</b> , 52	<i>Primovula rosewateri</i> .....	11, 21, 55
<i>Cuspirolva queenslandica</i> ...	9, 13, 21, <b>34</b> , <b>45</b> , 51	<i>Primovula cf. tropica</i> .....	11, <b>30</b> , 55
<i>Cuspirolva singularis</i> .....	12, 21, <b>32</b> , <b>44</b> , 52	<i>Prionovolva brevis</i> .....	3, 4, 21, <b>23</b> , <b>41</b> , 55
<i>Dentiovula dorsuosa</i> .....	14, <b>30</b> , 52	<i>Prionovolva nivea</i> .....	4, <b>23</b> , 55
<i>Dentiovula rutherfordiana</i> .....	14, <b>31</b> , 52	<i>Prosimnia semperi</i> .....	6, 22, <b>42</b> , 55
<i>Dentiovula species</i> .....	15, <b>31</b> , 52	<i>Sandalia cf. triticea</i> .....	7, 21, <b>30</b> , 55
<i>Diminovula alabaster</i> .....	6, 21, <b>26</b> , <b>41</b> , 52	<i>Testudovula bullum</i> .....	21, 55
<i>Globovula sphaera</i> .....	3, 21, <b>24</b> , 52	<i>Volva volva</i> .....	15, 21, <b>40</b> , 55
<i>Hiatavolva depressa</i> .....	21, 52		