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SINGAPORE MOLLUSCA: 1. THE FAMILY ANGARIIDAE (GASTROPODA: VETIGASTROPODA: ANGARIOIDEA)

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ABSTRACT. — This is the first in a series of group-by-group treatments of the taxonomy and nomenclature of the molluscs of Singapore based on a review of the literature and examination of geographically relevant material. The family Angariidae is treated. *Angaria delphinus* is the only representative of the family to be found in Singapore. It was first recorded in 1836 as a species of *Delphinula*, a synonym of *Angaria*. A record of *Delphinula turbinopsis* from Singapore in 1847 is believed to be a misidentification of *Turbo bruneus.*

KEY WORDS. — Mollusca, Angariidae, *Angaria*, *Delphinula turbinopsis*, Singapore

INTRODUCTION

A recent compilation of the molluscs of the Republic of Singapore listed 1,264 species (S. K. Tan & Woo, 2010). The main objective of that preliminary compilation was to list all species recorded from the territory and thus contained only names and literature records. Since then, several publications listing new records and rediscoveries or clarifying the taxonomy and nomenclature of molluscs from Singapore (e.g., S. K. Tan & Yeo, 2010; Lok et al., 2011; Wong, 2011; Neo & Todd, 2012, 2013; S. K. Tan & Clements, 2011; S. K. Tan & Low, 2011, 2013; S. K. Tan et al., 2011, 2013; S. K. Tan & Chan, 2012; Ang & S. K. Tan, 2013; Low et al., 2013) have appeared.

To build on and update the checklist of S. K. Tan & Woo (2010), it is felt that detailed group-by-group treatments of the molluscs of Singapore are necessary. The taxonomy and nomenclature of each group will be treated from the 'ground up', with original descriptions being checked for overlooked nomenclatural issues and the earliest Singapore records located (and corroborated where possible). It is also our intention to list and figure material from Singapore (where possible). These illustrations will thus serve as photographic records of the aspects of the malacofauna of Singapore (especially intraspecific variation), as well as aid in their identification.

This series of group-by-group treatments also seeks to clarify and discuss two important points related to historical records of molluscs from Singapore, namely wrongly-localised species and misidentified species. Wrongly-localised species are those that were recorded as originating from Singapore, or were described as new species based on material from Singapore, but are not found here. This is not surprising given Singapore's long history as a trading centre and later as an entrepôt. Mollusc shells were often brought to Singapore to be traded, sometimes from as far as away as Australia, as discussed briefly by Smith (1887: 465, 466).

The misidentification of species most often results from material from Singapore being identified with superficially similar species that are not known to found here. An example of this are records of *Delphinula turbinopsis* Lamarck, 1822, by Traill (1847: 241) and Balfour (1858: 350), which are discussed below. The misidentification of species can also result from changes in taxonomy and nomenclature which can lead to the name of a species previously recorded from Singapore later being used for another species.

This series thus aims to bring the information on Singapore Mollusca to as current a state as possible. The first of these treatments is on the family Angariidae Gray, 1857, a small family of gastropods comprised of some 15 living species assigned to the single genus *Angaria* Röding, 1798. Members of the family are today restricted to the Central Indo-Pacific region, although fossils have been found as far away as Europe (e.g., Kollmann, 2009). Little is known about their biology and ecology. The animals are associated with algae and assumed to be herbivorous (Poppe & Goto, 1993; Wilson, 1993).

The angariids have historically been regarded as a distinct family within the superfamily Trochoidea Rafinesque, 1815, or a subfamily within the Trochidae Rafinesque, 1815, or Turbinidae Rafinesque, 1815. Since Marshall (1979) first suggested that the group consists of possibly archaic turbinids based on shell and radular characters, the angariids are usually accepted as a turbinid subfamily (e.g., Vaught, 1989; Bouchet & Rocroi, 2005), although some authors

maintained them as a distinct trochoid family based on shell and operculum characters (e.g., Poppe & Goto, 1993). Results of recent molecular phylogenetic analyses suggest, however, that angariids are not only distinct from both the trochids and turbinids, but deserving of its own superfamily, Angarioidea (see Williams & Ozawa, 2006; Williams et al., 2008).

MATERIAL AND METHODS

Records were collated from the available literature, and geographically relevant material in collections was examined. Primary synonyms and records mentioning Singapore are listed. Abbreviations of the collections from which specimens were examined in the course of this study are: ZRC = Zoological Reference Collection, Raffles Museum of Biodiversity Research, National University of Singapore; and TSK = collection of the first author. Measurements are given in the form of shell height (SH) × shell width (SW). Shell height is defined as the distance from the apex to the lowest part of the basal side of the peristome, and shell width is the distance between the edges of the widest part of the body whorl (including spines) perpendicular to the coiling axis. All measurements are in millimetres (mm).

SYSTEMATIC ACCOUNTS

SUPERFAMILY ANGARIOIDEA GRAY, 1857

FAMILY ANGARIIDAE GRAY, 1857

Angarina Gray, 1857: 156 (type genus *Angaria* Röding, 1798).

***Remarks*.** — Angarina is the original spelling of Gray (1857; see also Bouchet & Rocroi, 2005: 27).

Genus *Angaria* Röding, 1798

Angaria Röding, 1798: 71 (*Turbo delphinus* Linnaeus, 1758, by subsequent designation by Fischer, 1875: 58).
Delphinula Lamarck, 1804: 108 (type species *Turbo delphinus* Linnaeus, 1758, by subsequent designation by Montfort, 1810: 131).

***Remarks*.** — The name *Delphinula* was established by Lamarck (1804: 108) with the inclusion of 11 species of *Turbo* Linnaeus, 1758, including *Turbo delphinus* and *Turbo distortus* (both described by Linnaeus, 1758). Montfort (1810: 131) emended *Delphinula* Lamarck, 1804, unnecessarily to *Delphinulus* and included only one species, *Delphinula spinosa* Roissy, 1804–1805, which becomes the type species of *Delphinulus* Montfort, 1810, by monotypy. Under the synonymy of *Delphinula spinosa*, Montfort (1810) included *Turbo delphinus* Linnaeus, 1758. This action means that Montfort (1810) designated *Turbo delphinus* Linnaeus, 1758, as the type species of *Delphinula* Lamarck, 1804 (Article 69.2.2 of the International Code of Zoological Nomenclature, hereafter the Code, ICZN, 1999: 72). *Delphinula* Lamarck, 1804, and *Angaria* Röding, 1798, are thus objective synonyms as they have the same type species (Article 61.3.3 of the Code, ICZN, 1999: 64).

Angaria delphinus (Linnaeus, 1758)
(Figs. 1–3)

Turbo delphinus Linnaeus, 1758: 764, no. 546 (type locality "O. Asiatico").
Turbo distortus Linnaeus, 1758: 764, no. 547 (type locality: none).
Delpinula laciniata Lamarck, 1816: 11, pl. 451, fig. 1a, b (type locality: "l'Océan indien" [see Lamarck, 1822: 230, 231]).
Delphinula atrata Reeve, 1842: 158, pl. 212, fig. 12 (type locality "Philippine Islands" [see Reeve, 1843: caption to *Delphinula* pl. 1, fig. 4]).

Singapore records:
Delphinula distorta – Jay, 1836: 50 [first record]. — Jay, 1839: 70.
Delphinula laciniata – Traill, 1847: 241. — Balfour, 1858: 350 [after Traill, 1847].
Delphinula sp. – Traill, 1847: 241.
Delphinula atrata – Lischke, 1869: 89. — von Martens, 1867: 237. — Troschel, 1879: 222. — Fischer, 1890: 202, 269.
Angaria (*Angaria*) *delphinus* forma *atrata* – Beets, 1950: 306.
Angaria atrata – Chuang, 1961: 150, pl. 56, fig. 5. — Chuang, 1973: 199. — Chou et al., 1994: 78.
Angaria delphinus atrata – Chuang, 1973: 186.

Angaria delphinus – Way & R. D. Purchon, 1981: 314 ("dredged off Pulau Sudong, Labrador, Raffles Light" [see R. D. Purchon & D. E. A. Purchon, 1981]). — Chou et al., 1994: 73. — K. S. Tan & Chou, 2000: 48. — S. K. Tan & Woo: 25 [after Chuang, 1973; Way & Purchon, 1981; Chou et al., 1994; K. S. Tan & Chou, 2000]. — S. K. Tan & Yeo, 2010: 294 (Pulau Semakau). — Wang et al., 2011: 294–295 ("... eastern shores and the Southern Islands"). — Ng, 2012: 143 (Pulau Semakau).

Angaria (*Angaria*) *delphinus* – Kulkarni et al., 2010: 312.

Material examined. — **Singapore**: Tanah Merah Ferry Terminal: (TSK 0707) 2 Oct.1999; (TSK uncat.) Dec.2002; (ZRC.MOL.5652) 26 Apr.2009. Pulau Hantu (ZRC.MOL.5613), 7 Jun.2009; Pulau Semakau (ZRC.MOL.5609), 3 Apr.2010; Cyrene Reef (ZRC.MOL.5651), 22 Jul.2012.

Distribution in Singapore. — See Fig. 1.

Habitat. — Intertidal to shallow water offshore, usually on weedy and algae covered rocks of breakwaters and seawalls, rocky and stony parts of the reef flats, and near coral reefs (Chuang, 1973; K. S. Tan & Chou, 2000; S. K. Tan, unpublished data).

Diagnosis. — The following diagnosis is based on specimens from Singapore and Poppe & Goto (1993). Shell round in shape, to about 70 mm in width; apex flat, early whorls strongly keeled with angular projections from the shoulder; body whorl keeled at the shoulder, generally with clusters of two or more hollow finger-like spines projecting at regular intervals; prominent keel bearing short hollow spines circling the open funnel-like umbilicus. Usually with one primary spiral rib with prominent spines between the shoulder and umbilical keels, two or more secondary ribs bearing shorter spines, and numerous fine interstitial ribs with very short spines or scales. Base colour cream to pinkish-brown, spines and ribs purplish-black. Peristome complete, distinctly concave at parietal side; aperture round, interior nacreous,

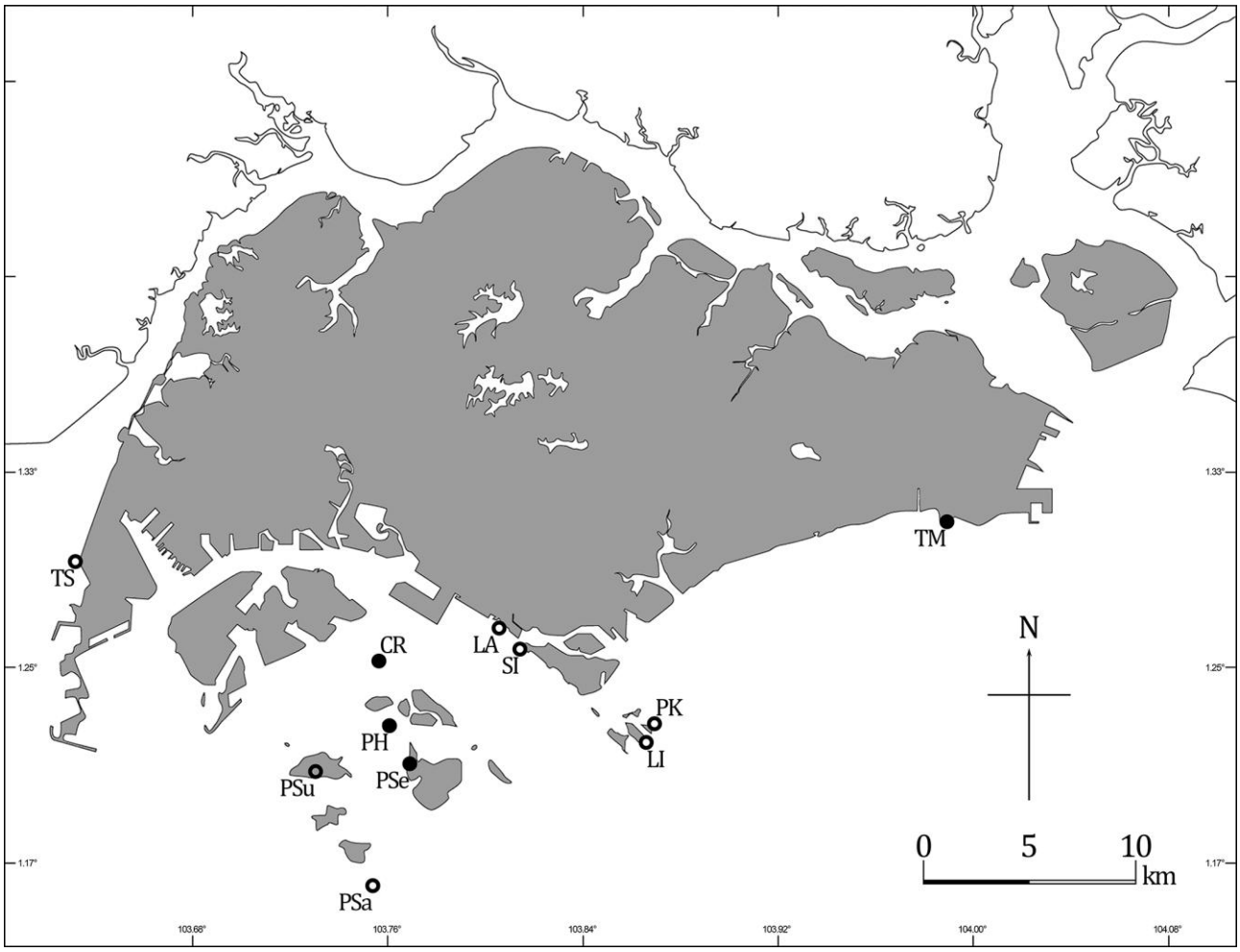

Fig. 1. Distribution records of *Angaria delphinus* in Singapore: CR, Cyrene Reefs; LA, Labrador; LI, Lazarus Island (Pulau Sakijang Pelepah); PH, Pulau Hantu; PK, Pulau Kusu (Kusu Island); PSa, Pulau Satumu (Raffles Lighthouse); PSe, Pulau Semakau; PSu, Pulau Sudong; SI, Sentosa Island (western end); TM, Tanah Merah Ferry Terminal; TS, Tuas South. Solid circles (●) represent records based on material examined, while open circles (O) represent records from published literature and unpublished data.

bordered with pink at the edge; interior usually with two indistinct grooves that correspond to the shoulder keel and primary rib on the body whorl; a triangular canal-like extension prominent at the anterior end of the lip, a similar but less distinct one is aligned with the shoulder keel.

***Remarks*.** — The first record of *Angaria delphinus* (Linnaeus, 1758), from Singapore was by Jay (1836: 50, as *Delphinula distorta*; see Discussion below). This is also the only angariid species confirmed to occur in Singapore waters, and is the most widespread of the living species (Poppe & Gotto, 1993). This species has also been recorded from Singapore as *Delphinula laciniata* Lamarck, 1816, and *Delphinula atrata* Reeve, 1842, which are junior synonyms of *Angaria delphinus* (Linnaeus, 1758). The figures of the type material (Mermod & Binder, 1963: fig. 232; Reeve, 1843: pl. 1, fig. 4) clearly depict specimens that fall within the intraspecific variation of *Angaria delphinus* (Linnaeus, 1758). *Turbo distortus* Linnaeus, 1758, has long been considered a synonym of *Turbo* (now *Angaria*) *delphinus* Linnaeus, 1758. Even Linnaeus (1758: 764) expressed doubt as to the validity of this species. All modern authors (e.g., Poppe & Gotto, 1999: 18; Tomida, 2005: 223) accept *Turbo distortus* as a junior synonym of *Turbo delphinus*, and we concur. An extensive list of synonyms of this species can be found in Poppe & Gotto (1993: 18).

"*Delphinula distorta* Lamarck, 1822" is sometimes listed as available name (e.g., Poppe & Goto, 1999: 18), however, Lamarck (1822: 231) listed "*Turbo distortus*. Lin. Gmel. p. 3600, no. 46" under the synonym of this name, clearly indicating that he was simply transferring *Turbo distortus* Linnaeus, 1758, to the genus *Delphinula* Lamarck, 1804, and not proposing a new name.

Poppe & Goto (1993: 18) restricted the type locality of *Angaria delphinus* to the Philippines. Their action, however, is not valid in the sense of Article 76 of the Code (ICZN, 1999: 86, 87), since the type locality of a species is defined by the origin of the holotype (or its equivalent). The type locality of *Angaria delphinus* (as given by Linnaeus, 1758: 764) is thus the Asian seas ("O. Asiatico").

Angaria delphinus shows remarkable variation in the form of the shell, sculpture and extent of the spines (Figs. 2, 3). The shell colouration and sculpture, structure of the spines, and prominent keel around the umbilicus are characteristics to separate this species from morphologically close congeners. The body whorl is sometimes scarcely attached at the suture or separated near the aperture. Shell colouration is also known to be variable with extremities having red and white banded shells (see Poppe & Goto, 1993). Nevertheless, radical variations in shell form and colouration have not been observed in specimens from Singapore thus far.

DISCUSSION

Three species of *Delphinula*, namely *Delphinula laciniata*, *Delphinula turbinopsis*, and an unidentified *Delphinula* species were mentioned by Traill (1847: 241), who listed shells from Singapore and its vicinity. The records of *Delphinula laciniata* and *Delphinula turbinopsis* of Traill (1847) were also listed by Balfour (1858: 350). However we have little doubt that *Delphinula laciniata* and the unidentified *Delphinula* species are conspecific with the species now known as *Angaria delphinus*, since there are no other known congeneric species occurring in Singapore or its immediately adjacent areas. As pointed out by Iredale (1929: 273), *Delphinula turbinopsis* [=*Turbo turbinopsis*] is synonymous with the species more commonly called *Turbo laminiferus* Reeve, 1848, which is known only from Australia and Papua New Guinea (Alf & Kreipl, 2003). The species identified from Singapore as *Delphinula turbinopsis* by Traill (1847), is most likely *Turbo bruneus* Röding, 1798, which is the morphologically closest *Turbo* species known from Singapore.

Although most authors accept that there is remarkable variability in shell form and colouration in *Angaria delphinus*, there seems to be no easily perceivable morphological characteristic that is distinctive. Some forms appear to be restricted to only parts of this species' known range, while many populations show regularity in shell colour and sculpture. It is thus possible that *Angaria delphinus* may in fact represent a species-complex. The taxonomy of the angariids has thus far been based only on external morphology and future molecular studies should allow for the clarification and confirmation of our current understanding of the family.

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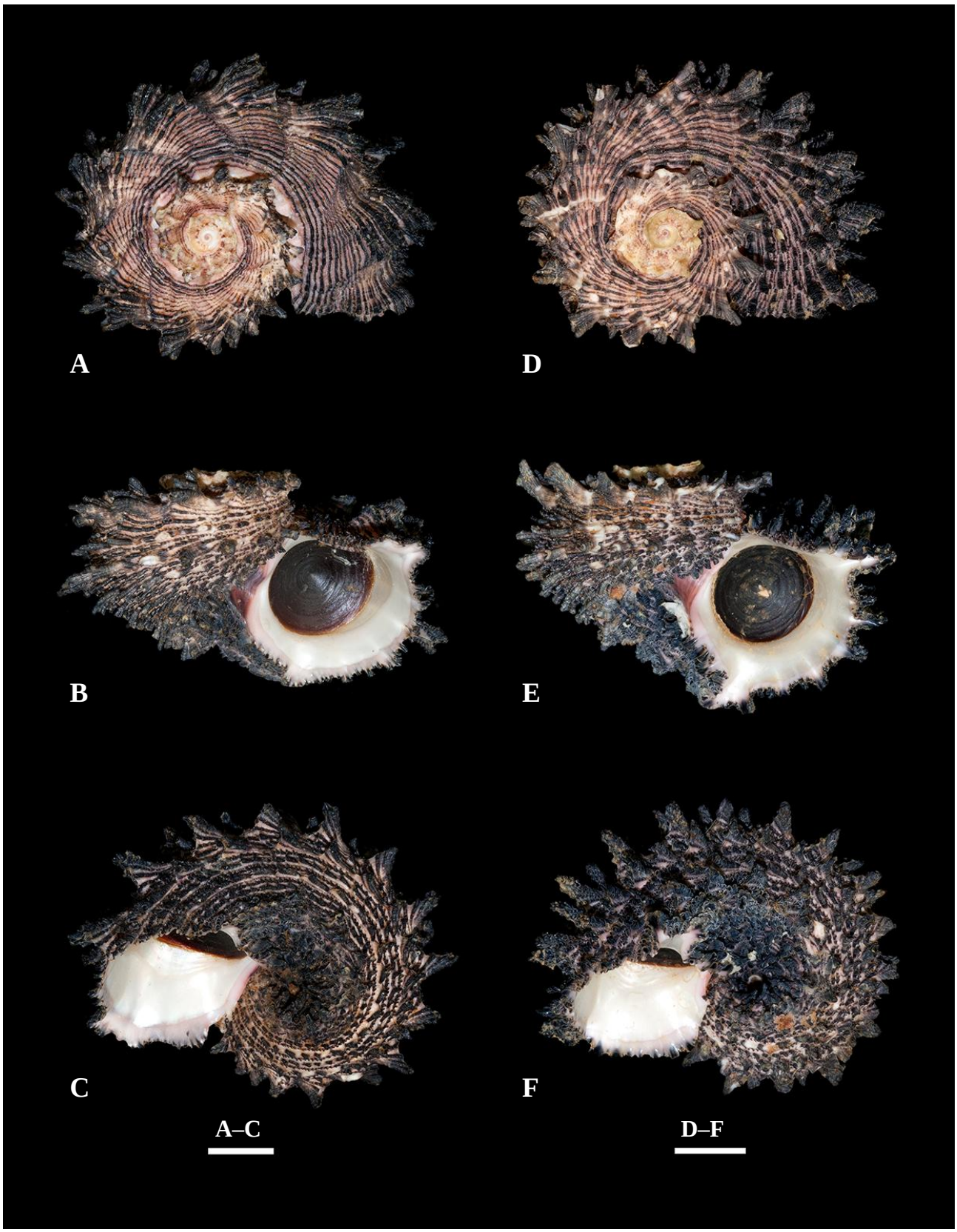

Fig. 2. Cleaned specimens of *Angaria delphinus* (Linnaeus, 1758) from Tanah Merah Ferry Terminal, Singapore: A–C, SH 35.5 × SW 51.7 mm; D–F, SH 35.1 × 58.7 mm. Views: A, D, apical; B, E, apertural; C, F, umbilical. Scale bars = 10 mm. (Photographs by: S. K. Tan).

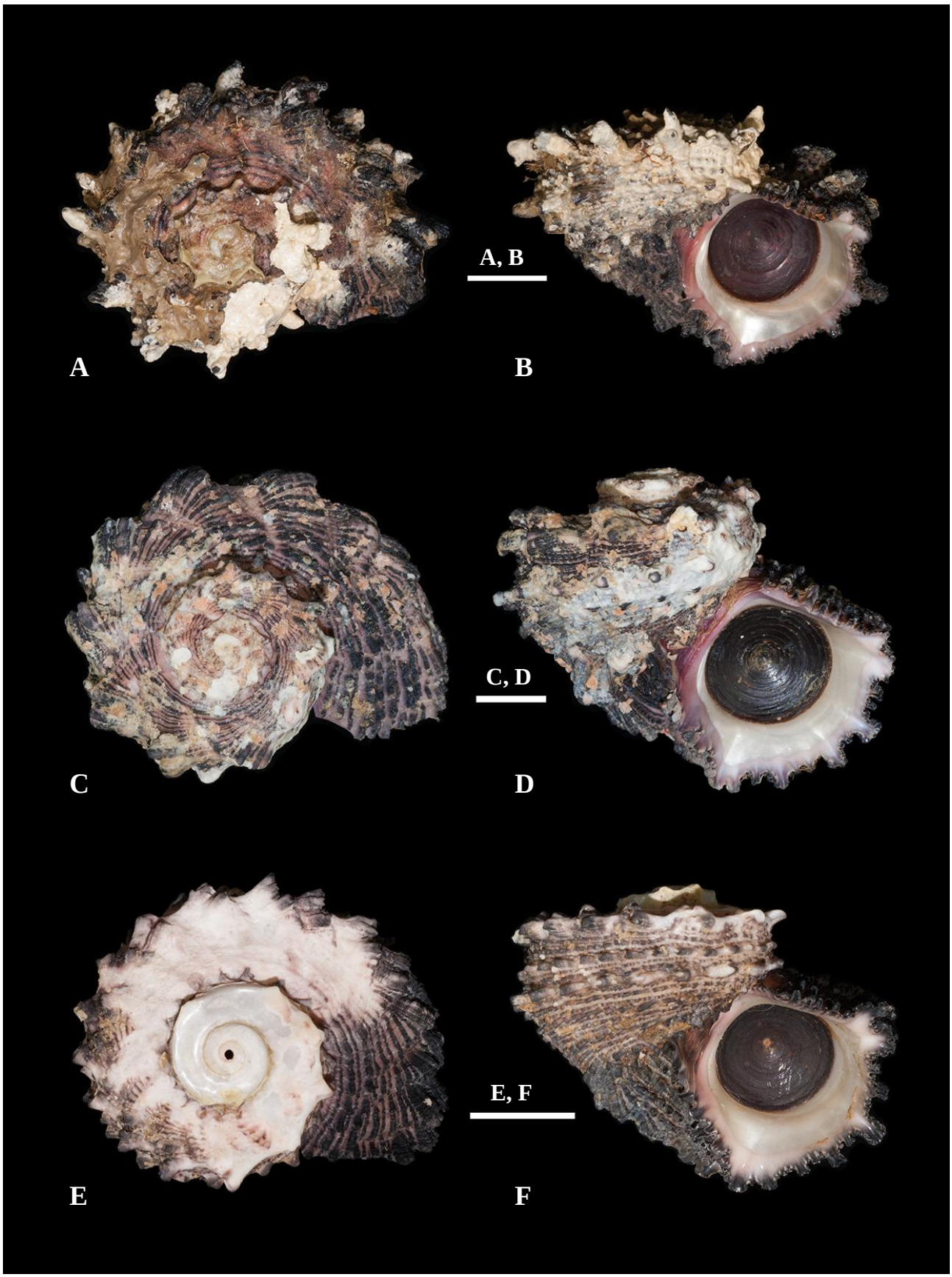

Fig. 3. Representative variations of *Angaria delphinus* from various Singapore localities: A, B, Pulau Hantu (SH 34 × SW 48.5 mm; ZRC.MOL.5613); C, D, Tanah Merah Ferry Terminal (SH 48.5 × SW 57.1 mm; TSK); E, F, Pulau Semakau (SH 29.7 × SW 37.1 mm; ZRC.MOL.5609). Views: A, C, E, apical; B, D, F, apertural. Scale bars = 10 mm. (Photographs by: S. K. Tan).

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