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Research article

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Cheilostome Bryozoa from Penang and Langkawi, Malaysia

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Abstract. Twenty-three species of cheilostome bryozoans are described from the Malaysian islands of Penang and Langkawi based on a brief reconnaisance survey of shore localities. These are the first bryozoans to be formally described from either island and they demonstrate the potential for further research on these neglected suspension feeders. Of the 23 species recorded, 12 are anascans, half of which are malacostegines, and 11 are ascophorans. The new combinations *Acanthodesia falsitenuis* (Liu, 1992), *A. perambulata* (Louis & Menon, 2009) and *A. irregulata* (Liu, 1992) are introduced. Most of the species recorded are widespread in the Indo-Pacific, and some are apparently globally distributed in the tropics and subtropics, including the invasive fouling species *Bugula neritina*, *Hippoporina indica* and *Schizoporella japonica*, as well as the coral reef associates *Cranosina coronata* and *Hippopodina feegeensis*. Plastic debris and glass bottles were encrusted by *Jellyella eburnea*, a coloniser of floating biological and man-made objects that is becoming widespread in the tropics and subtropics of the world's oceans.

Keywords. Taxonomy, Bryozoa, Cheilostomata, fouling, Malaysia.

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Introduction

Bryozoans are a phylum of colonial metazoans, numbering almost 6000 species (Bock & Gordon 2013) and found in all of the world's oceans. Knowledge of bryozoan faunas is still remarkably poor for some parts of the world. Among these are the seas around Malaysia. For example, the review of coastal marine biodiversity in Malaysia by Mazlan *et al.* (2005) contains no mention of bryozoans. As bryozoans are common fouling animals, this is clearly anomalous and undoubtedly reflects lack of study rather than the true absence of these benthic suspension feeders. Bryozoans provide habitats and the food for numerous other marine animals (e.g., Bradstock & Gordon 1983; Cocito 2004; Wood *et al.* 2013), including commercial species, and therefore concern about their vulnerability to environmental change is not entirely academic. In particular, most bryozoans have calcareous skeletons that in tropical species include an apparently high proportion of species biomineralizing aragonite or magnesium-calcite (Taylor *et al.* 2015), minerals susceptible to ocean acidification because of their relatively high solubilities.

Penang is an island of 1048 km^2 in the Strait of Malacca; Langkawi, 80 km to the north, is an archipelago of islands in the Andaman Sea, both off the west coast of the Malaysian Peninsula (Fig. 1). With one exception, a survey of the literature failed to find any mention of bryozoans from either Penang or Langkawi; the only reference to bryozoans that could be found was by Waters (1885) in a paper describing fossil bryozoans from South Australia in which the presence of one species – identified as *Membranipora savartii* Audouin, 1826 – is recorded from an unspecified locality in Penang.

Accordingly, a short reconnaisance survey of the shores of Penang and Langkawi was undertaken in October 2013 to ascertain the presence of bryozoans, identify the species present, and obtain material for mineralogical analysis to evaluate vulnerability to ocean acidification. The aim of this paper is to describe the species found, thereby increasing the awareness in Malaysia of these neglected marine animals and enlarging known species distributions.

A total of 23 cheilostome species is recorded and described from Penang and Langkawi for the first time. Many of these are invasive fouling species that are known to be widely distributed.

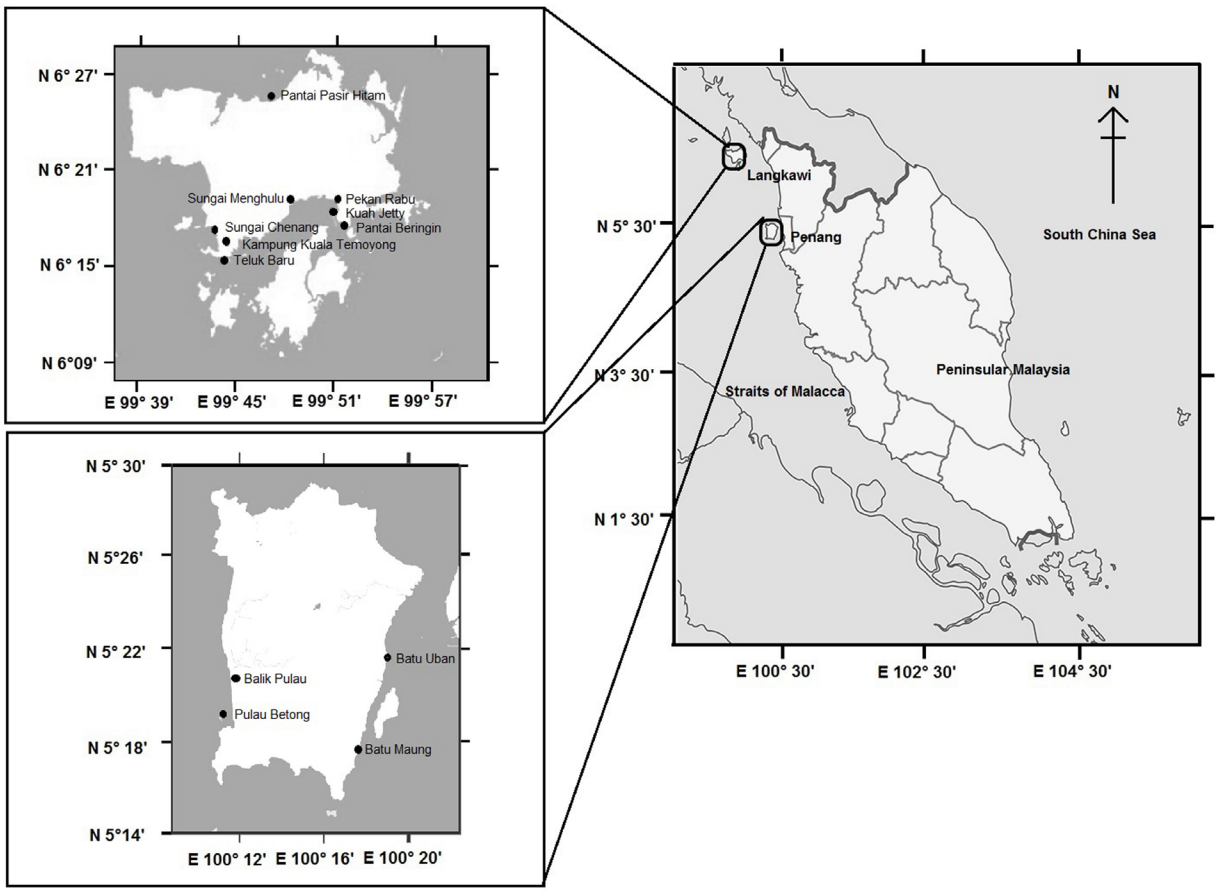

Fig. 1. Map showing sampling localities in Langkawi (top left) and Penang (bottom left), and the locations of these islands in Malaysia (right).

Material and methods

Localities

Shore collections were made from the following localities in Penang and Langkawi (Fig. 1).

Penang

1. Batu Uban (5°22' N, 100°19' E): a fishing wharf located on the eastern side of the island next to the main bridge between the peninsula and the island.
2. Batu Maung (5°27' N, 100°17' E): a fishing wharf at the eastern side of the island sheltered by a peripheral island (Pulau Jerejak).
3. Pulau Betong (5°18' N, 100°11' E): a commercial oyster aquaculture centre on floating cages off the coast of the small island of Pulau Betong southwest of the main island of Penang.
4. Balik Pulau (5°22' N, 100°12' E): sandy beach in the southwestern part of Penang.

Langkawi

1. Pantai Beringin (6°17' N, 99°51' E): sheltered sandy beach in a small bay on the southeastern part of the island with rocky shore at both ends of the beach.
2. Kuah jetty (6°18' N, 99°51' E): small wooden jetty adjacent to the main ferry terminal.
3. Pekan Rabu (6°19' N, 99°50' E): floating dock built from modular plastics connected to each other and used as a docking area for small local boats.
4. Sungai Menghulu (6°19' N, 99°48' E): a fishing wharf at the river mouth leading to the Straits of Malacca in the south of the island.
5. Kampung Kuala Temoyong (6°17' N, 99°44' E): a fishing wharf at the river mouth leading to the Straits of Malacca in the southwest of the island.
6. Teluk Baru (6°15' N, 99°44' E): a large wharf located in the southern part of the island used for tourist and fishing boats.
7. Pantai Chenang (6°17' N, 99°43' E): exposed sandy beach at the southern tip of the island, forming a narrow shoreline frequented by tourists.
8. Pantai Pasir Hitam (6°25' N, 99°47' E): sandy beach with fine sand in the north of the island. A reef flat composed of discontinuous growing corals is located about 30–40 m seawards from the beach. The reef is highly sedimented with fine sand.

Repository

All figured specimens are deposited in the collections of the Marine Science Laboratory, Universiti Sains Malaysia, Penang (abbreviated MSL). Letters following the number are used to indicate different species encrusting the same specimen.

Study methods

Collections were made by examining all available artificial and natural hard substrates evident at the localities visited, using a hand lens to confirm the presence of bryozoans. Only a small proportion of mollusc shells was found to be bryozoan-encrusted, but artificial substrates, such as pier wharves and fishing floats, were very commonly fouled by bryozoans. Specimens were washed and dried after collection. After preliminary study with a binocular microscope, specimens of each species present were chosen for scanning electron microscopy (SEM). Prior to SEM, colonies were bleached for up to a day in a dilute solution of commercial bleach to remove soft tissues and expose the skeleton. The exact time of bleaching was adjusted according to the species concerned and the requirement to conserve features such as delicate spines while removing cuticular components including the opercula. Bleached colonies were studied uncoated using a LEO 1455-VP scanning electron microscope and employing a backscattered electron detector. Measurements were made from SEM images.

Results

Locality records

Penang

Batu Uban
Bugula neritina (Linneaus, 1758)
Batu Maung
Acanthodesia cf. *irregulata* (Liu, 1992)
Sinoflustra amoyensis (Robertson, 1921)
Pulau Betong
Acanthodesia cf. *irregulata* (Liu, 1992)
Arbopercula sp.
Parasmittina winstonae Liu *et al*., 2001
Parasmittina raigioidea Liu *et al*., 2001
Hippoporina indica Pillai, 1978
Scorpiodinipora costulata (Canu & Bassler, 1929)
Balik Pulau
Acanthodesia cf. *irregulata* (Liu, 1992)
Nellia oculata Busk, 1852

Langkawi

Pantai Beringin
Hippoporina indica Pillai, 1978
Kuah jetty
Cradoscrupocellaria sp.
Celleporaria aperta (Hincks, 1882)
Parasmittina winstonae Liu *et al*., 2001
Parasmittina sp. 1
Hippoporina indica Pillai, 1978
Schizoporella japonica Ortmann, 1890
Pekan Rabu
Schizoporella japonica Ortmann, 1890
Sungai Menghulu
Hippoporina indica Pillai, 1978
Kampung Kuala Temoyong
Aetea ligulata Busk, 1852
Acanthodesia cf. *falsitenuis* (Liu, 1992)
Antropora minor (Hincks, 1880)
Adeonella lichenoides (Lamarck, 1816)
Parasmittina sp. 1
Microporella sp.
Scorpiodinipora costulata (Canu & Bassler, 1929)
Teluk Baru
Acanthodesia perambulata (Louis & Menon, 2009)
Hippoporina indica Pillai, 1978
Pantai Chenang
Jellyella eburnea (Hincks, 1891)
Pantai Pasir Hitam
Aetea ligulata Busk, 1852
Acanthodesia perambulata (Louis & Menon, 2009)

Cranosina coronata (Hincks, 1881)
Hippopodina feegeensis (Busk, 1884)

Taxonomic descriptions

The descriptions below are based entirely on material collected from Penang and Langkawi and are not intended to be comprehensive for the species described. Synonymies are abbreviated to include only the original description plus one key recent reference. All measurements were taken from SEM images of Malaysian specimens, with ranges of autozooid lengths and widths usually based on 10 zooids.

Order Cheilostomata Busk, 1852
Suborder Inovicellina Jullien, 1888
Family Aeteidae Smitt, 1868

Aetea Lamouroux, 1812

Aetea ligulata Busk, 1852
Fig. 2A–F

Aetea ligulata Busk, 1852: 31, pl. 42.

Aetea ligulata – Osburn 1950: 13, pl. 1, fig. 4.

Material

MALAYSIA: MSL BRY001a, Pantai Pasir Hitam, Langkawi, collected intertidally from coral reef, fouling *Hippopodina feegeensis*. MSL BRY002, Kampung Kuala Temoyong, Langkawi, encrusting shell found among fishing debris.

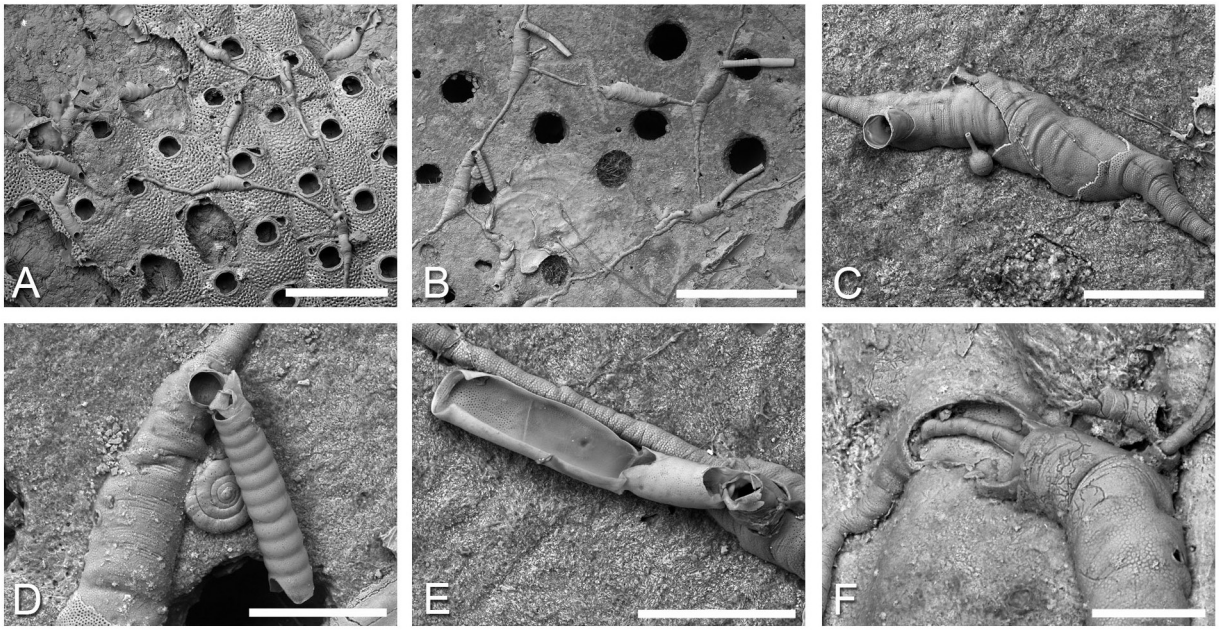

Fig. 2. *Aetea ligulata* Busk, 1852. **A**. Colony fouling *Hippopodinella feegeensis*; Pantai Pasir Hitam, Langkawi, MSL BRY001a. **B–F**. Kampung Kuala Temoyong, Langkawi, MSL BRY002. B. Zooids growing aroung clionid-bored shell. C. Zooid with repaired skeleton. D. Erect part of zooid collapsed against substrate to reveal annulations on distal side. E. Erect part of zooid collapsed to show opesia on proximally facing side. F. Broken zooid showing intramural 'stolon'. Scale bars: A–B = 1 mm; C–E = 200 μm; F = 100 μm.

Description

Colony encrusting, uniserial, runner-like with widely spaced branches (Fig. 2A–B), delicate, feebly calcified. Autozooids slender with elongate pyriform proximal base and an erect distal part; proximal base 1.1–1.3 mm long by about 0.13 mm maximum width (Fig. 2C), with irregular transverse growth wrinkles and locally minutely porous or with finely reticulate ornamentation, a narrow proximal cauda of about same length as broader distal part; erect part often broken off or collapsed, about 0.42 mm long by 0.07 mm maximum width, proximally with widely spaced, hoop-like annulations about 0.02 mm apart (Fig. 2D), expanding a little distally where an elongated opesia, 0.25 mm long by 0.05 mm wide, is developed on proximal-facing side (Fig. 2E).

Remarks

This species was erected by Busk (1852) based on material collected by Charles Darwin from the coast of Patagonia and the Magellan Strait. Busk's figure shows clearly the coarsely annulated erect parts of the zooids, very different from the finely striated annulations seen in the two common cosmopolitan species *Aetea anguina* (Linnaeus, 1758) and *A. sica* (Couch, 1844). A modern systematic study of *Aetea* combining morphological and molecular data is required and in the meantime there must be reservations about the identities of species with such seemingly wide latitudinal distributions as *A. ligulata*.

Abundant evidence of damage and repair can be observed in the skeleton. The skeletons of some zooids were apparently partly destroyed, eliciting reparative growth, sometimes on multiple occasions (Fig. 2C). Broken zooids may also reveal internal stolon-like structures (Fig. 2F), indicating growth through the dead zooid to re-establish connections between zooids and allow growth from the open ends of branches. Although the straggly, runner-like form of *Aetea* and various other uniserial cheilostomes would suggest a reduced commitment to maintaining the integrity of the colony, reparative growth that renews links between zooids and re-uses substrate space once occupied by dead zooids is a common feature of such bryozoans, Recent and fossil (Taylor 1988).

Suborder Malacostegina Levinsen, 1909
Family Membraniporidae Busk, 1852

Acanthodesia Canu & Bassler, 1919

Remarks

The genus *Acanthodesia*, with the type species *Membranipora savartii* Audouin, 1826 (see Taylor & Foster 1994), is here interpreted to include numerous species once assigned to *Membranipora* but having more robustly calcified colonies, or, alternatively, to *Biflustra* but generally having encrusting colonies rather than the erect vincularian colonies of the type species of this genus. Although many bryozoologists use *Biflustra* in preference to *Acanthodesia*, the critical early astogeny is unknown in the type species of the former genus.

The paucity of skeletal morphological characters – avicularia and ovicells are lacking – makes species identification difficult. Molecular studies are much needed in this genus to clarify its diversity.

Acanthodesia cf. ***falsitenuis*** (Liu, 1992) comb. nov.
Fig. 3A–C

cf. *Membranipora falsitenuis* Liu, 1992: 112, figs 3–6.

Material

MALAYSIA: MSL BRY003, Kampung Kuala Temoyong, Langkawi, encrusting an oyster found among fishing debris.

Description

Colony encrusting, multiserial, unilamellar, locally multilamellar. Ancestrula and early astogenetic stages not observed. Autozooids subhexagonal or subrectangular, distally well-rounded, elongate, 0.53–

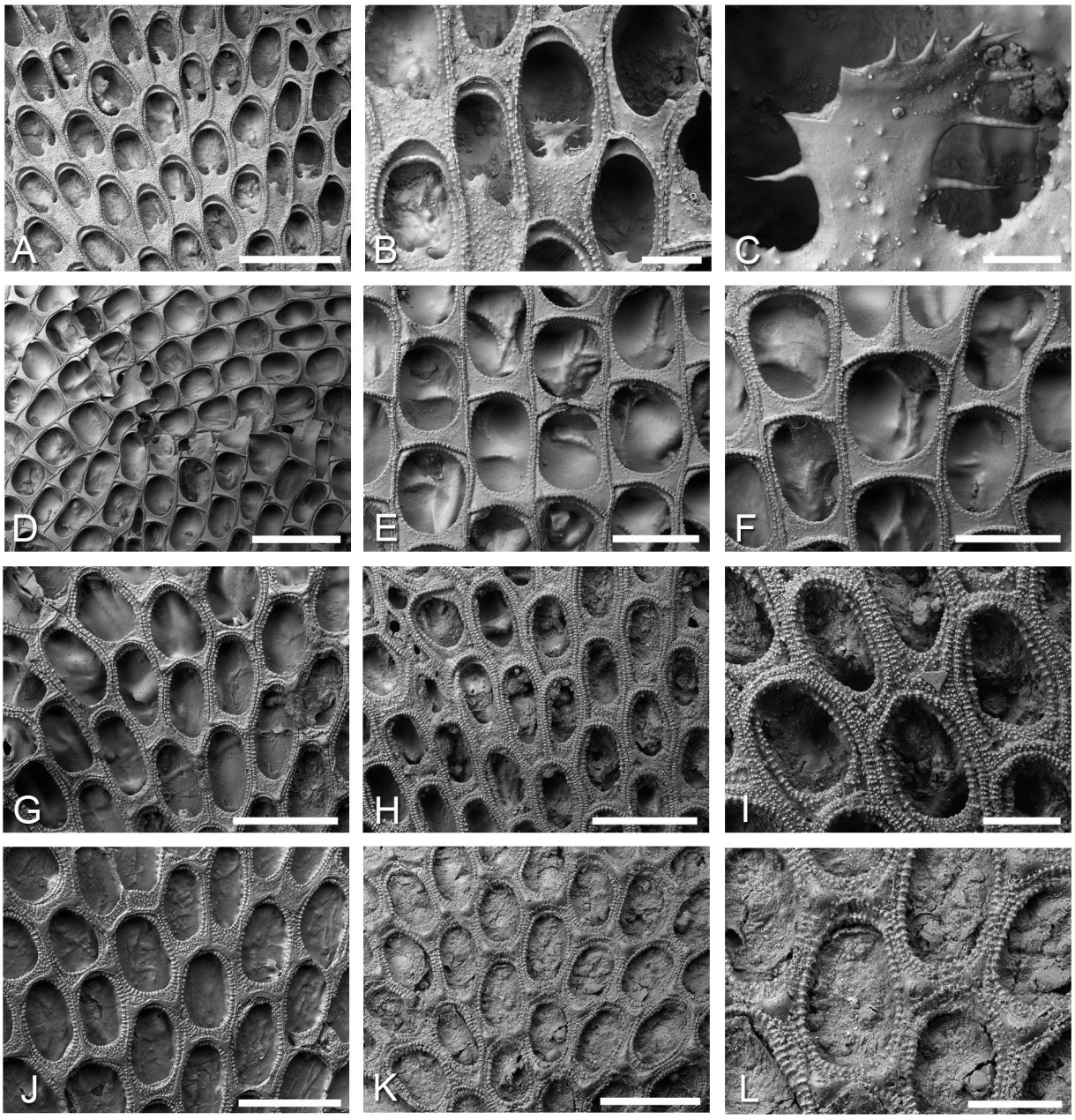

Fig. 3. Species of *Acanthodesia*. — **A–C**. *A*. cf. *falsitenuis* (Liu, 1992). Kampung Kuala Temoyong, Langkawi, MSL BRY003. A. Zooids. B. Detail. C. Cryptocystal process. — **D–F**. *A. peramabulata* (Louis & Menon, 2009). Pantai Pasir Hitam, Langkawi, MSL BRY004. D. Part of colony with overgrowth. E. Group of zooids. F. Wide zooid immediately before a row bifurcation. — **G–L**. *A*. cf. *irregulata* (Liu, 1992). Note variation between specimens in the width of the lateral mural rim, which is particularly broad in I, and the development of tubercles, present only in the colony shown in K and L. G. Pulau Betong, Penang, MSL BRY005. H–I. Batu Muang, Penang, MSL BRY026. J. Balik Pulau, Penang, MSL BRY006. K–L. Batu Maung, Penang, MSL BRY007. Scale bars: A, D = 1 mm; B, I, L = 200 µm; C = 50 µm; E–H, J–K = 500 µm.

0.73 mm long by 0.30–0.40 mm wide, zooidal boundaries marked by a fissure; mural rim salient, narrow, pustulose, pustules forming a single row; opesia occupying most of frontal surface, rim broadened distally, edged with tiny pustules; gymnocyst lacking; cryptocyst occupying one-third to almost one-half of proximal end of zooid, planar, sparsely pustulose, with a variably developed, anvil-shaped process bearing long spines extending for up to 0.14 mm over opesia (Fig. 3B–C); no spine bases, spinules or tubercles. Kenozooids developed at convergences between colony lobes (Fig. 3A, upper right corner), variable in shape and size, opesia ovoidal.

Remarks

The most striking feature of this species is the anvil-shaped, spinose cryptocystal process projecting over the opesia (Fig. 3B–C). Similar processes were depicted in zooids of two species from the South China Sea – *Acanthodesia similis* (Liu, 1992) (see Liu *et al*. 2001: pl. 9, fig. 2) and *A. falsitenuis* (Liu, 1992) (see Liu 1992: fig. 3) – and also in *Acanthodesia crenulata* (Okada, 1923), described by Tilbrook (2006: pl. 2b) from the Solomon Islands. Autozooids of *A. similis* are about half the length of those of the species described here from Langkawi, but judging from the scale bar shown by Liu (1992) in his figure of *A. falsitenuis*, this latter species is about the same size as the Langkawi material. However, the cryprocystal process is less developed in the Chinese material of *A. falsitenuis* and this also has zooids of a more rectangular shape with more ragged edges to the lateral cryptocyst.

Acanthodesia perambulata (Louis & Menon, 2009) comb. nov.
Fig. 3D–F

Biflustra perambulata Louis & Menon, 2009: 61, figs 2–7.

Material

MALAYSIA: MSL BRY004, Pantai Pasir Hitam, Langkawi, on floating plastic washed ashore.

Description

Colony encrusting, multiserial, unilamellar, locally multilamellar (Fig. 3D). Ancestrula and early astogenetic stages not observed. Autozooids rounded rectangular, gently convex distally, 0.43–0.60 mm long by 0.30–0.50 mm wide, the first zooids in new rows narrow and about 2 × longer than wide, later zooids becoming progressively broader until approximately equidimensional immediately before row bifurcation (Fig. 3F); zooidal boundaries marked by a fine fissure; mural rim salient, narrow, pustulose; opesia occupying nearly all frontal surface, ovoidal; gymnocyst lacking; cryptocyst narrow, broadest at proximolateral corners, planar, with sporadic pustules that increase in abundance and become dense around edge of opesia; no spine bases, spinules or tubercles. Kenozooids developed at convergences between colony lobes, variable in shape and size, opesia ovoidal.

Remarks

This species was originally described from Cochin, India, where colonies are erect and bilamellar, unlike the encrusting colonies from Langkawi assigned here to *Acanthodesia perambulata*. However, the skeletal morphology and dimensions of the autozooids is almost identical in the Indian and Malaysian material and it is known that a single species can exist as either encrusting or erect bifoliate colonies. Tilbrook & Gordon (2015) list this species (as *Biflustra perambulata*) from the Straits of Johor, Singapore. Compared to the similar species *Acanthodesia grandicella* Canu & Bassler, 1929 (e.g., Gordon *et al*. 2008; Tilbrook 2012), *A. perambulata* has smaller zooids that are less granular and have weaker calcification. Nevertheless, molecular sequence data is needed to show that these fouling invasive species really are distinct from one another.

Acanthodesia cf. ***irregulata*** (Liu, 1992) comb. nov.
Fig. 3G–L

cf. *Membranipora irregulata* Liu, 1992: 124, figs 14–17.

Biflustra irregulata – Gordon *et al.* 2007: 46, fig. 1d.

Material

MALAYSIA: MSL BRY005, Pulau Betong, Penang, on oyster rafts. MSL BRY006, Balik Pulau, Penang, on plastic. MSL BRY007, BRY026, Batu Maung, Penang, on gastropod shells found among fishing debris.

Description

Colony encrusting, multiserial, unilamellar. Ancestrula twinned, proximally overgrown by later zooids in the example scanned. Autozooids subhexagonal, gently convex distally, 0.36–0.54 mm long by 0.22–0.30 mm wide; zooidal boundaries marked by a fine fissure; mural rim salient, narrow to moderately wide, pustulose; opesia occupying nearly all frontal surface, ovoidal, sometimes pear-shaped; gymnocyst absent or represented by low, rounded tubercles at proximal and proximolateral corners of zooids (Fig. 3K–L); cryptocyst narrow, broadest proximally where it forms a shallow planar shelf, variable in width laterally, pustulose. Kenozooids developed at growth irregularities, diamond-shaped, variable in size, opesia teardrop-shaped.

Remarks

Acanthodesia irregulata was originally described from the South China Sea and subsequently identified by Gordon *et al.* (2007) from Bangladesh. Two characteristic features were noted by Liu (1992): the presence of cuticular spinules on the frontal membrane and operculum, and tubercles at the proximal corners of some of the zooids. The former have not been observed in the studied material from Malaysia, which is bleached. However, tubercles do occur in some of the studied Malaysian specimens (Fig. 3K–L) and the size of the autozooids is very similar to that given by Gordon *et al.* (2007) in their Bangladeshi material. The paucity of taxonomic characters in the skeleton of the Malaysian specimens precludes certain identification as *A. irregulata*. It should also be noted that more than one species may be represented in Penang to judge from the variations in skeletal morphology; for example, tubercles can be present (Fig. 3K–L) or absent (Fig. 3G–J), and the width of the mural rim varies between specimens (Fig. 3G–L).

Jellyella Taylor & Monks, 1997

Jellyella eburnea (Hincks, 1891)
Fig. 4

Membranipora eburnea Hincks, 1891: 289, pl. 7, fig. 5.

Jellyella eburnea – Taylor & Monks 1997: 42, figs 1–2, 4–13, 16–19.

Material

MALAYSIA: MSL BRY008, Pantai Chenang, Langkawi, on plastic and glass bottles.

Description

Colony encrusting, multiserial, unilamellar (Fig. 4A, E). Ancestrula twinned. Autozooids subhexagonal, rounded distally, twice as long as wide, 0.52–0.67 mm long by 0.29–0.33 mm wide; zooidal boundaries marked by a fine fissure; opesia occupying nearly all frontal surface, roughly ovoidal; cryptocyst forming a narrow, crescent-shaped shelf at distal end of zooid (Fig. 4B); gymnocyst variably developed,

when well-developed folded into rucks or spines projecting over proximal and later margins of opesia (Fig. 4C); basal walls with large uncalcified window; intramural buds present but rare.

Remarks

This species was fully described by Taylor & Monks (1997) who made it the type species of the new genus *Jellyella*, noting the pan-oceanic, tropical to subtropical occurrence of *J. eburnea* as an encruster of floating shells of the squid *Spirula*, and occasionally of the living planktonic gastropod *Janthina*. The pseudoplanktonic ecology of *J. eburnea* has apparently 'pre-adapted' it to the colonization of floating anthropogenic debris, especially plastic objects (e.g., Moyano 2005) but also glass bottles (Fig. 4D–E).

Family Electridae Stach, 1937

Arbopercula Nikulina, 2010

Arbopercula sp.
Fig. 5A–C

Material

MALAYSIA: MSL BRY009, Pulau Betong, Penang, on oyster rafts.

Description

Colony encrusting, multiserial, unilamellar, thinly calcified. Ancestrula and early astogeny not observed. Autozooids subhexagonal, slender, two or more times longer than wide, 0.49–0.63 mm long by 0.19–0.28 mm wide; boundaries between zooids in adjacent rows marked by a narrow fissure, lacking between zooids in the same row; opesia occupying nearly all frontal surface, ovoidal; cryptocyst developed

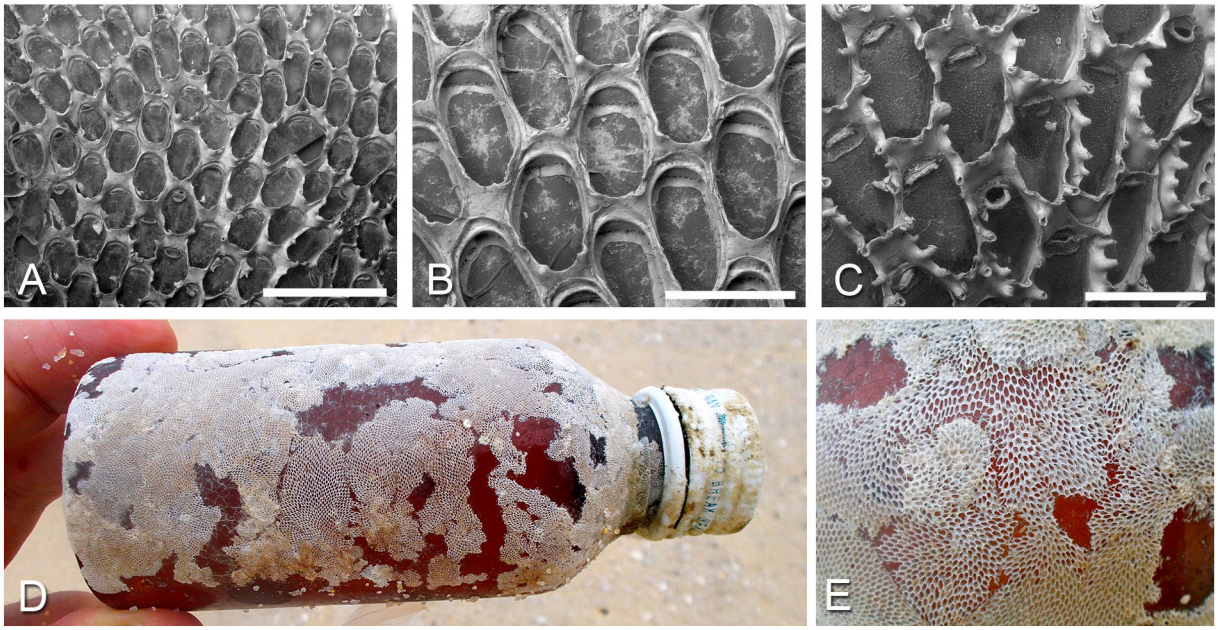

Fig. 4. *Jellyella eburnea* (Hincks, 1891). Pantai Chenang, Langkawi. **A–C**. Scanning electron micrographs showing variable development of the gymnocyst; MSL BRY008. A. Group of zooids. B. Slightly oblique view of zooids with poorly developed gymnocysts. C. Zooids with well developed gymnocysts. **D–E**. Colonies encrusting a small bottle photographed in the field. Scale bars: A = 1 mm; B–C = 500 µm.

only proximally, extremely narrow, steeply sloping; gymnocyst narrow, broadening in proximolateral corners; two oral spines, erect, short, tapering distally, often with ends closed; circumopesial spines numbering 6–14, generally paired on either side of opesia, long, tapering distally, overarching frontal membrane, not overlapping or touching (Fig. 5B); proximal circumopesial spine located close to and resembling morphologically the oral spines (Fig. 5C).

Remarks

The genus *Arbopercula* – type species *Electra bengalensis* Stolizcka, 1869 – was proposed by Nikulina (2010) for species previously included in *Electra*, but which have spines on the operculum. These unmineralized structures have not been observed in the dried material from Penang, which has lost the opercula. Nevertheless, the Penang bryozoan does show a strong overall resemblance to the specimen figured by Gordon *et al*. (2007, fig. 1C) as the type species, particularly in the gymnocystal spinosity, and also to *Arbopercula devinensis* (Robertson, 1921), although differences in the distribution and number of spines, plus the extent of the proximal gymnocyst, preclude unequivocal identification as either of these two species.

Family Sinoflustridae Gordon, 2009

Sinoflustra Liu & Yang, 1995

Sinoflustra amoyensis (Robertson, 1921)
Fig. 5D–F

Membranipora amoyensis Robertson, 1921: 49, fig. 6.

Sinoflustra amoyensis – Liu & Yang 1995: 349, figs 1–2.

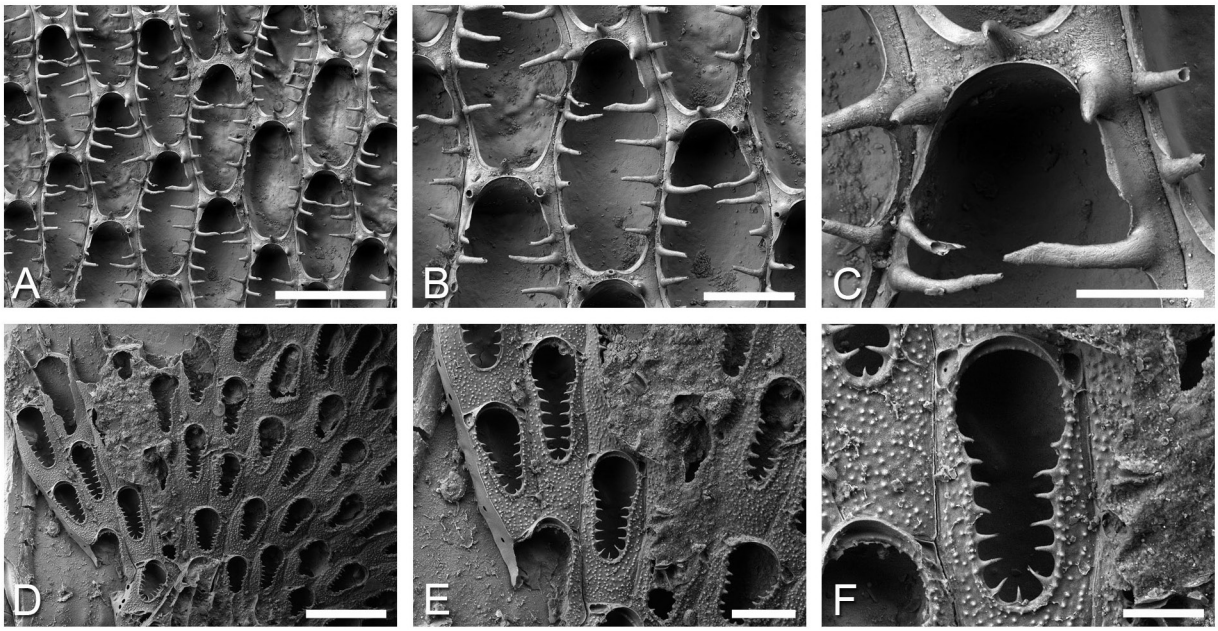

Fig. 5. — **A–C**. *Arbopercula* sp. Pulau Betong, Penang, MSL BRY009. A. Group of zooids. B. Zooids showing spines. C. Distal end of a zooid with a pair of oral spines and the proximal circumopesial spine of the next distal zooid. — **D–F**. *Sinoflustra amoyensis* (Robertson, 1921). Batu Muang, Penang, MSL BRY010. D. Part of a colony. E. Detail of a group of zooids at the broken edge. F. Opesia and cryptocystal spinules. Scale bars: A, D = 500 µm; B, E = 200 µm; C, F = 100 µm.

Material

MALAYSIA: MSL BRY010, Batu Muang, Penang, encrusting a barnacle from debris adjacent to a fishing jetty.

Description

Colony encrusting, multiserial, unilamellar. Ancestrula and early astogeny not observed. Autozooids subrectangular, rounded distally, slender, typically twice as long as wide, 0.43–0.63 mm long by 0.18–0.28 mm wide; zooidal boundaries marked by a narrow fissure; opesia occupying two-thirds of frontal surface, elongate inverted pear-shaped; cryptocyst convex, widest proximally, narrowing distally, covered by small pustules, about 10–16 cryptocystal spinules extending from mural rim over proximal two-thirds of opesia, but not meeting, distal third of opesia broad and spineless (Fig. 5F); gymnocyst lacking. Spines present at distolateral corners of autozooids, spines broken off in studied specimens, leaving a small rounded triangular base with a central pore (Fig. 5F). Avicularia not observed.

Remarks

The original figure of Robertson (1921: fig. 6) shows zooids with branching spines at the distolateral corners. Although spines are not preserved in the studied material from Penang, their bases are clearly visible in these locations. Robertson's Chinese material also has slightly shorter cryptocystal spinules and the opesia is ellipsoidal in outline compared with the elongate inverted pear-shaped opesia of the Penang specimens. However, Liu *et al.* (2001: pl. 18, fig. 3) figured a Chinese specimen of *S. amoyensis* with longer spinules and opesia that broaden distally. A putative colony of this species epizoic on a turtle has broader autozooids and short cryptocystal spinules (Frazier *et al.* 1992: fig. 1). In view of the morphological variability encompassed by specimens assigned to the species, the Penang material can be identified as *S. amoyensis*.

Not seen in the Malaysian specimens, but sporadically developed elsewhere in this species, are vicarious avicularia (e.g., Liu *et al.* 2001: pl. 18, fig. 3). These are longer and wider than the autozooids, and the distal part of the opesia is particularly broad, raised slightly and separated from the proximal part by two small, condyle-like indentations.

Suborder Flustrina Smitt, 1868
Family Calloporidae Norman, 1903

Cranosina Canu & Bassler, 1933

Cranosina coronata (Hincks, 1881)
Fig. 6

Membranipora coronata Hincks, 1881: 147, pl. 10, fig. 1.

Cranosina coronata – Chimonides & Cook 1994: 44, fig. 1a.

Material

MALAYSIA: MSL BRY011, Pantai Pasir Hitam, Langkawi, collected intertidally encrusting cobbles from coral reef.

Description

Colony encrusting, multiserial, unilamellar; growing edge stepped, revealing distolateral pore windows, generally three in each distolateral wall. Ancestrula and early astogeny not observed. Autozooids subhexagonal to almost diamond-shaped, stout, about 0.40–0.50 mm long by 0.34–0.44 mm wide; zooidal

boundaries marked by a narrow fissure; opesia occupying most of frontal surface, ovoidal; cryptocyst well developed proximally and laterally, sloping inwards, pustulose, the pustules tending to be radially aligned, especially towards inner side of cryptocyst; gymnocyst sometimes present distolaterally; spines lacking. Ovicells inconspicuous, ooecia small. Intramural buds present. Avicularia present distally of autozooids (Fig. 6C), small, transversely orientated, with long, open-ended rostrum.

Remarks

According to Tilbrook *et al.* (2001: p. 45), *Cranosina coronata* is common throughout the Indo-West Pacific.

Family Antroporidae Vigneaux, 1949

Antropora Norman, 1903

Antropora minor (Hincks, 1880)
Fig. 7A

Membranipora trifolium var. *minor* Hincks, 1880: 87, pl. 11, fig. 6.

Antropora minor – Tilbrook 1998: 34, fig. 2a–f.

Material

MALAYSIA: MSL BRY012a, Kampung Kuala Temoyong, Langkawi, colony encrusting interior of large gastropod shell.

Description

Colony encrusting, multiserial, unilamellar or multilamellar. Ancestrula and early astogeny not observed. Autozooids subovoidal, about twice as long as wide, 0.34–0.40 mm long by 0.18–0.40 mm wide; zooidal boundaries marked by a narrow fissure; opesia occupying one-half to two-thirds of frontal surface, pear-shaped, generally pinched slightly at about two-thirds of length; cryptocyst well developed proximally and shelf-like, tapering distally, pustulose; gymnocyst visible proximally and proximolaterally, narrow, tapering distally; spines lacking. Ovicells not observed in studied Malaysian material but elsewhere described as small, partly immersed in distal zooid and with cap-like ooecia (e.g., Tilbrook 1998). Avicularia interzooidal, directed distally, small, about 0.06–0.09 mm long by 0.04–0.05 mm wide, present at proximal corner or less often at two proximolateral corners of most autozooids; rostrum rounded, a little longer but narrower than opesia.

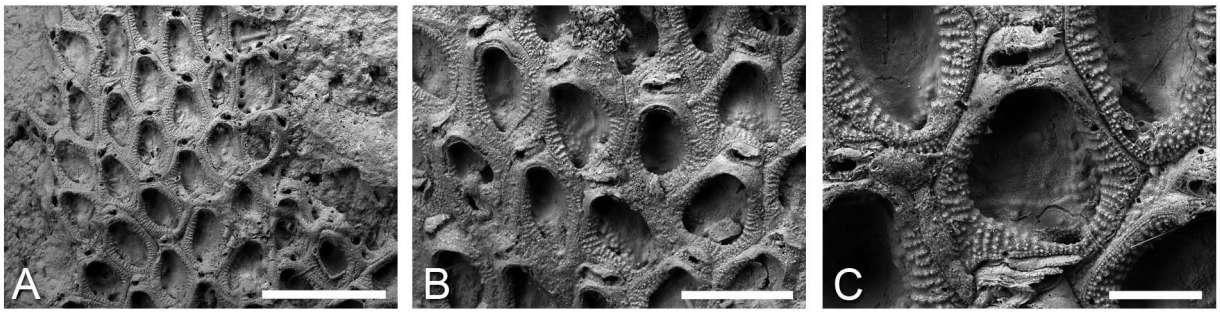

Fig. 6. *Cranosina coronata* (Hincks, 1881). Pantai Pasir Hitam, Langkawi, MSL BRY011. **A**. Part of a colony encrusting a cobble. **B**. Group of zooids. **C**. Autozooid with distal avicularium. Scale bars: A = 1 mm; B = 500 µm; C = 200 µm.

Remarks

Large vicarious avicularia sometimes develop in this species (e.g., Tilbrook 1998: fig. 2e) but were not seen in the studied colony from Langkawi. *Antropora minor* is widely distributed in the tropics, occurring in the Caribbean, South Atlantic, Pacific and Indian Oceans, including East Sumbawa, Malaysia (Tilbrook 1998).

Family Quadricellariidae Gordon, 1984

Nellia Busk, 1852

Nellia oculata Busk, 1852
Fig. 7B–E

Nellia oculata Busk, 1852: 18, pl 64, fig. 6, pl 65 bis, fig. 5.

Nellia oculata – Winston *et al*. 2014: 161, fig. 13.

Material

MALAYSIA: MSL BRY013, Balik Pulau, Penang, small colony washed ashore on a sandy beach.

Description

Colony erect, articulated, forming a tiny dichotomously branched bush composed of quadriserial internodes with 4–7 autozooids each linked by chitinous joints, basally rooted by kenozooids. Autozooids slender, about 0.38–0.50 mm long by 0.13–0.15 mm wide; opesia occupying about three-quarters of surface, elongate elliptical in shape; gymnocyst widest proximally, tapering distally along sides of

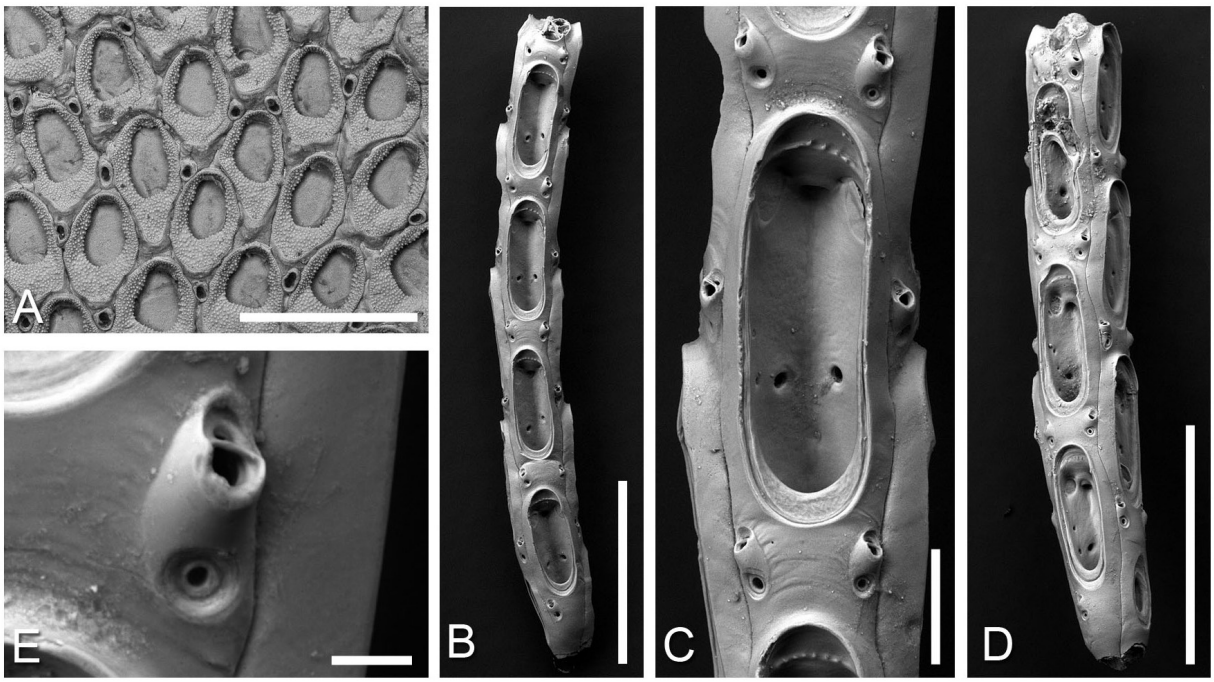

Fig. 7. — **A**. *Antropora minor* (Hincks, 1880). Part of a colony encrusting a large gastropod shell; Kampung Kuala Temoyong, Langkawi, MSL BRY012a. — **B–E**. *Nellia oculata* Busk, 1852. Balik Pulau, Penang, MSL BRY013. Internodes from a single colony. B, D. Complete internodes. C. Autozooid. E. Detail of tiny avicularium with proximal pore. Scale bars: A–B, D = 500 µm; C = 100 µm; E = 20 µm.

zooid, spines lacking; cryptocyst forming a slightly sunken, inwardly sloping crescent at proximal end of opesia, smooth-surfaced; various pores and depressions visible through opesia in basal walls of zooids, plus a low spinose, curved ridge on distal interior wall of zooid (Fig. 7C); ovicell not observed in studied material but described elsewhere as endozooidal (Winston *et al.* 2014). Avicularia tiny (Fig. 7E), located as pairs on left and right proximolateral gymnocyst of autozooids, inclined to plane of cryptocyst and directed proximally; rostrum rounded; cross-bar calcified, straight; opesia smaller than rostrum, with a slightly depressed cryptocyst; countersunk pore positioned on autozooidal gymnocyst beneath avicularium.

Remarks

This species has often been regarded as a junior synonym of *Nellia tenella* (Lamarck, 1816), but following Winston *et al.* (2014) we here retain Busk's species name *oculata* pending a revision of Lamouroux's material to test the synonymy. Ostensibly, *Nellia oculata* has a wide tropical and subtropical distribution, as well as a long fossil record, but there is need for a taxonomic re-evaluation using molecular data.

Family Bugulidae Gray, 1848

Bugula Oken, 1815

Bugula neritina (Linnaeus, 1758)
Fig. 8A–B

Sertularia neritina Linnaeus, 1758: 815.

Bugula neritina – Ryland & Hayward 1977: 162, fig. 78.

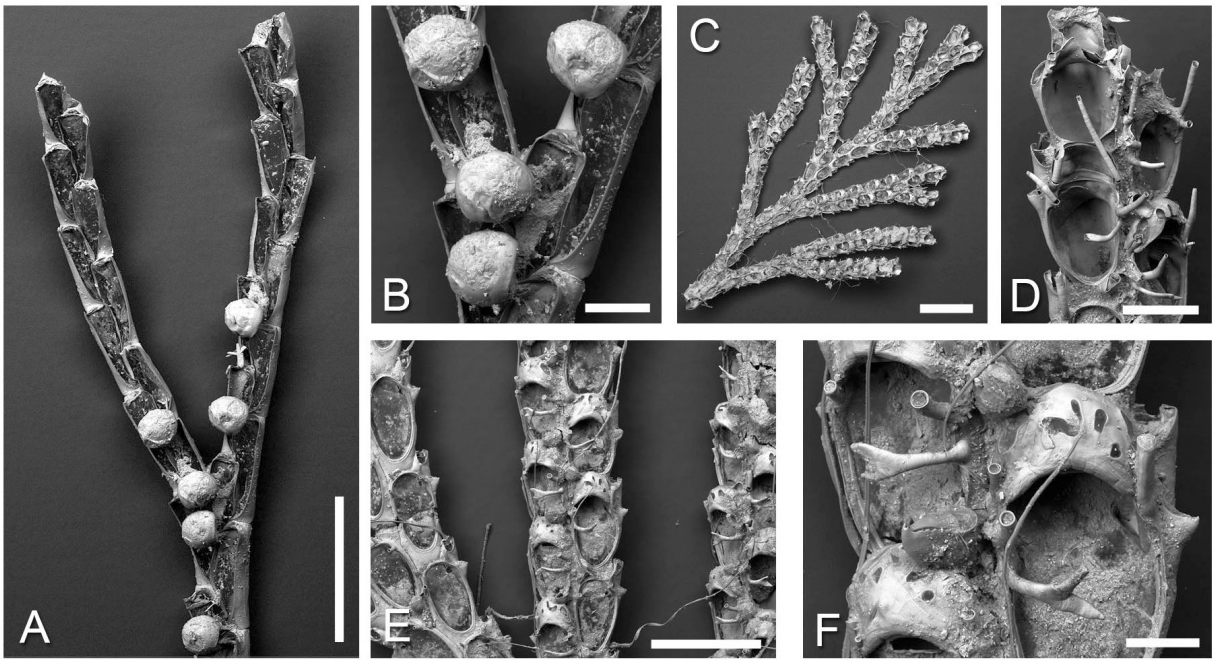

Fig. 8. — **A–B**. *Bugula neritina* (Linnaeus, 1758). Batu Uban, Penang, MSL BRY014. A. Part of a colony. B. Detail showing four globose ovicells. — **C–F**. *Cradoscrupocellaria* sp. Kuah jetty, Langkawi, MSL BRY015. C. Colony fragment. D. Zooids near branch tip showing spines and scuta. E. Branches and vibracular seta (bottom). F. Ovicells, spines and scuta. Scale bars: A, C = 1 mm; B, D = 200 µm; E = 500 µm; F = 100 µm.

Material

MALAYSIA: MSL BRY014, Batu Uban, Penang, attached to float hanging from fishing jetty.

Description

Colony erect, weakly mineralized, forming a luxuriant bush comprising bifurcating branches with zooids in two alternating rows opening on one side of branch, purple-brown in colour. Autozooids slender, about 0.48–0.56 mm long by 0.15–0.18 mm wide; opesia occupying almost all of frontal surface, squared-off distally; operculum absent; gymnocyst forming sides and back walls of zooids; spines and cryptocyst lacking; ovicell globular, large and prominent (Fig. 8B), attached to inner distal angle of zooid by a short peduncle. Avicularia lacking.

Remarks

Considerable attention has been focused on *Bugula neritina* as a source of the natural product bryostatin. Molecular studies have recently shown that morphologically defined, *B. neritina* is a complex comprising at least three separate species (Fehlauer-Ale *et al.* 2014). The complex is very widely distributed in tropical, subtropical and even temperate waters, and is an important fouling taxon dispersed anthropogenically (e.g., Ryland *et al.* 2011).

Family Candidae d'Orbigny, 1851

Cradoscrupocellaria Vieira *et al*., 2013

Cradoscrupocellaria sp.
Fig. 8C–F

Material

MALAYSIA: MSL BRY015, Kuah jetty, Langkawi, fouling a rope hanging from the jetty.

Description

Colony erect, bushy, jointed, dichotomously branched, ramifications typically after every four zooids, zooids arranged alternately and opening on one side of branch only. Autozooids elongate, about 0.40–0.50 mm long by 0.20–0.24 mm wide; opesia occupying most of frontal surface, oval; gymnocyst moderately well developed proximally; cryptocyst very narrow, smooth; 4 or 5 long, basally articulated spines in distal half of zooid, the one that is more proximal and closest to branch axis forming a scutum bending over frontal membrane and bifid at the end (Fig. 8F); ovicell globular, wider than long, ectooecium with about 4–6 distal pores near distal edge, circular or radially elliptical (Fig. 8F). Avicularia small, located either on: (1) proximal gymnocyst on side closest to branch axis, orientated transversely or proximolaterally and facing outwards, often absent, variable in size, rostrum dentate, tip hooked; or (2) edge of branch close to distal end of autozooids, orientated outwards and facing distally, rostrum triangular, tip hooked. Vibracula located on outer proximal gymnocyst of autozooid, orientated proximally, seta up to 1 mm long.

Remarks

Vieira *et al.* (2014) have recently subdivided the species-rich genus *Scrupocellaria*. The taxonomy of this group is complex and the material collected from Langkawi is tentatively assigned to the genus *Cradoscrupocellaria* pending a more detailed study.

Superfamily Adeonoidea Busk, 1884
Family Adeonidae Busk, 1884

Adeonella Busk, 1884

Adeonella lichenoides (Lamarck, 1816)
Fig. 9A–G

Eschara lichenoides Lamarck, 1816: 176.

Adeonella lichenoides – Hayward 1988: 126, figs 1c, 2–3.

Material

MALAYSIA: MSL BRY016, Kampung Kuala Temoyong, Langkawi, found among fishing debris.

Description

Colony erect, rigidly calcified, bushy (Fig. 9A), comprising bifurcating, bifoliate, strap-like branches, about 2.2–2.5 mm wide, with approximately a dozen series of zooids across width of branch. Autozooids small, rounded hexagonal, longer than wide, 0.29–0.38 mm long by 0.19–0.24 mm wide, distinct with deep interzooidal grooves, frontal shield convex, a slight umbo sometimes developed centrally, densely granular in surface texture, with large areolar pores covering most of surface; primary orifice more or less equidimensional, about 0.08 mm long, a shallow U-shaped sinus separated from anter by small condyles (Fig. 9E); secondary orifice somewhat transversely elliptical, a subcircular spiramen separated from secondary orifice by a calcified bridge in mature zooids (Fig. 9F–G). Gonozooids larger than autozooids, with a broad, shallow orifice separated from a wide spiramen by a deep calcified bridge with a process on proximal edge. Adventitious avicularia (Fig. 9F) developing on frontal shield of autozooids,

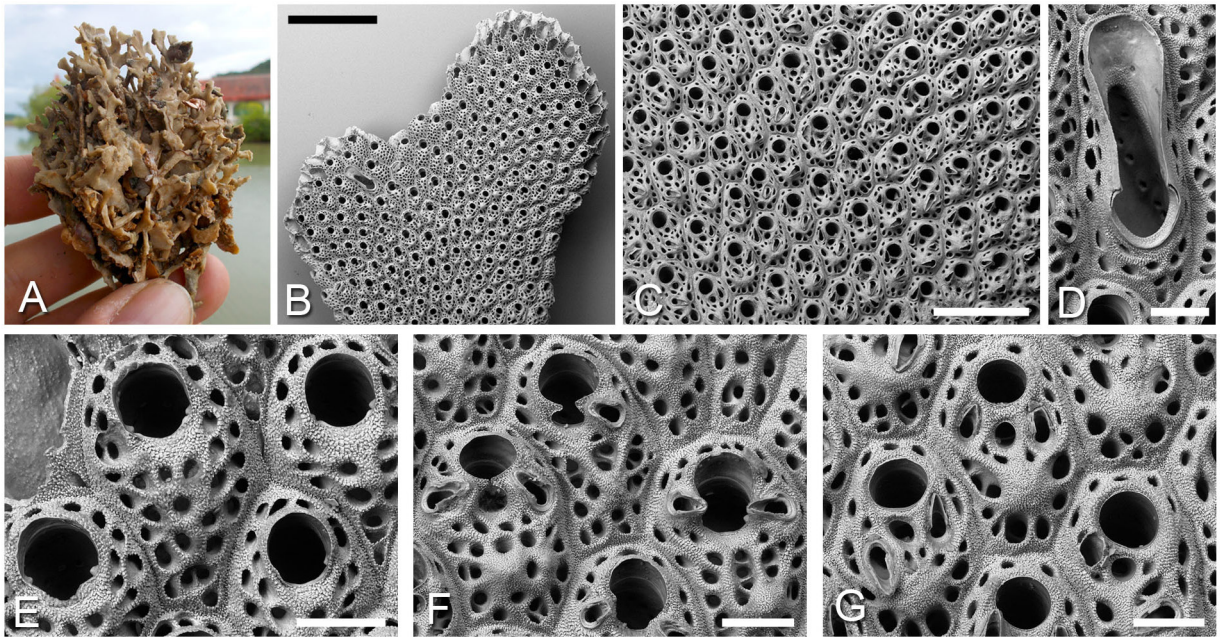

Fig. 9. *Adeonella lichenoides* (Lamarck, 1816). **A**. Field photograph of colony found among fishing debris at Kampung Kuala Temoyong, Langkawi. **B–G**. MSL BRY016, fragment of colony shown in A. B. Bifurcating branch. C. Group of zooids. D. Vicarious avicularium. E. Young zooids near growing edge before development of the spiramen. F. Zooids with adventitious avicularia and variably developed calcified bridges isolating the spiramen. G. Older zooids with fully developed spiramens and variously orientated adventitious avicularia. Scale bars: B = 1 mm; C = 500 µm; D–G = 100 µm.

often laterally to spiramen but occasionally more proximally, generally one or two per autozooid, sometimes absent, orientated variously; rostrum high gothic arch-shaped; cross-bar uncalcified; opesia rounded, a little wider than rostrum. Vicarious avicularia sporadically distributed (Fig. 9D), longer than autozooid, about 0.57 mm long by 0.21 mm wide; rostrum elongate, spatulate with a distal shelf; cross-bar uncalcified; opesia roughly semicircular with a sloping cryptocyst-like proximal edge; frontal shield with areolar pores similar to those of autozooids. Kenozooids present along some branch edges.

Remarks

Found among debris discarded from a fishing net, *Adeonella lichenoides* is the only rigidly erect bryozoan collected in either Langkawi or Penang during the fieldwork in October 2013. This species is distributed throughout the Indo-West Pacific region (Hayward 1988).

Superfamily Lepralielloidea Vigneaux, 1949
Family Lepraliellidae Vigneaux, 1949

Celleporaria Lamouroux, 1821

Celleporaria aperta (Hincks, 1882)
Fig. 10A–F

Schizoporella aperta Hincks, 1882: 126, pl. 5, fig. 3.

Celleporaria aperta – Gordon *et al*. 2007: 49, fig. 2f–g.

Material

MALAYSIA: MSL BRY017a, Kuah jetty, Langkawi, fouling mussel shell attached to rope hanging from jetty.

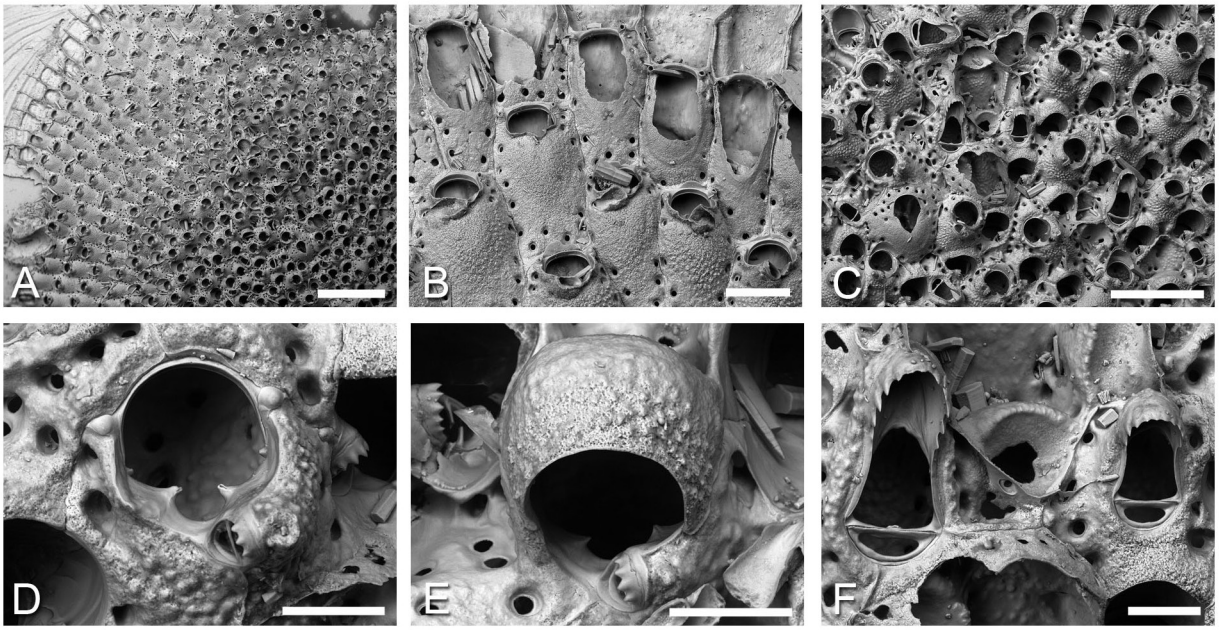

Fig. 10. *Celleporaria aperta* (Hincks, 1882). Kuah jetty, Langkawi, MSL BRY017a. **A**. View of colony showing growing edge (top left) and older region (bottom right) with frontal buds. **B**. Developing zooids at growing edge. **C**. Region with frontal buds. **D**. Orifice of non-ovicellate autozooid and steeply inclined suboral avicularium with dentate distal edge of rostrum. **E**. Ovicell. **F**. Two interzooidal avicularia. Scale bars: A = 1 mm; B = 200 µm; C = 500 µm; D–F = 100 µm.

Description

Colony encrusting, multiserial, becoming multilamellar through frontal budding. Basal autozooids (Fig. 10B) subhexagonal, 0.38–0.53 mm long by 0.20–0.28 mm wide; frontally budded autozooids (Fig. 10C) irregularly shaped, about 0.34 mm long by 0.28 mm wide; zooidal boundaries marked by fine fissures; frontal shield gently convex, smooth when first formed, becoming pustulose, peripheral ring of large subcircular areolar pores; orifice generally inclined distally, about 0.15 mm long by 0.13 mm wide, with a distinct rounded sinus (Fig. 10D), a pair of condyles present in proximal part of anter; two short, widely separated oral spines with closed ends can occur (Fig. 10D); ovicell hood-like (Fig. 10E), broad, about 0.10 mm long by 0.20 mm wide, surface with pustules, non-porous. Adventitious avicularia located suborally (Fig. 10D–E), slightly eccentric to median axis, frontal plane almost perpendicular to surface of autozooid, small; rostrum rounded, tip dentate; cross-bar calcified. Interzooidal avicularia (Fig. 10F) distributed irregularly among frontally budded autozooids, variable in size, up to 0.32 mm long by 0.15 mm wide, distal end slightly raised; rostrum spatulate, rounded, distally dentate; cross-bar calcified, some with small lingulum; opesia semielliptical, wider than long.

Remarks

Malaysian specimens of *Celleporaria aperta* clearly show the dentate distal tips of the avicularian rostra (Fig. 10F), like those depicted by Hincks (1882: pl. 5, fig. 3), but not apparent in all material attributed to the species by subsequent authors. Hincks (1882: 126) gave the provenance of his material as "Singapore or Philippines" and the species is regarded as widespread in the tropical and subtropical Indo-Pacific (Gordon *et al.* 2007).

Superfamily Smittinoidea Levinsen, 1909
Family Smittinidae Levinsen, 1909

Parasmittina Osburn, 1952

Parasmittina winstonae Liu *et al.*, 2001
Fig. 11A–L

Parasmittina winstonae Liu *et al.*, 2001: 623, pl. 55, figs 1–7.

Parasmittina winstonae – Tilbrook 2006: 156, pl. 29b, 30d–e.

Material

MALAYSIA: MSL BRY018, Kuah jetty, Langkawi, several colonies encrusting bivalves growing on a rope hanging from jetty. MSL BRY019a, Kuah jetty, Langkawi, encrusting barnacles and bivalve growing on a rope hanging from jetty. MSL BRY020a, BRY021a, Pulau Betong, Penang, encrusting barnacles from oyster rafts.

Description

Colony encrusting, multiserial, unilamellar; growing edge developing giant buds (Fig. 11J). Ancestrula tatiform (Fig. 11C), about 0.22 mm long by 0.17 mm wide, with subcircular opesia 0.16 mm long by 0.14 mm wide surrounded by 9 spines, becoming overgrown in older colonies; periancestrular zooids numbering 5 or 6, 0.26–0.32 mm long by 0.22–0.30 mm wide, some bearing adventitious avicularia, calcification of their frontal shields extending as short lobes between oral spines of ancestrula (Fig. 11D). Autozooids subhexagonal, distally rounded, 0.32–0.45 mm long by 0.22–0.33 mm wide; boundary walls salient with a fine fissure; frontal shield gently convex, coarsely pustulose, about 15–20 marginal areolar pores separated by ridges, areolae impinging on central part of shield in older zooids (Fig. 11H), no pseudopores; primary orifice egg-shaped to rounded rectangular, 0.10–0.11 mm long by

0.10 mm wide, large relative to zooid size, lappets developed distolaterally, lyrula narrow, 17–20 µm high by 25–37 µm wide at top edge, condyles present about one-third distance along orifice, 15 µm high, medioproximal edge serrated (Fig. 11K); oral spine bases usually numbering two, occasionally one or

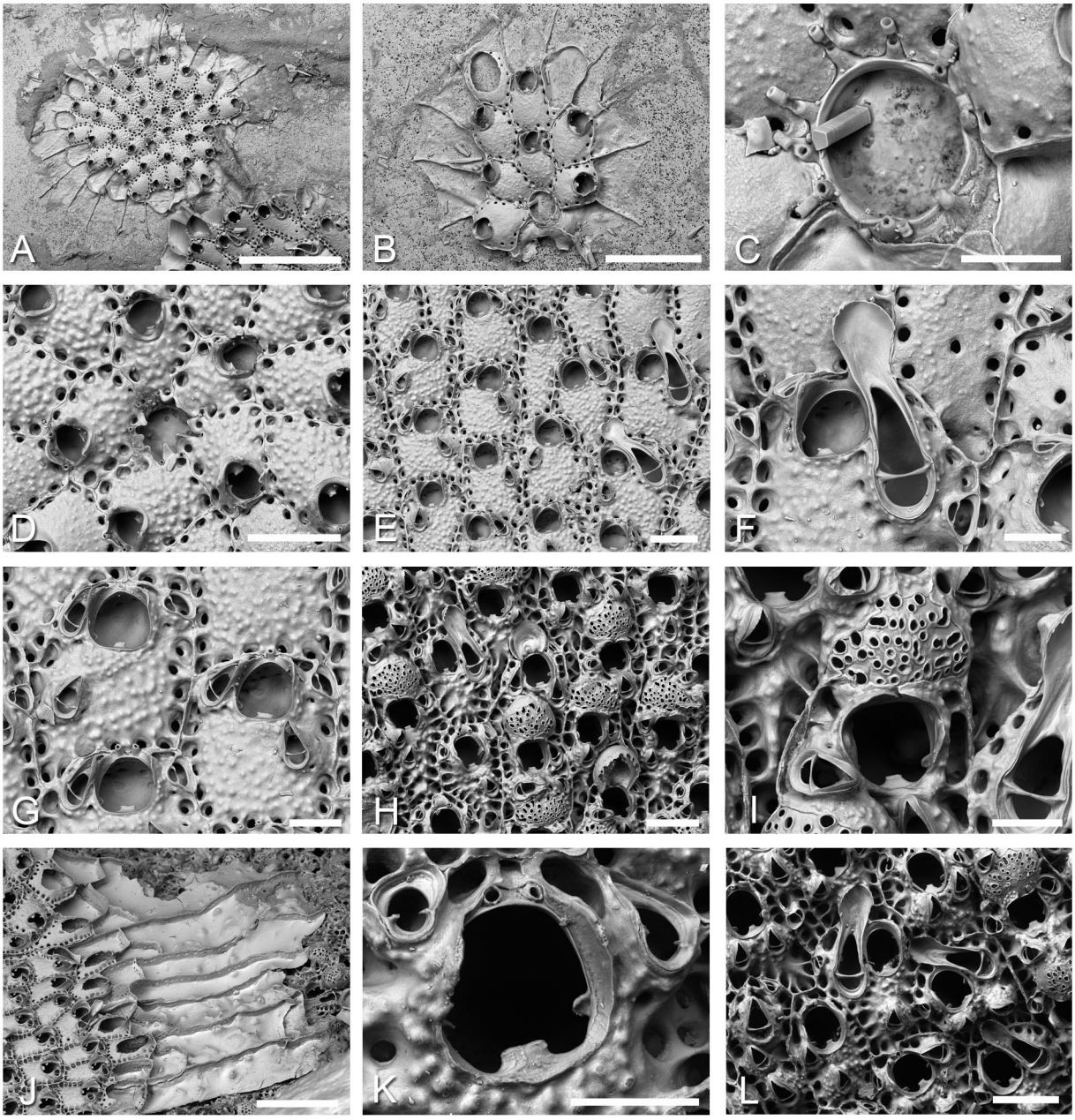

Fig. 11. *Parasmittina winstonae* Liu *et al*., 2001. — **A–I**. Kuah jetty, Langkawi, MSL BRY018. A. Small colony. B. Tiny colony on same substrate. C. Ancestrula of colony shown in B (note that the prism is from a disaggregated bivalve shell). D. Early stages of another colony showing five budded autozooids surrounding the ancestrula. E. Group of zooids. F. Giant avicularium with small plectrum-shaped adventitious avicularium at right proximolateral corner. G. Young autozooids and small adventitious avicularia. H. Older autozooids and adventitious avicularia. I. Ovicell. — **J**. MSL BRY019a, same locality details; oblique view of growing edge with giant bud. — **K–L**. Pulau Betong, Penang. K. MSL BRY020a. Slightly oblique view of orifice showing oral spine bases, condyles and lyrula, with plectrum-shaped adventitious avicularia distolaterally. L. MSL BRY021a. Old part of colony with numerous avicularia. Scale bars: A = 1 mm; B, J = 500 µm; C, F–G, I, K = 100 µm; D–E, H, L = 200 µm.

lacking; ovicell hyperstomial (Fig. 11H–I), broader than long, 0.13–0.16 mm long by 0.18 mm wide, containing 25–40 pores with raised rims, variable in size, circular, elliptical or dumbbell-shaped, margins overgrown by cryptocystal calcification. Avicularia adventitious, of three types: small acuminate, small plectrum-shaped, and giant. Small acuminate avicularia variously located (Fig. 11G, I), increasing in number during ontogeny, usually directed distally or distolaterally to laterally and towards midline of zooid, occasionally proximolaterally, about 0.09–0.12 mm long by 0.05–0.06 mm wide; rostrum acuminate, a high triangle, shallow rostral shelf; cross-bar calcified, straight or slightly concave; opesia semicircular. Small plectrum-shaped avicularia located laterally or distolaterally of orifice (Fig. 11K), occasionally in more proximal positions around perimeter of autozooid, directed and inclined outwardly, narrow proximally, broadening distally, about 0.05–0.06 mm long by 0.05–0.08 mm wide (measured in plane of colony surface); rostrum rounded trapezoidal, shallow rostral shelf; cross-bar completely or incompletely calcified, straight; opesia semicircular, small. Giant avicularia occasionally present (Fig. 11F), directed distally, originating proximolaterally and passing laterally of orifice, which may be torqued, extending over frontal shield of distal zooid, straight or curved towards autozooid midline, 0.35–0.40 mm long by 0.11–0.13 mm wide; rostrum spatulate, long, with a deep shelf occupying one-third to two-thirds of length; cross-bar slightly concave; opesia semicircular.

Remarks

Parasmittina is a very diverse genus with a global distribution. Different species are best characterised by their avicularia, which are often of more than one morph within a single colony. First described formally from South China (Liu *et al.* 2001), *Parasmittina winstonae* has three kinds of avicularia: small acuminate, small plectrum-shaped, and giant. The distally directed giant avicularia in *P. winstonae* (Fig. 11F) are very unusual, as giant avicularia in *Parasmittina* are normally directed proximally, for example in the numerous species described by Soule & Soule (1973), Hayward & Parker (1994) and Harmelin *et al.* (2009). Harmer (1957: 943) noted the rarity of distally directed giant avicularia when describing material, some from Malaysia and since assigned to *P. winstonae* by Liu *et al.* (2001: 802), as *Smittina parsevalii* (Audouin, 1826). Likewise, the small plectrum-shaped avicularia lateral to the orifice are highly unusual, if not unique, to *P. winstonae* within *Parasmittina*.

Liu *et al.*'s (2001) original description of this species from the South China Sea gives a slightly longer autozooid size (0.37–0.67 mm) than both the Malaysian material described here (0.32–0.45 mm) and specimens from the Solomon Islands (*c*. 0.45 mm) described by Tilbrook (2006), who did not mention the presence of plectrum-shaped avicularia. This leaves some doubt about whether the three occurrences are truly conspecific, which will require further studies to test.

Parasmittina raigioidea Liu *et al.*, 2001
Fig. 12A–C

Parasmittina raigioidea Liu *et al.*, 2001: 629, pl. 58, figs 1–2.

Material

MALAYSIA: MSL BRY020b, Pulau Betong, Penang, encrusting barnacle on oyster raft.

Description

Colony encrusting, multiserial, unilamellar. Ancestrula and early astogeny not observed. Autozooids subhexagonal, distally rounded, about 0.24–0.51 mm long by 0.19–0.27 mm wide; boundary walls salient with a fine fissure; frontal shield convex, coarsely pustulose, about 20 marginal areolar pores separated by ridges, impinging on central part of shield in older zooids, no pseudopores; primary orifice elliptical, about 0.09 mm long by 0.10 mm wide, lappets developed laterally, lyrula broad, about 9 µm high by 25 µm wide at top edge, condyles present about one-quarter along orifice; oral spine bases

numbering 1 or 2; ovicell not observed. Avicularia adventitious, variable in size, shape and orientation but not clearly polymorphic (i.e., intermediates existing between common morphologies); usually located lateral to orifice or on proximal frontal shield, the former directed proximally, the latter distally or laterally, 0.08–0.23 mm long by 0.05–0.08 mm wide; rostrum acutely triangular to spatulate with a moderate shelf, straight or slightly curved; cross-bar calcified, straight to concave; opesia semielliptical.

Remarks

Acknowledging the problems in discriminating between species of *Parasmittina*, this material is tentatively assigned to *P. raigioidea*, a species described originally from South China, on account of the similar range of avicularian morphologies to those seen in pl. 58, figs 1 and 2 of Liu *et al.* (2001). These authors recognised two types of small avicularia – triangular and spatulate – as well as giant avicularia.

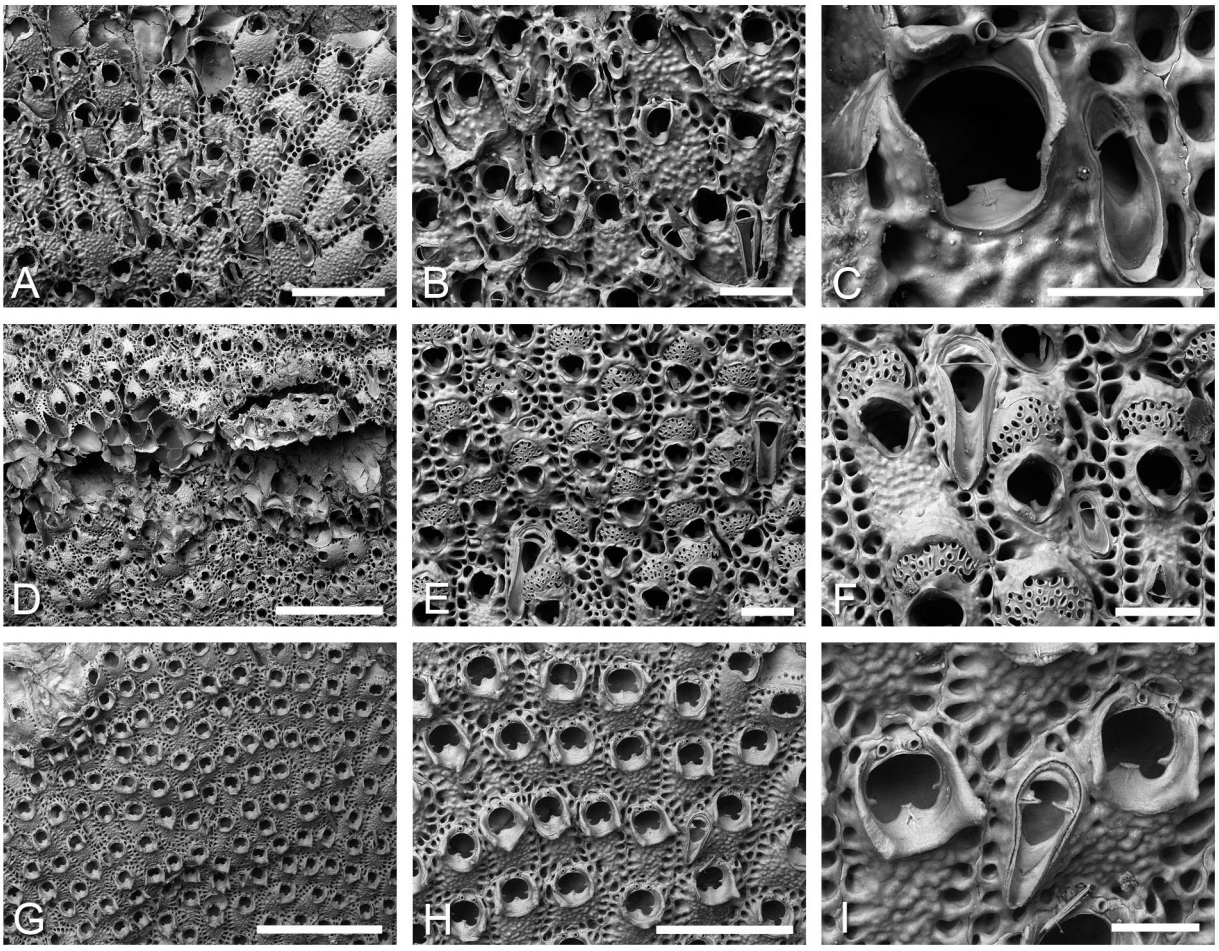

Fig. 12. *Parasmittina* spp. — **A–C**. *P. raigioidea* Liu *et al*., 2001. Pulau Betong, Penang, MSL BRY020b. A. Part of colony. B. Autozooids and avicularia. C. Orifice with lyrula and proximally directed adventitious avicularium. — **D–F**. *Parasmittina* sp. 1. Kuah jetty, Penang, MSL BRY021b. D. Colony (bottom) becoming overgrown by a colony of *P. winstonae* (top). E. Ovicellate zooids and proximally directed vicarious avicularia. F. Detail showing a proximally directed vicarious avicularium (upper left of centre) with a proximally directed spatulate adventitious avicularium to its lower right and a distally directed acuminate adventitious avicularium to the lower right of that. — **G–I**. *Parasmittina* sp. 2. Kampung Kuala Temoyong, Langkawi, MSL BRY012b; encrusting a large gastropod shell. G. Part of colony. H. Group of zooids. I. Autozooids and an adventitious avicularium. Scale bars: A, H = 500 μm; B, E–F = 200 μm; C, I = 100 μm; D, G = 1 mm.

The Malaysian material shows a range of avicularian morphologies and sizes and it is unclear whether there is one highly variable type of avicularium or several polymorphs.

Parasmittina sp. 1

Fig. 12D–F

Material

MALAYSIA: MSL BRY021b, Kuah jetty, Langkawi, on fouled rope hanging from jetty (with *P. winstonae*).

Description

Colony encrusting, multiserial, unilamellar. Ancestrula and early astogeny not observed. Autozooids subhexagonal, small, about 0.30–0.32 mm long by 0.25–0.28 mm wide; boundary walls salient with a fine fissure; frontal shield convex, coarsely pustulose, marginal areolar pores large, no pseudopores; secondary orifice elliptical, about 0.10–0.12 mm wide, lappets highest proximolaterally, lyrula variable, typically narrow, 13–18 µm wide at tip; oral spine bases not observed; ovicell hyperstomial, broad, about 0.12–0.16 mm long by 0.15–0.20 mm wide, ectooecium with about 30 ridged pores, proximal and distal edges of ovicell overgrown by cryptocystal calcification. Avicularia of three types: (1) adventitious acuminate avicularia present on some proximal frontal shields, about 0.11 mm long by 0.07 mm wide, usually distally or distolaterally directed, rostrum an acute triangle, tip raised, rostral shelf shallow, cross-bar calcified, opesia semicircular; (2) adventitious spatulate avicularia present on some frontal shields, about 0.14 mm long by 0.05 mm wide, directed proximally or laterally towards autozooid median line, rostrum rounded with deep shelf, cross-bar calcified, opesia semicircular; (3) vicarious avicularia large, 0.23–0.38 mm long by 0.13–0.15 mm wide, scattered, directed proximally, rostrum initially tapering before becoming parallel-sided, tip well rounded, distal edge slightly serrated, rostral shelf deep, occupying half or more of rostrum length, cross-bar calcified, concave, opesia relatively small, crescent shaped (Fig. 12F).

Remarks

It has not been possible to identify this species of *Parasmittina* despite the combination of distinctive large vicarious avicularia and small adventitious avicularia of spatulate and acuminate types. Pending a more detailed study and a comprehensive comparison with the myriad of species of *Parasmittina*, it is therefore left in open nomenclature as *Parasmittina* sp. 1.

Parasmittina sp. 2

Fig. 12G–I

Material

MALAYSIA: MSL BRY012b, Kampung Kuala Temoyong, Langkawi, colony encrusting interior of large gastropod shell.

Description

Colony encrusting, multiserial, unilamellar. Ancestrula and early astogeny not observed. Autozooids subhexagonal, small, about 0.24–0.32 mm long by 0.18–0.24 mm wide; boundary walls salient with a fine fissure; frontal shield convex, coarsely pustulose, marginal areolar pores large, no pseudopores; orifice slightly wider than high, about 0.09 mm long by 0.10 mm wide, lappets well-developed, highest proximolaterally, tapering distally, a sloping shelf-like proximal orificial rim extending between lappets, lyrula variable, condyles stout; usually two oral spine bases, occasionally one or three; ovicell broader than long, observed only partly formed. Avicularia adventitious present on a small minority of autozooids,

located proximolaterally or laterally of orifice, directed proximally or less often laterally, variable in size, up to 0.21 mm long by 0.08 mm wide; rostrum acutely triangular with rounded end, shelf variable, occupying up to one-half length; cross-bar complete or with a medial gap; opesia semi-elliptical.

Remarks

Compared with the other three species of *Parasmittina*, this unidentified species has very sparse avicularia and prominent lappets highest at the proximolateral corners of the orifice and tapering in height distally (Fig. 12I). There are some similarities with *Parasmittina hastingsae* Soule & Soule, 1973 (see Tilbrook *et al.* 2001: fig. 14c–d), but the latter has larger autozooids with long condyles and the lappets are highest mediolaterally rather than proximolaterally.

Family Bitectiporidae MacGillivray, 1895

Hippoporina Neviani, 1895

Hippoporina indica Pillai, 1978
Fig. 13A–F

Hippoporina indica Pillai, 1978: 62, figs 1–4.

Hippoporina indica – McCann *et al.* 2007: 331, fig. 7a–d.

Material

MALAYSIA: MSL BRY017b, Kuah jetty, Langkawi, fouling mussel shell attached to rope hanging from jetty. MSL BRY022, Pulau Betong, Penang, fouling a bivalve from an oyster raft. MSL BRY023, Sungai Menghulu, Langkawi, fouling a barrel.

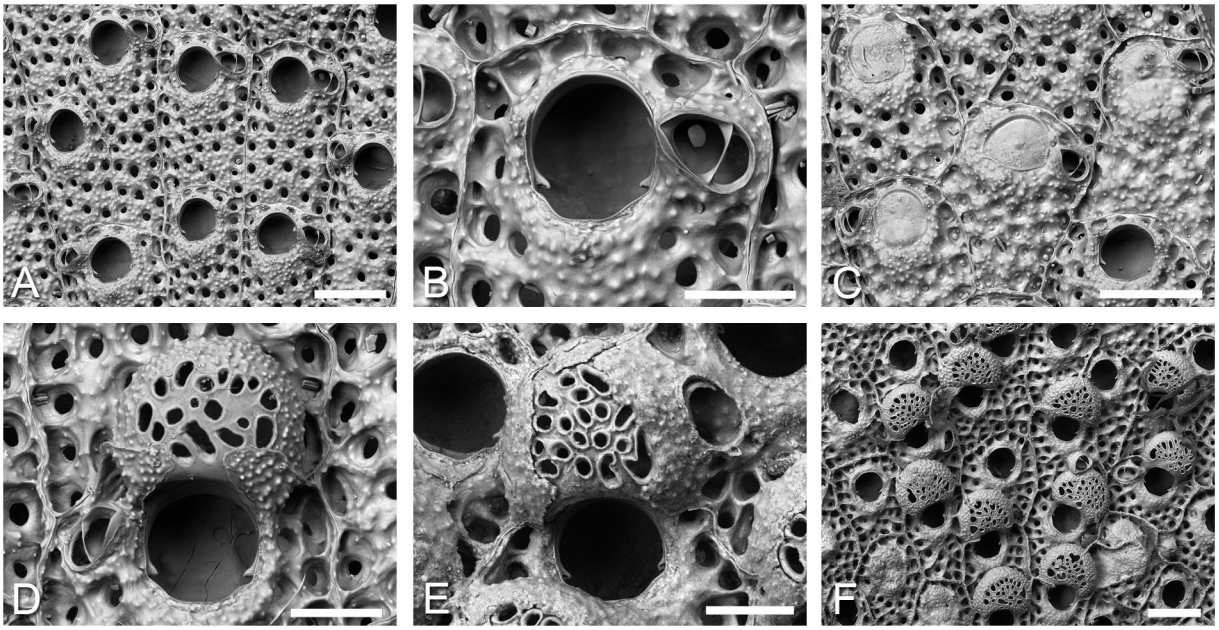

Fig. 13. *Hippoporina indica* Pillai, 1978. – **A–D**. Kuah jetty, Langkawi, MSL BRY017b. A. Group of zooids. B. Autozooidal orifice and avicularium. C. Autozooids with closed orifices. D. Ovicell. – **E**. Pulau Betong, Penang, MSL BRY022; ovicell. – **F**. Sungai Menghulu, Langkawi, MSL BRY023; group of ovicellate zooids. Scale bars: A, C, F = 200 µm; B, D–E = 100 µm.

Description

Colony encrusting, multiserial, unilamellar, except for frontal buds covering early astogenetic stages and apparent reparative growths. Autozooids subrectangular, elongate, 0.35–0.63 mm long by 0.23–0.33 mm wide; frontal shield gently convex, pustulose, porous, with large marginal areolar pores and large pseudopores, which are lacking from an apron proximal of orifice; orifice longer than wide (Fig. 13B), about 0.13 mm long by 0.11 mm wide, sinus broad and shallow, with medial edge almost straight, a pair of proximally directed, pointed condyles separating sinus from semicircular poster, closed by cryptocystal calcification in some zooids (Fig. 13C); ovicell hyperstomial, prominent, broader than long, about 0.16–0.18 mm long by 0.21–0.23 mm wide; about 10–20 rimmed pores of various shapes and sizes, becoming overgrown from the margins by a lamina of interior wall (Fig. 13D–E). Avicularia adventitious, small, about 0.10 mm long by 0.07 mm wide, normally located laterally to orifice and directed distolaterally towards orifice, usually single, lacking in many zooids, occasional avicularia with variable orientations present more proximally; rostrum pointed, arch-shaped; cross-bar calcified, narrow; opesia semielliptical, broader than long.

Remarks

Despite being described as late as 1978 (from Bombay Harbour), *Hippoporina indica* is rapidly becoming widespread as an invasive fouling species. It has been reported from the southeastern USA (McCann *et al.* 2007), New Zealand (Gordon *et al.* 2008) and Australia (Tilbrook 2012), and its presence in Penang and Langkawi is therefore unsurprising.

Superfamily Schizoporelloidea Jullien, 1883
Family Schizoporellidae Jullien, 1883

Schizoporella Hincks, 1877

Schizoporella japonica Ortmann, 1890
Fig. 14A–F

Schizoporella unicornsis var. *japonica* Ortmann, 1890: 49, pl. 3, fig. 35.

Schizoporella japonica – Ryland *et al*. 2014: 485, figs 2–5.

Material

MALAYSIA: MSL BRY019b, BRY024, Kuah jetty, Langkawi, encrusting bivalves fouling a rope hanging from the jetty.

Description

Colony encrusting, multiserial, unilamellar, growing edge locally developing giant buds (Fig. 14B); vivid yellow-orange when alive (Fig. 14A). Autozooids small, 0.48–0.60 mm long by 0.18–0.38 mm wide, elongate, on average 1.9 × longer than wide; frontal shield convex, with marginal areolar pores and abundant deep pseudopores, suboral umbo; orifice about as long as wide, 0.11–0.14 mm in both dimensions, sinus wide, shallow, broad condyles occupying outer two-thirds of hingeline on either side of sinus (Fig. 14D); ovicell prominent, porous (Fig. 14E–F). Adventitious avicularia (Fig. 14D) present in about one-third of autozooids, typically lacking in narrower examples, never more than one per zooid, proximal end level with proximal edge of orifice, directed distolaterally, about 0.11 mm long by 0.06 mm wide; rostrum a high triangle with slightly concave edges and rounded distal end somewhat raised; cross-bar straight; opesia semicircular.

Remarks

Ryland *et al*. (2014) comprehensively redescribed *Schizoporella japonica* and provided information on its geographical distribution, focusing especially on its recent introduction into western Europe. Living colonies of *S. japonica* from Langkawi have a vibrant yellow-orange colour, similar to the specimen from Friday Harbor, Washington depicted by Ryland *et al.* (2014: fig. 2d), although some of the colonies described by these authors are redder in colour. The Langkawi material has rather smaller autozooids than is usual for this species, which may reflect the warm ambient seawater temperature, and the avicularia tend to be slightly more laterally orientated.

Family Hippopodinidae Levinsen, 1909

Hippopodina Levinsen, 1909

Hippopodina feegeensis (Busk, 1884)
Fig. 15A–C

Lepralia feegeensis Busk, 1884: 144, pl. 22, fig. 9, 9a, 9b.

Hippopodina feegeensis – Tilbrook 1999: 451, fig. 1a–h.

Material

MALAYSIA: MSL BRY001b, Pantai Pasir Hitam, Langkawi, collected intertidally from coral reef.

Description

Colony encrusting, multiserial, unilamellar or multilamellar, often large in size; growing edge revealing line of buttressed pores in transverse walls. Ancestrula and early astogeny not observed in studied

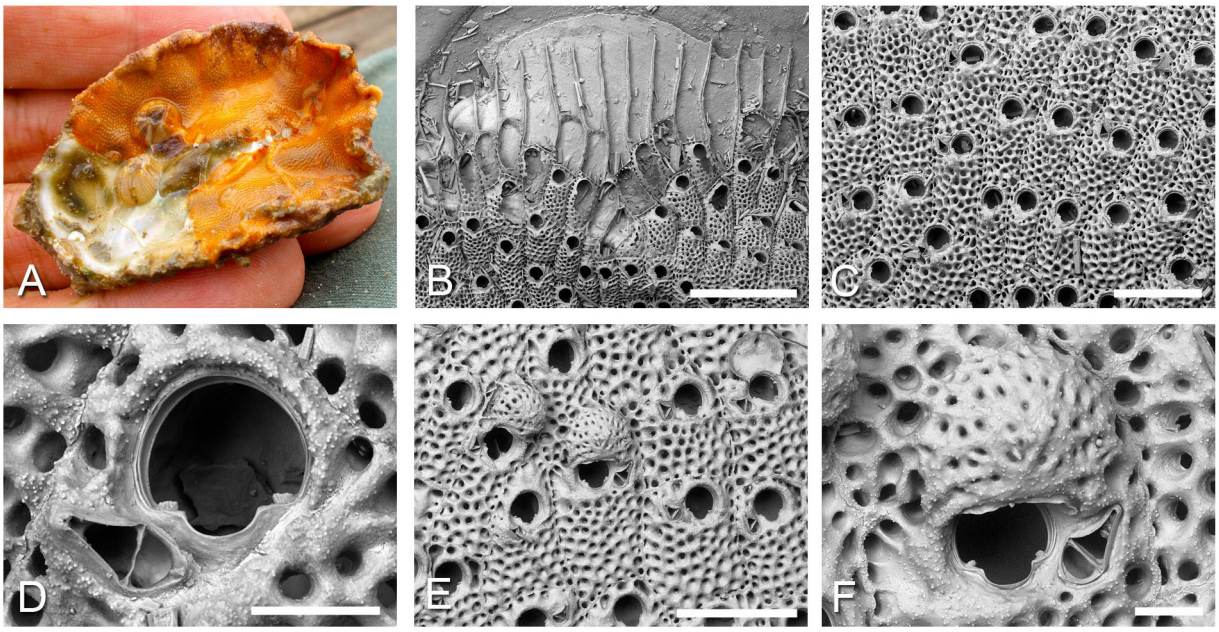

Fig. 14. *Schizoporella japonica* Ortmann, 1890. Kuah jetty, Langkawi. — **A**. Colony photographed in the field showing colour when alive. — **B–D**. MSL BRY024. B. Growing edge with giant buds. C. Group of zooids. D. Orifice and avicularium. — **E–F**. MSL BRY019b. E. Group of zooids, two ovicellate. F. Ovicell. Scale bars: B = 1 mm; C, E = 500 µm; D, F = 100 µm.

Malaysian material; elsewhere ancestrula comprising a tetrad of zooids (e.g., Tilbrook 1999: fig. 1b). Autozooids large, 0.75–1.00 mm long by 0.42–0.58 mm wide, subrectangular to subhexagonal; distinct with interzooidal grooves; frontal shield gently convex, perforated by numerous small, closely spaced pores, pustulose; orifice large, hoof-shaped, almost equidimensional, 0.20–0.22 mm long by 0.18–0.20 mm wide, proximal edge gently concave, wide, condyles rounded, lateral; ovicell large (Fig. 15B), 0.46–0.50 mm long by 0.44–0.50 mm wide, evenly porous, calcification resembling frontal shield but lacking pustules, primary orifice of ovicellate zooids a little larger than in non-ovicellate zooids, secondary orifice broad, 0.12 mm long by 0.24 mm wide, incipient ovicell evident as a sparsely porous, smooth depression in proximal gymnocyst of distal zooid. Adventitious avicularia (Fig. 15C) present in less than one-half of autozooids, singly or paired, 0.18–0.26 mm long by 0.12–0.16 mm wide; located distolaterally of orifice, directed transversely towards midline of supporting autozooid; rostrum a

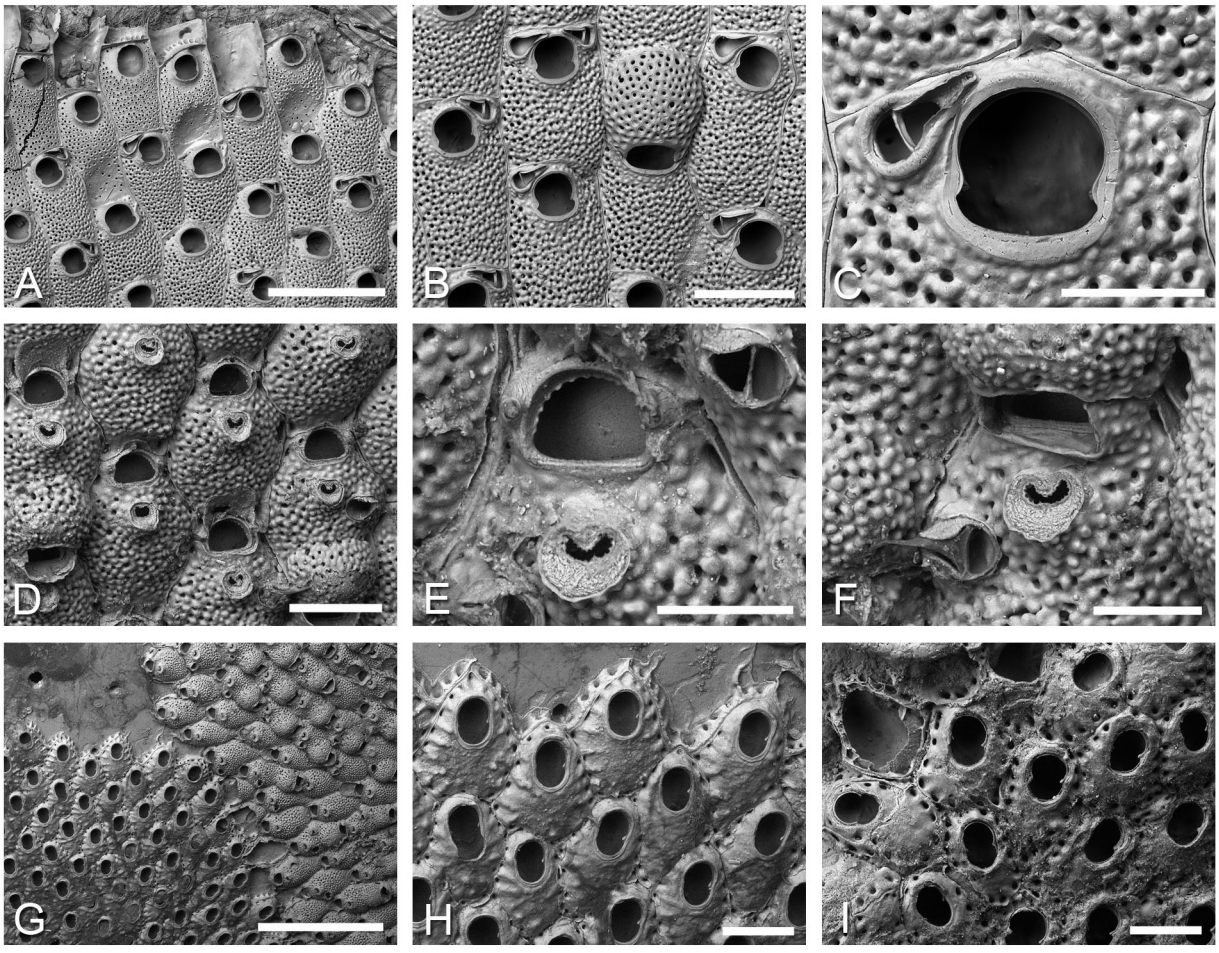

Fig. 15. — **A–C**. *Hippopodina feegeensis* (Busk, 1884). Pantai Pasir Hitam, Langkawi, MSL BRY001b. A. Zooids near growing edge (top). B. Group of autozooids and an ovicell. C. Autozooidal orifice with an adventitious avicularium. — **D–F**. *Microporella* sp. Kampung Kuala Temoyong, Langkawi, MSL BRY012d. D. Group of zooids. E. Ascopore, orifice and avicularium (top right). F. Oblique view of ovicellate autozooid showing ascopore and avicularium with mandible. — **G**. *Scorpiodinipora costulata* (Canu & Bassler, 1929) (left) and *Microporella* (right). MSL BRY012c and MSL BRY012d, respectively. Kampung Kuala Temoyong, Langkawi. — **H–I**. *Scorpiodinipora costulata* (Canu & Bassler, 1929). H. Kampung Kuala Temoyong, Langkawi, MSL BRY012c. Zooids at the growing edge. I. Pulau Betong, Penang, MSL BRY025. Group of zooids. Scale bars: A, G = 1 mm; B = 500 µm; C–D, H–I = 200 µm; E–F = 100 µm.

high triangle with slightly concave sides, pointed distally; cross-bar calcified in most, straight; opesia semicircular.

Remarks

This is a common species circumtropically, often occurring in coral reefs, which is widely distributed in the Pacific, Indian and Atlantic Oceans and also recorded from the Mediterranean and Red Seas (see Powell 1969: fig. 2). The large sizes of both the colonies and their constituent zooids are notable.

Colonies of this species found at Pantai Pasir Hitam, Langkawi were remarkable for being concentrated in a small area and absent from similar-looking habitats in the area. This suggests localized recruitment, perhaps from a single founding colony.

Family Microporellidae Hincks, 1879

Microporella Hincks, 1879

***Microporella* sp.**
Fig. 15D–G

Material

MALAYSIA: MSL BRY012d, Kampung Kuala Temoyong, Langkawi, colony encrusting interior of large gastropod shell.

Description

Colony encrusting, multiserial, unilamellar. Ancestrula and early astogeny not observed. Autozooids small, about 0.35–0.37 mm long by 0.28 mm wide, subhexagonal, rounded distally; distinct with interzooidal grooves; frontal shield convex, porous, a few elongate areolar pores around perimeter and numerous smaller circular pseudopores elsewhere, coarsely pustulose; orifice semi-elliptical, small, about 0.06 mm long by 0.08–0.09 mm wide, proximal edge straight, without teeth or condyles, distal edge beaded; oral spines numbering three in non-ovicellate zooids, one distal medial and two lateral, level with orifice mid-length, not visible in ovicellate zooids; ascopore crescent-shaped, about 0.04 mm wide, toothed, set in a rugose prominence about 0.06 mm long by 0.08 mm wide, close to proximal edge of orifice, but separated by a narrow band of non-porous frontal shield (Fig. 15E); ovicell personate, proximal border of secondary orifice broadly U-shaped, ooecium broader than long, about 0.16 mm long by 0.20 mm wide, porous except in the most proximal medial part, calcification continuous with that of frontal shield of distal zooid, on which ovicell rests without extending as far distally as ascopore. Adventitious avicularia present in a minority of autozooids, single, located about mid-length on autozooid, directed laterally outwards, small, about 0.08 mm long by 0.06 mm wide; rostrum with concave sides and open end (i.e., channeled); mandible setose, almost twice length of rostrum; opesia semicircular.

Remarks

Microporella is a highly species-rich genus with a global distribution (Taylor & Mawatari 2005). Differences between species can be very subtle. The species described here is characterized by having: (1) unpaired avicularia, often lacking altogether, laterally directed; (2) a broad crescent-shaped ascopore set in a wide rugose prominence; (3) three oral spines; and (4) an orifice lacking both teeth and condyles along the proximal edge but having a beaded distal edge. A beaded (or denticulate) distal orificial edge occurs in relatively few species of *Microporella*, such as *M. serrata* Mawatari & Suwa, 1998, *M. rogickae* Winston, Hayward & Craig, 2000, and *M. browni* Harmelin, Ostrovsky, Cáceres-Chamizo & Sanner,

2011. In *M. serrata* the avicularia are located much more distally than in the species from Langkawi and the ascopore is cribriform. Condyles are present at the proximolateral corners of the orifice in both this species and *M. rogickae*, the latter having 4–5 oral spines (*cf.* 3 in the species described here) and a much thicker proximal edge to the personate ovicells, whereas in *M. serrata* 4 oral spines are present and the ovicells are not personate. Although the Langkawi species may be new, its formal description must await additional material.

Superfamily Celleporoidea Johnston, 1838
Family Hippoporidridae Vigneaux, 1949

Scorpiodinipora Balavoine, 1959

Scorpiodinipora costulata (Canu & Bassler, 1929)
Fig. 15G–I

Schizoporella costulata Canu & Bassler, 1929: 317, pl. 36, fig. 10.

Scorpiodinipora costulata – Harmelin *et al.* 2012: 129, figs 1–4.

Material

MALAYSIA: MSL BRY012c, Kampung Kuala Temoyong, Langkawi, colony encrusting interior of large gastropod shell. MSL BRY025, Pulau Betong, Penang, on gastropod from oyster rafts.

Description

Colony encrusting, multiserial, unilamellar; buttressed pore chambers visible at stepped growing edge. Ancestrula and early astogeny not observed. Autozooids rounded subhexagonal, 0.35–0.41 mm long by 0.23–0.26 mm wide, zooidal boundaries with narrow grooves; frontal shield convex, mammillated, bordered by large areolar pores separated by radial ridges, imperforate centrally; orifice large relative to zooid size, ovoidal, longer than wide, 0.13–0.15 mm long by 0.09–0.10 mm wide, anter and poster similarly sized, well rounded, separated by condyles that mark beginning of a rim outlining anter; oral spines lacking; ovicells absent. No avicularia.

Remarks

This widely distributed species was revised by Harmelin *et al.* (2012) who noted its preference for gastropod shells. The two colonies collected in Malaysia, one from Langkawi and the other from Penang, are both on gastropod shells, though not a living gastropod in the case of the Langkawi specimen, which encrusts an interior surface.

Discussion

There appear to be no descriptions in the literature of bryozoans from either Penang or Langkawi, and the only mention of a bryozoan that could be found from either island is in a paper (Waters 1885: 287) describing Australian fossils in which a bryozoan identified as *Membranipora savartii* Audouin (probably one of the species of *Acanthodesia* described above) is recorded in Penang. The notion that bryozoans might be rare was dispelled by the discovery of 23 species, some abundant, during just a few days of shore collecting. Given the economic importance of the marine environment for these islands, it is remarkable that bryozoans, many of which are significant foulers of man-made structures, have been totally neglected in the past.

Of the 23 species collected during the current shore survey, 14 were found only at Langkawi, 6 only at Penang and 3 at both islands. In terms of taxonomy, 12 of the species recorded are anascan cheilostomes

and 11 ascophorans. Half of the anascans are malacostegines, a group characterised uniquely among living cheilostomes by the possession of planktotrophic, cyphonautes larvae. The high proportion of malacostegines may be due to the long-lived larvae, allowing colonization of floating substrates by some species (notably *Jellyella eburnea*), and also the ability of other species to tolerate low and fluctuating salinity environments (e.g., Winston 1977), such as those with high levels of freshwater run-off. Surprisingly, no cyclostome bryozoans were found, but the failure to record soft-bodied ctenostomes may simply be due to the fact that most samples were collected in a dry condition.

Only 4 of the 23 species have erect colonies, the majority being encrusters. Unique in having robustly calcified erect colonies is *Adeonella lichenoides*. This ascophoran was found at one locality on Langkawi among what appeared to be fishing by-catch. It seems possible that it came from deeper waters further offshore than the other bryozoans recorded here. This is supported by the 5.5–113 m total depth range of the material of *A. lichenoides* listed by Hayward (1988).

Several of the species collected are known to be invasive foulers. These include *Bugula neritina*, *Hippoporina indica* and *Schizoporella japonica*, which are becoming more widespread at the present day (see, e.g., http://invasions.si.edu/nemesis/browseDB/GroupSummary.jsp?GRP=Bryozoans). The impacts of these species on the indigenous biota, as well as on economic fisheries and on ships and man-made structures such as wharves, are in general poorly understood and completely unknown in Malaysia.

Appreciation of the true diversity of bryozoans around Penang and Langkawi and their geographical and habitat distributions will require considerably more research, employing denser sampling and diving and dredging to obtain bryozoans from subtidal habitats including reefs. For instance, cobbles from subtidal soft bottoms in nearby southwest Thailand were found by Sanfilippo *et al.* (2011) to be colonized by a rich fauna of bryozoans. No comparable sampling for bryozoans has yet been done in Malaysia.

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