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Bryozoa from the Straits of Johor, Singapore, with the description of a new species

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Abstract. A checklist of 33 bryozoan species (named and known-undescribed) is presented from the Straits of Johor. This is the first such inventory for the island country of Singapore and focuses on the estuarine waters between it and Malaysia. Although this level of diversity is greater than anticipated it still only represents a small proportion of the total bryozoan fauna from Singaporean waters (thought to be some 200 or so species). The majority (63%) of species found in this fauna produce encrusting, two-dimensional colony morphologies, but erect-flexible (24%), and erect-rigid (12%) colony morphologies are well represented. These proportions of colony morphologies are more akin to those found in the neighbouring South China Sea bryozoan fauna than those found in the local fouling bryozoan communities. The Johor Straits bryozoan fauna is noteworthy in containing the first species of *Alcyonidium* from the tropical Indo-Pacific. *A. jauhar sp.* nov., which is formally described herein, and *Amphibiobeania epiphylla*; an amphibious mangrove-leaf-encrusting bryozoan, is recorded for the first time outside of Australian waters.

Key words. Johor, Bryozoa, estuarine, new species, *Alcyonidium*, checklist

INTRODUCTION

The marine flora and fauna of Singapore has been formally studied since the colonial days of the 19th century, but the extent to which this has taken place varies from one organismal group to another. Singapore today is far different from that explored in those early days, owing to significant coastal development that has reclaimed many natural marine habitats. Few original marine habitats remain; artificial seawalls and lagoons now dominate the shoreline, but even in these seemingly challenging habitats marine organisms continue to thrive, albeit perhaps with reduced diversity and altered inventory.

The Comprehensive Marine Biodiversity Survey of Singapore waters (CMBS; launched in November 2010) was a national initiative to take stock of Singapore's extant fauna, and determine, as far as possible, its composition, distribution, abundance, and ecology. As part of the survey, a workshop with international participants was held on Pulau Ubin, a small island between Singapore Island and Peninsular Malaysia in the East Johor Straits, from 15 October to 2 November 2012. Sampling effort during this workshop concentrated on the estuarine and deeper water habitats in the Johor Straits. The Johor Straits has a range of natural intertidal habitats including mangroves, mudflats, seagrass meadows, as well as rocky and sandy shores whereas subtidally it comprises mud and sand, with occasional areas of gravel substrata, all at depths of <20 m; most of these habitats were sampled, though not all produced bryozoans. No diving was undertaken owing to the turbid water conditions.

Bryozoa is a phylum of sessile, colonial, invertebrate, suspension-feeders, with about 5900 described living species (Bock & Gordon, 2013); there are more than double this number of described fossil species ranging back to the Ordovician. Whilst bryozoan individuals (zooids) are mostly very small (<0.5–1.5 mm) in size [some attenuated forms can be up to 1 cm long], maximum colony size can run through several orders of magnitude from less than a millimetre to more than a metre, and only a handful of individuals to many millions, and is independent of the size of the constituent individuals. The majority of living species are marine and produce a calcified exoskeleton. As might be expected, given the vast difference in maximum colony size, colony morphology varies greatly too. Whilst the majority of bryozoan species produce two-dimensional encrusting colonies, some larger, more heavily calcified, erect colonies are reminiscent of hydrocorals or even scleractinian corals; others that are lightly calcified, or totally uncalcified, may be small and erect and resemble hydroids.

Until very recently, there had been little reference made to bryozoans from Singaporean waters save for a few random notes in some taxonomic works (e.g., Levinsen, 1909; Harmer 1926, 1957); there had certainly been no systematic study carried out. It was not until Goh (2010), who made a study of fouling bryozoans in Singaporean waters that a list of resident bryozoan species began to accumulate. However, she was able to identify only 22 of her 51 specimens, attributing them to just seven species.

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The Bryozoa described and listed in the current paper were collected by the authors and, in some cases, by persons accompanying the authors in the field. The first author participated in the CMBS workshop in 2012, which sampled mainly from the eastern end of the straits, and the majority of species recorded herein were found during that time. The second author and participants in a workshop on the biology and taxonomy of Bryozoa collected additional species during April 2013. Finally, the first author has recently been able to re-examine Goh's (2010) material, identifying all 51 specimens and the pertinent results have also been added to this checklist.

At least 33 species of Bryozoa are documented from the Straits of Johor. Pending detailed taxonomic study based on examination of type and other museum material, some of the taxa listed here are identified only to genus. Findings of particular interest are the first species of *Alcyonidium*, *A. jauhar* sp. nov., to be formally described from the tropical Indo-Pacific, and the first record of the amphibious mangrove-leaf-encrusting bryozoan *Amphibiobeania epiphylla* Metcalfe, Gordon & Hayward, 2007 beyond Darwin, northern Australia. What is remarkable is that *A. epiphylla* was found in Singapore surviving subaerially, some 1.5 m above the local low-tide datum.

MATERIAL AND METHODS

The material recorded here was either collected by hand, as part of the CMBS or Goh's (2010) survey work, or is from dredge material collected by the National University of Singapore's research vessel Galaxea. All of the material was initially examined fresh by the first author. Depending on the tentative identification given the material was either fixed in 70% alcohol after sub-samples were taken for impending molecular work (fixed in 95% ethanol and refrigerated), or preserved in a weak formalin solution. Most of the alcohol-fixed specimens were then air-dried for ease of storage. All of the specimens recorded here have recently been re-examined by the first author and registered for incorporation into the collections of the Lee Kong Chian Natural History Museum (ZRC.BRY), including type material of the new species.

Station data.

SW10 16 October 12: West of Sungei Besar, 1°25.151' N, 103°57.196' E, 0 m, hand collection, seaward section of fence and intertidal cobbles/stones.

SW47 20 October 12: OBS Camp 1, intertidal, 1°25.120' N, 103°55.743' E, 0 m, hand collection, muddy.

SW93 26 October 12: Fish farm, FC12E, near Pulau Ubin Jetty, 1°23.933' N, 103°57.841' E, 0 m, hand collection, hand net, fish net, attached to pontoon.

SW95 26 October 12: Mouth of Sungei Besar, 1°25.025' N, 103°57.607' E, 0 m, hand collection, sandy shore, mudflat with mangrove.

SW100 27 October 12: OBS Camp 1, intertidal, 1°25.120' N, 103°55.743' E, 0 m, hand collection, rocky area.

SW106 27 October 12: Lim Chu Kang, mangrove area, 1°26.772' N, 103°42.509' E, 0 m, hand collection, hand net, tangle net, muddy, mangrove.

SW107 28 October 12: OBS Camp 1, jetty for OBS staff, 1°25.174' N, 103°55.658' E, 0 m, hand collection, 'bubu' trap.

SW109 28 October 12: Changi [no coordinates].

SW114 29 October 12: OBS Camp 1, mangrove next to boat shed (Kayak shed 4), 1°25.147' N, 103°55.759' E, 0 m, hand collection, algae, leaf litter.

SW123 29 October 12: Between OBS Camp 1 and Camp 2, intertidal, 1°24.983' N, 103°56.021' E, 0 m, hand collection, rocky/muddy.

SW127 30 October 12: Oyster Farm (Lighthouse Seafarms Pte Ltd) FC83E, Pulau Tekong Coastal Area, 1°25.797' N, 104°4.018' E, 0 m, hand collection from empty oysters cages, near mangrove.

DW18 17 October 12: Pulau Ubin, northern side, start 1°25.794' N, 103°55.897' E, end 1°25.647' N, 103°55.592' E, 12.9–6.2 m, beam trawl.

DW39 19 October 12: Off Pulau Ubin jetty, start 1°23.608' N, 103°58.355' E, end 1°24.709' N, 103°58.377' E, 24–22 m, beam trawl.

DW40 19 October 12: Opposite Changi Chalet Radar, start 1°23.797' N, 103°58.751' E, end 1°23.768' N, 103°58.908' E, 21–15.6 m, rectangular dredge.

DW57 22 October 12: Pulau Tekong, east of Pulau Tekong, start 1°25.342' N, 104°04.775' E, end 1°24.949' N, 104°05.080' E, 10.3–10.6 m, beam trawl.

DW61 23 October 12: Pulau Serangoon, off Pulau Serangoon, start 1°24.962' N, 103°55.341' E, end 1°25.207' N, 103°55.154' E, 7.4–11.0 m, beam trawl, muddy.

DW64 23 October 12: Pulau Seletar, Channel between Pulau Seletar and Nee Soon, start 1°26.290' N, 103°51.752' E, end 1°26.584' N, 103°51.511' E, 4.2–4.8 m, beam trawl.

DW78 24 October 12: Channel between Changi Ferry Terminal and West Pulau Tekong (Kuala Johor), start 1°22.720' N, 104°01.221' E, end 1°22.997' N, 104°00.962' E, 20.5–23.6 m, beam trawl, some dead wood.

DW79 24 October 12: Channel between Pengerang and East Pulau Tekong (off Tanjung Pengelih), start 1°21.612' N, 104°04.572' E, end 1°21.972' N, 104°04.657' E, 11.7–12.6 m, beam trawl, mud and rubbish, dead wood.

DW81 24 October 12: Pulau Tekong, northeast Pulau Tekong, start 1°25.463' N, 104°04.650' E, end 1°25.511' N, 104°04.599' E, 10.7–9.9 m, epibenthic sled.

DW87 25 October 12: Changi East, off restricted area, start 1°20.178' N, 104°02.322' E, end 1°19.732' N, 104°02.507' E, 7.3–8.1 m, beam trawl, mud.

DW88 25 October 12: Changi East, off restricted area, start 1°20.296' N, 104°03.348' E, end 1°20.503' N, 104°03.110' E, 8.5–8.7 m, beam trawl, mud.

DW119 29 October 12: Changi, between Changi Point Ferry Terminal and Sekudu, start 1°23.912' N, 103°58.577' E, end 1°23.875' N, 103°58.512' E, 17.3–18.2 m, otter trawl, sandy.

DW120 29 October 12: Changi, between Changi Point Ferry Terminal and Ubin, start 1°23.934' N, 103°58.629' E, end 1°23.742' N, 103°58.372' E, 20.6–21.4 m, beam trawl, sandy/muddy.

DW128 30 October 12: Near Johor, no landmark, start 1°19.669' N, 104°04.596' E, end 1°19.801' N, 104°03.882' E, 21.8–18.3 m, rectangular dredge, muddy.

DW129 30 October 12: Near Johor, no landmark, start 1°19.075' N, 104°04.249' E, end 1°19.318' N, 104°03.868' E, 22.5–21.7 m, beam trawl, muddy with some clay.

CFF#1 22 July 09: Changi fish farm, 01°23.56' N, 103°57.50' E, <1 m.

CFF#2 10 December 09: Changi fish farm, 01°23.56' N, 103°57.50' E, <1 m.

AB 26 October 09: Angler Buoy, 01°21.09' N, 104°03.01' E, <1 m.

CAAS2 1 September 09: CAAS Buoy 2, 01°23.68' N, 103°59.60' E, <1 m.

MF69 01 May 13: End of Lim Chu Kang Road, 1°26' 44.1" N, 103°42' 26.4" E, 0 m, at base of mangroves and on rope and other debris.

TAXONOMY

This systematic account follows the ordering set out by Bock & Gordon (2013).

Order Ctenostomata Busk, 1852

Superfamily Alcyonidioidea Johnston, 1838

Family Alcyonidiidae Johnston, 1838

Genus *Alyconidium* Lamouroux, 1813

Alcyonidium jauhar new species

(Fig. 1A–F)

Material examined. Holotype: ZRC.BRY.0548, stn SW95, west of Nordin Beach swimming area, Pulau Ubin, Singapore. Intertidal. Paratypes: ZRC.BRY.0549 [six colonies], ZRC. BRY.0550 [five colonies], stn SW95 (same details as Holotype).

Etymology. Alluding to Johor Strait where the species was discovered, the name Johor being derived from the Arabic, *jauhar*, gem, jewel; used as a noun in apposition.

Description. Colony encrusting, unilaminar, up to 15 cm^2 in area. Autozooids contiguous, regularly quincuncial; shape of developing zooids at colony margin on flat substratum more or less polygonal, 4–6-sided, becoming longer with further differentiation to form an elongate 4-sided-diamond shape, distally acute, or with the interpolation of a short length of lateral wall on each side to make 6 sides in all; distal end can also be slight rounded [ZL 210–270 (av. 235) μm, ZW 80–130 (av. 103) μm]. Zooids transparent, some with refractive inclusions, lateral walls not thickened. Retracted tentacle crown whitish-opaque, its distal end beneath a very short orificial papilla. Where two lobes of the same colony meet, kenozooids, smaller than autozooids, form at the boundary; some of these may be suberect and bubble-like. Polypide with 15–16 transparent tentacles. No intertentacular organ or embryos observed.

Remarks. Bock (2014) lists 64 species of *Alcyonidium*. Of these, 33 (~52%) were formally described from the temperate or boreal Atlantic and the Arctic; 19 others (~30%) were described from the tropical West Atlantic, South Atlantic, South Africa, southern South America and Antarctica. Only 13 species have been named from the Pacific Ocean—three from the NE Pacific, two from New Zealand and eight from Japan. Thus, remarkably, not a single species has been formally named and described from the tropical Indo-Pacific and it is highly unlikely that any of the temperate species would survive in Johor Strait should they inadvertently be transported there. Harmer (1915) described a single small colony of an *Alcyonidium* from Torres Strait that he attributed to a European species. It was highly transparent and growing on *Euthyrisella obtecta* (Hincks, 1882); it had only "about 12" tentacles and appears not to be conspecific with *Alcyonidium jauhar* sp. nov., which is less transparent and has 15–16 tentacles.

All of the Japanese species are from Sagami Bay (c. 35°N) northwards to Hokkaido. Most have a robust, erect colony form but *Alcyonidium nanum* Silén, 1942, *A. nipponicum* d'Hondt & Mawatari, 1986 and *A. shizuoi* d'Hondt & Mawatari, 1986 are encrusting. These, however, differ from *A. jauhar* sp. nov. in several respects—*A. nanum* has about 20 tentacles and the orifice is wholly non-projecting; *A. nipponicum* has whitish colonies when alive, fusiform to oval zooidal outlines and very thick interior walls; and *A. shuzoi* has only 12–15 (mostly 13–14) tentacles, a wide-diameter peristome, and many quadrangular interzooidal kenozooids. The two named New Zealand species of *Alcyonidium* respectively differ from *A. jauhar* sp. nov. in colonial morphology and the presence of frontally adventitious kenozooids (Gordon 1984, 1986).

A further species of *Alcyonidium* has been seen from Heron Island, southernmost Great Barrier Reef; this was also transparent but a bright orange colour in life (Tilbrook, pers. obs.).

Distribution. Nordin Beach, Pulau Ubin, Johor Strait, Singapore, intertidal. All the material noted was found encrusting the black synthetic fabric lining of a tartan jacket caught on the barbed wire of the anti-immigration fence that runs the length of the northern shore of Pulau Ubin.

Order Cheilostomata Busk, 1852

Suborder Malacostegina Levinsen, 1902

Superfamily Membraniporoidea Busk, 1852

Family Electridae Stach, 1937

Genus *Arbopercula* Nikulina, 2010

Arbopercula bengalensis (Stoliczka, 1869)

(Fig. 2A–D)

Electra bengalensis Stoliczka, 1869: 55, pl. 12; McCann et al., 2007: 326, fig. 5a,b (cum syn.).
Electra anomala Osburn, 1950: 36, pl. 3, fig. 6.

Remarks. Nikulina (2010) established *Arbopercula* for two electriform species with branching cuticular spines on the operculum, *Membranipora bengalensis* Stoliczka, 1869 (designated type species) from West Bengal and *Electra anomala* Osburn, 1950 from the vicinity of the Panama Canal. It is our opinion that these two species must be regarded as synonymous because, despite their seemingly disparate occurrences, the two descriptions and Osburn's (1950) figure are undoubtedly this well-known fouling species of the Indo-Pacific; its point of origination is unknown, it just happened

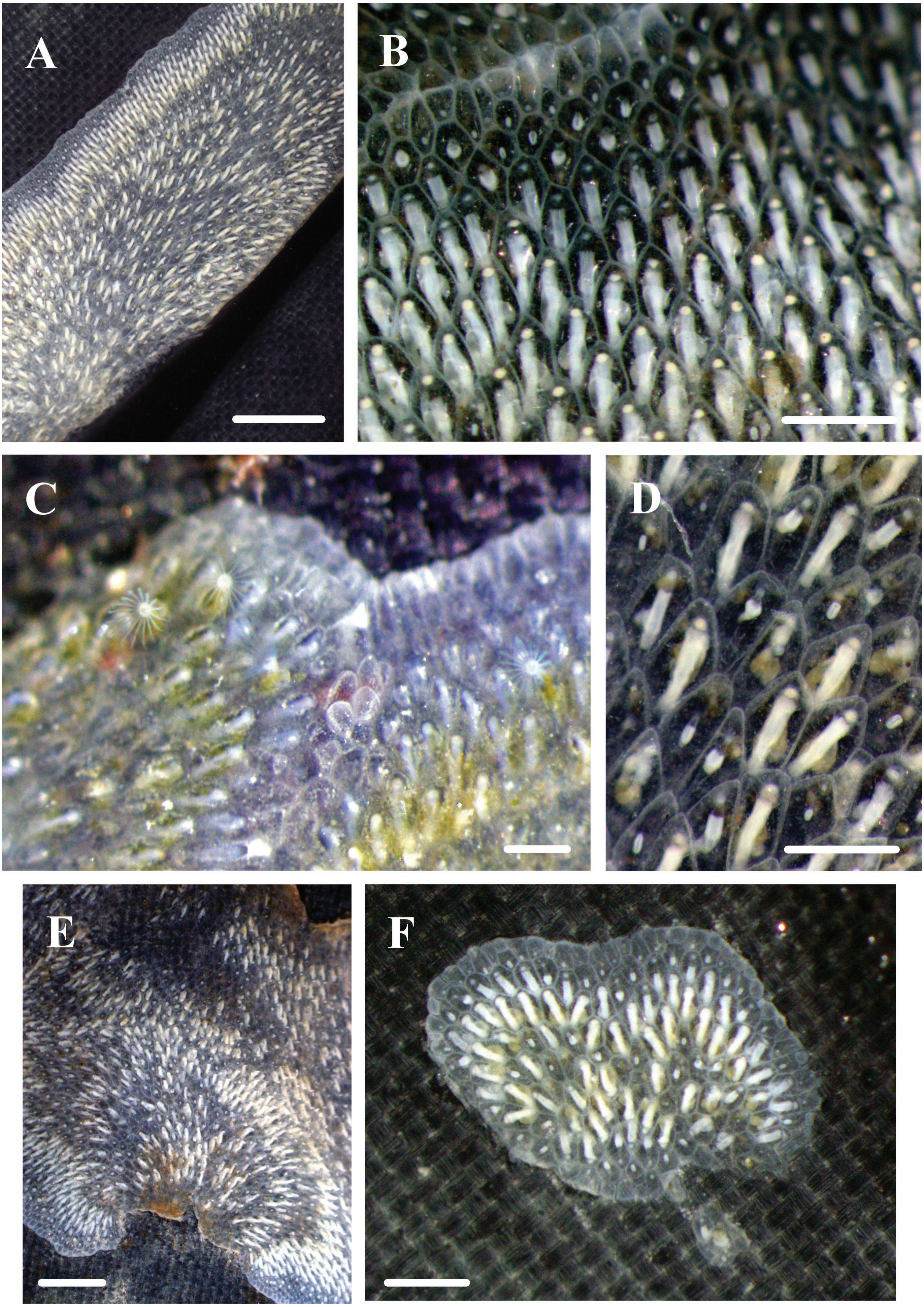

Fig. 1. *Alcyonidium jauhar* sp. nov. A, D, F, paratype ZRC.BRY.0549; B, E, paratype ZRC.BRY.0550; C, Holotype ZRC.BRY.0548. A, low magnification view of a large colony; B, high magnification view of another colony; C, high magnification view of the living colony where two lobes meet, the tentacles of four autozooids can be seen; D, very high magnification view of autozooids and kenozooids; E, low magnification view of a large colony; F, low magnification view of a very small colony, with the colony origin intact. Scale bars = 1 mm [A, E]; 250 µm [B, D]; 200 µm [C]; 500 µm [F].

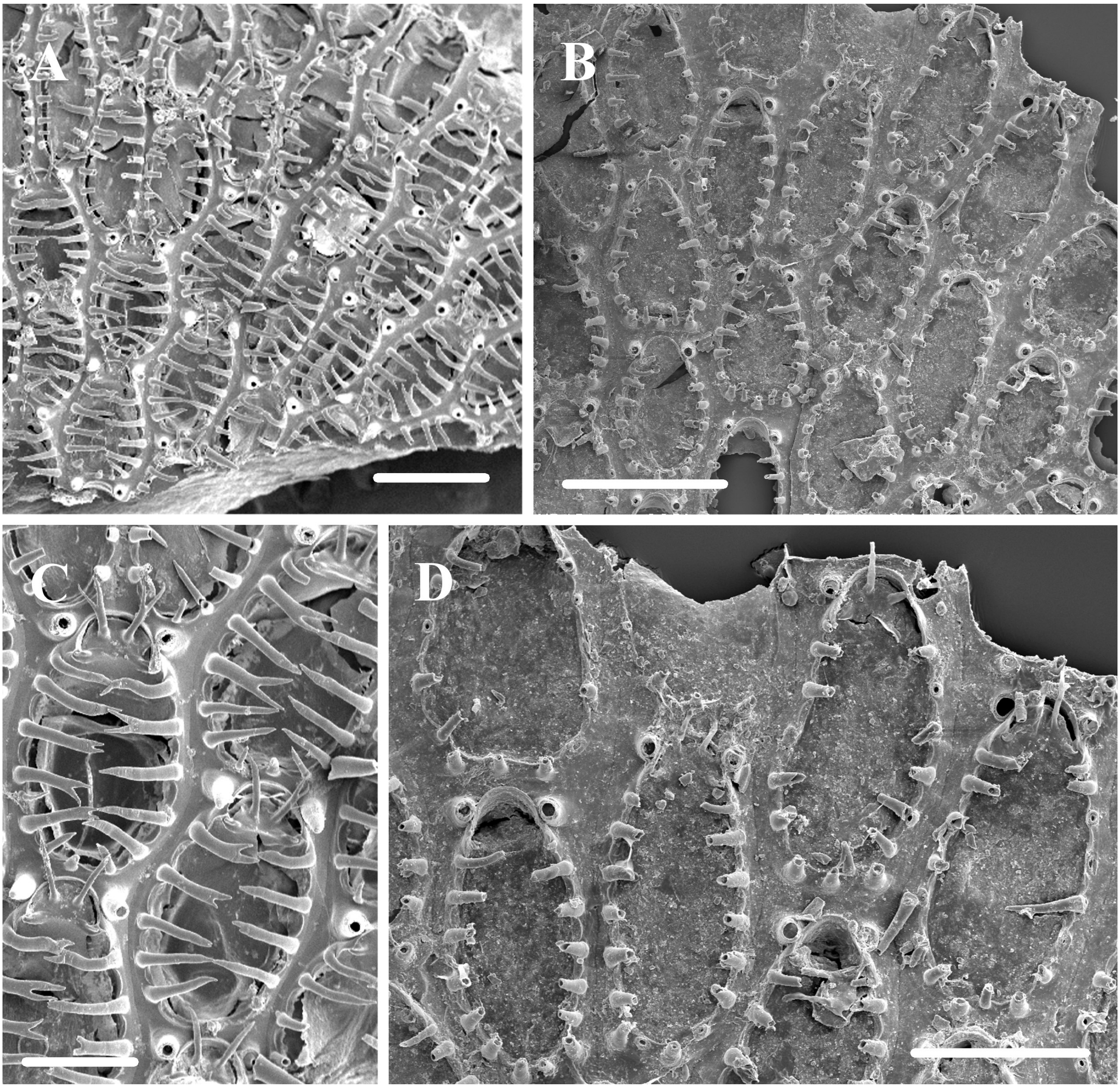

Fig. 2. *Arbopercula bengalensis* (Stoliczka, 1869). Comparison between mature zooids (A, C; ZRC.BRY.0454.) and neanic zooids (B, D; ZRC.BRY.0075.) as discussed in the text. Scale bars = 500 µm [A, B]; 250 µm [C, D].

to be described as different at each extreme of its known distribution. Osburn (1950) based his description on "eight colonies encrusting wood", which can be assumed as flotsam.

It should be noted that spination in *Arbopercula bengalensis* varies according to zooid age and possibly environmental conditions. Many zooids, generally neanic, may have fewer, shorter periopesial spines and short, inconspicuous spines on the operculum; these latter can easily be overlooked and, of course, opercula are lacking in dead colonies (as are the spines often). In this state, *A. bengalensis* resembles *Electra angulata* Levinsen, 1909, first described from Thailand and redescribed from the Sunda Archipelago (Harmer, 1926). Levinsen described *E. angulata* as having "on the margin 12 not very thick spines, which reach the middle of the area [opesia] or even surpass it", with many such spines often lacking. From his illustration (Levinsen 1909, pl. 22, fig. 4a), it would seem that he may have meant 12 spines along each margin, as one complete zooid is shown as having 18 spines and/or spine bases and the incomplete neighbouring zooids would have more. On the other hand, Harmer (1926) mentions only 6–8 pairs of marginal spines in *E. angulata* and he seems to have had the same species. Both authors showed a narrow granular cryptocyst in *E. angulata* that is more developed than in *A. bengalensis* and neither depict cuticular spines on the operculum. Silén (1941) found what appears to have been *E. angulata* in Japan [his figured zooid (Silén 1941, fig. 14) shows 11 marginal spines] but he synonymised it with *Membranipora tenella* Hincks, 1880 from Florida. Marcus (1937) kept the two species separate noting that zooids of *M. tenella* beyond the colony margin may have 6–8 such spines, although Hincks did not describe or illustrate periopesial spines. If Winston's (1982) illustration of *Electra tenella* [without marginal spines] is indeed Hincks's species (as appears likely), then the two species are separate. Notwithstanding, the similarity of neanic zooids of *A. bengalensis* to these species may give a clue as to the generic identity of both *E. tenella* and *E. angulata*. Studies by Nikulina (2007, 2010) and Nikulina & Schäfer (2008) distributed a number of species previously attributed *Electra* (Lamouroux, 1816) to new genera but these did not include *E. tenella* and *E. angulata*. The highly distinctive opercular spines in *A. bengalensis* are taken as characteristic of the genus but, given that they can be so small in neanic zooids, it is highly likely that there may be congeneric species in which they are lacking but otherwise resemble *A. bengalensis*. Such is the case with *E. tenella* and *E. angulata*. Accordingly, we respectively recognise these species as *Arbocuspis tenella* comb. nov. and *Arbocuspis angulata* comb. nov. Marcus (1938) and Mawatari (1953) respectively showed that the ancestrulae of these species derive from cyphonautes larvae. To this group we tentatively add *Membranipora devinensis* Robertson, 1921, as *Arbopercula devinensis* comb. nov., although she notes, but fails to illustrate, "Oecium small, projecting over the zoecium above, almost to its pores" (Robertson, 1921: 50, fig. 7).

CHECKLIST OF BRYOZOANS FROM STRAITS OF JOHOR

Class GYMNOLAEMATA
Order CTENOSTOMATA Busk, 1852
Superfamily Alcyonidioidea Johnston, 1838
Family Alcyonidiidae Johnston, 1838
***Alcyonidium jauhar* sp. nov.** – SW95.
Superfamily Victorelloidea Hincks, 1880
Family Sundanellidae Jebram, 1973
Sundanella sibogae (Harmer, 1915) – MF69
Superfamily Arachnidioidea Hincks, 1880
Family Nolellidae Harmer, 1915
Nolella cf. *gigantea* (Busk, 1856) – SW106, DW64.
Superfamily Vesicularioidea Johnston, 1847
Family Vesiculariidae Johnston, 1847
Amathia vermetiformis Harmer, 1926. – SW95, SW107, SW109.
Zoobotryon verticillatum (Della Chiaje, 1828) – SW47, SW93, SW95, SW107, SW114, SW123, DW18, DW61, DW64.
Order CHEILOSTOMATA
Suborder Inovicellina Jullien, 1888
Superfamily Aeteoidea Smitt, 1868
Family Aeteidae Smitt, 1868
Aetea ligulata Busk, 1852 – DW82.
Suborder Malacostegina Levinsen, 1902
Superfamily Membraniporoidea Busk, 1852
Family Electridae Stach, 1937
Arbopercula bengalensis (Stoliczka, 1869) – SW93, SW95, SW100, SW109, SW127, DW128, CFF#1, CFF#2.
Conopeum sp. – DW80.
Family Membraniporidae Busk, 1852
Biflustra perambulata Louis & Menon, 2009 – SW93, SW127, CFF#1, CFF#2.
Family Sinoflustridae Gordon, 2009
Sinoflustra amoyensis (Robertson, 1921) – DW128.
Sinoflustra annae (Osburn, 1953) – SW100, SW127, AB, CAAS2.
Suborder Thalamoporellina Ostrovsky, 2013
Superfamily Thalamoporelloidea Levinsen, 1902
Family Thalamoporellidae Levinsen, 1902
Thalamoporella labiata Levinsen, 1909 – AB.
Suborder Neocheilostomina d'Hondt, 1985
Superfamily Calloporoidea Norman, 1903
Family Quadricellariidae Gordon, 1984
Nellia tenella (Lamarck, 1816) – SW127.
Superfamily Buguloidea Gray, 1848
Family Beaniidae Canu & Bassler, 1927
Amphibiobeania epiphylla Metcalfe, Gordon & Hayward, 2007 – MF69.
Family Bugulidae Gray, 1848
Bugula neritina (Linnaeus, 1758) – SW93, SW107, SW109, SW127, CFF#1, CFF#2.
Bugula sp. – SW127
Family Candidae d'Orbigny, 1851
Licornia diadema (Busk, 1852) – SW127.
Paralicornia sinuosa (Canu & Bassler, 1927) – SW95, DR14.
Family Epistomiidae Gregory, 1893
Synnotum aegyptiacum (Audouin, 1826) – DW82.
Superfamily Microporoidea Gray, 1848
Family Calescharidae Cook & Bock, 2001
Caleschara minuta (Maplestone, 1909) – DW128.
Superfamily Lepralielloidea Vigneaux, 1949
Family Lepraliellidae Vigneaux, 1949
Celleporaria aperta (Hincks, 1882) – SW95, DW82.
Celleporaria cf. *tridenticulata* (Busk, 1881) – SW95, DW82.
Superfamily Smittinoidea Levinsen, 1909
Family Smittinidae Levinsen, 1909
Parasmittina galerita Ryland & Hayward, 1992 – DW80, DW82.
Parasmittina sp. 2 – DW82.
Family Bitectiporidae MacGillivray, 1895
Hippoporina indica Pillai, 1978 – SW93, SW95, CFF#1.
Family Lanceoporidae Harmer, 1957
Calyptotheca tenuata Harmer, 1957 – SW95.
Superfamily Schizoporelloidea Jullien, 1882
Family Hippopodinidae Levinsen, 1909
Hippopodina feegeensis (Busk, 1884) – SW10.
Hippopodina iririkiensis Tilbrook, 1999 – SW127.
Family Microporellidae Hincks, 1879
Microporella sp. – DW82.
Family Petraliellidae Levinsen, 1909
Petraliella dentilabris (Ortmann, 1892) – no loc.

Superfamily Celleporoidea Johnston, 1838
Family Colatooeciidae Winston, 2005
Cigclisula fruticosa Hayward & Ryland, 1995 – DW88, DW129.
Family Phidoloporidae Gabb & Horn, 1862
Iodictyum sanguineum (Ortmann, 1890) – DW80.
Triphyllozoon arcuatum (MacGillivray, 1889) sensu Hayward (1999) – DW39, DW40, DW57, DW79, DW 79, DW 80, DW 82, DW 88, DW 89, DW 119, DW 120, DW 128, DW 129

DISCUSSION

The checklist presented here contains 33 species that are present in the estuarine waters of the Straits of Johor. Many of these species are known to tolerate turbid estuarine conditions similar to those found within the straits and many are fouling species, noted for their tolerance of a variety of environmental conditions. That being said, this level of diversity is more than anticipated.

Gordon (1987) noted the proportions of various colony morphologies of some 837 species of Bryozoa from New Zealand's Exclusive Economic Zone (NZEEZ) — 58% encrusting two-dimensional, 26% erect-flexible, 12% erect-rigid, 3% rooted-conical, and 1% free-living. His more recent analyses for the South China Sea (SCS), noting some 515 bryozoan species (Gordon, in press), has similar proportions — 57% encrusting two-dimensional, 22% erect-flexible, 14% erect-rigid, 6% rooted-conical, and 1% free-living. When these proportions are adjusted to exclude the "rooted-conical" and "free-living" elements (as the fauna recorded herein lacks them), i.e., with just three colony morphologies considered, the proportions change to 60/62% encrusting two-dimensional, 27/23% erect-flexible, 13/15% erect-rigid for the NZEEZ and SCS respectively. These are remarkably similar to the proportions found in this fauna — 63% encrusting two-dimensional, 24% erect-flexible, 12% erect-rigid. In contrast, Goh's (2010) fouling bryozoan fauna (16 species) consists of 69% encrusting two-dimensional, 19% erect-flexible, 12% erect-rigid; obviously with fewer species, each has a disproportionately large effect on the ratios. Preliminary work on the entire bryozoan fauna of Singapore (Tilbrook & Gordon, unpubl. data; ca 120 species) is more similar to the local fouling fauna with proportions at 73% encrusting two-dimensional, 19% erect-flexible, and 8% erect-rigid.

As these preliminary comparisons suggest, the entire Singaporean bryozoan fauna (fouling, estuarine, reef, and intertidal faunas combined, some 120 species approximately) is remarkably different to that of the adjacent SCS (in total) although it contributes to its number. Whilst Gordon (in press) believes that some 900–1000 bryozoan species might result from a comprehensive investigation of the SCS, the bryozoan fauna from Singaporean waters will probably attain over 200 species, with more 'bryozoan-specific' sampling methods. It is worth noting that the investigations of the Bryozoa from little-explored Southwest Pacific areas (e.g., Vanuatu, Solomon Islands) have yielded between 22% and 40% of species as new (Tilbrook et al., 2001; Tilbrook 2006), but these are probably still conservative in actual number. Although this has not been found to be the case herein, most probably due to the tolerances required for the estuarine environment, the surrounding seas are comparatively unknown. Intensive sampling of the relatively little-studied Andaman and Java Seas, not to mention the Indian Ocean, would be required to adequately assess the faunal affinities of the Singapore fauna, in as much as Singapore itself sits at a gateway, or rather a crossroads, between them all. As such it is also the major shipping hub for the region and as a consequence the chances for introducing non-native species are extremely high. Therefore this, and the forth-coming paper inventorying the entire Singaporean bryozoan fauna, will act as a baseline against which future monitoring can be compared, but one should not think that this represents the original fauna of this island country.

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LITERATURE CITED

Audouin JV (1826) Explication sommaire des planches de Polypes de l'Égypte et de la Syrie, publiées par Jules-César Savigny [Planches 1–14 by J.-C. Savigny (1817)]. In: Description de l'Égypte, ou receuil des observations et des recherches qui ont été faites en Égypte pendant l'Expedition de l'Armée française, publié par les orders de sa majesté l'Empéreur Napoléon le Grand. Histoire naturelle, 1(4): 225–244.

Bock PE (2014) *Alcyonidium* Lamouroux, 1813. The Bryozoa Home Page. http://bryozoa.net/etenostomata/alcyonidiidae/alcyonidium.html (Accessed 31 July 2014).

Bock PE & Gordon DP (2013) Phylum Bryozoa Ehrenberg, 1831. Zootaxa, 3703(1): 67–74.

Busk G (1852) An account of the Polyzoa, and sertularian zoophytes, collected in the voyage of the Rattlesnake, on the coasts of Australia and the Louisiade Archipelago. In: MacGillivray J (ed.) Narrative of the Voyage of H.M.S. Rattlesnake, commanded by the late Captain Owen Stanley … 1846–1850; including discoveries and surveys in New Guinea, the Louisiade Archipelago, etc., to which is added the account of Mr E. B. Kennedy's expedition for the exploration of the Cape York Peninsula [including Mr W. Carron's narrative]. Volume 1. T. W. Boone, London. Pp. 343–402 and pl. 1.

Busk G (1856) Zoophytology. Quarterly Journal of Microscopical Science, 4: 93–96.

Busk G (1881) Descriptive catalogue of the species of *Cellepora* collected on the *Challenger* Expedition. Journal of the Linnean Society, Zoology, 15: 341–356.

Busk G (1884) Report on the Polyzoa collected by H.M.S. Challenger during the years 1873–76. Part 1. The Cheilostomata. Report on the Scientific Results of the Voyage of H.M.S. Challenger, Zoology, 10 (30): 1–216.

Canu F & Bassler RS (1927) Classification of the Cheilostomatous Bryozoa. Proceedings of the United States National Museum, 69(14): 1–42.

Cook PL & Bock PE (2001) Calescharidae, a new family for the Tertiary to Recent genera *Caleschara* MacGillivray and *Tretosina* Canu & Bassler (Bryozoa: Cheilostomata). Invertebrate Taxonomy, 15: 527–550.

Delle Chiaje S (1828) Memorie sulla storia e notomia degli animali senza vertebre del regno di Napoli Vol. 3. pp.1-xx+232. Società tipografica, Napoli.

Gabb WM & Horn GH (1862) The fossil Polyzoa of the Secondary and Tertiary Formations of North America. Journal of the Academy of Natural Sciences of Philadelphia, 5: 111–179

Goh K (2010) Fouling bryozoans from Singapore waters and seasonal settlement of *Bugula neritina*. Undergraduate Research Opportunities in Science Project Report, Department of Biological Sciences, The National University of Singapore. 54 + [4] p. [unpublished report]

Gordon DP (1984) The marine fauna of New Zealand: Bryozoa: Gymnolaemata from the Kermadec Ridge. New Zealand Oceanographic Institute Memoir, 91: 1–198.

Gordon DP (1986) The marine fauna of New Zealand: Bryozoa: Gymnolaemata (Ctenostomata and Cheilostomata Anasca) from the western South Island continental shelf and slope. New Zealand Oceanographic Institute Memoir, 95: 1–121.

Gordon DP (1987) The deep-sea Bryozoa of the New Zealand region. In: Ross JRP (ed.) Bryozoa: present and past: 97–104. Western Washington University, Bellingham.

Gordon DP (2009) *Baudina* gen. nov., constituting the first record of Pasytheidae from Australia, and Sinoflustridae fam. nov., with a checklist of Bryozoa and Pterobranchia from Beagle Gulf. The Beagle, Records of the Museums and Art Galleries of the Northern Territory, 25, 43–54.

Gordon DP (in press) Bryozoa of the South China Sea. Raffles Bulletin of Zoology, Supplement.

Gray JE (1848) Polyzoa In: Gray JE (ed.) List of the Specimens of British Animals in the Collections of the British Museum. Part 1. Centrionae or Radiated Animals Vol. Trustees of the British Museum, London. Pp. 91–151.

Gregory JW (1893) On the British Palaeogene Bryozoa. Transactions of the Xoological Society of London, 13: 219–279.

Harmer SF (1915) The Polyzoa of the Siboga Expedition Part I. Entoprocta, Ctenostomata and Cyclostomata. Siboga-Expeditie, 28a: 1–180, pls 1–12.

Harmer SF (1926) The Polyzoa of the Siboga Expedition Part II. Cheilostomata Anasca. Siboga-Expeditie, 28b: 181–501, pls 13–34.

Harmer SF (1934) The Polyzoa of the Siboga Expedition Part III. Cheilostomata Ascophora. I. Family Reteporidae. Siboga-Expeditie, 28c: 503–640, pls 35–41.

Harmer SF (1957) The Polyzoa of the Siboga Expedition. Part 4. Cheilostomata Ascophora II. Siboga Expeditie, 28D: 641–1147.

Hayward PJ (1999) Taxonomic studies on some Australian Phidoloporidae (Bryozoa: Cheilostomatida). Journal of Zoology, London, 249: 219–240.

Hayward PJ & Ryland JS (1995) Bryozoa from Heron Island, Great Barrier Reef. 2. Memoirs of the Queensland Museum, 38: 533–573.

Hincks T (1879) On the classification of the British Polyzoa. Annals and Magazine of Natural History, (5) 3: 153–164.

Hincks T (1880) Contributions towards a general history of the marine Polyzoa. II. Foreign Membraniporina (continued). Annals and Magazine of Natural History, ser. 5, 6: 376–384, pls 16, 17.

Hincks T (1882) Contributions towards a general history of the marine Polyzoa. X. Foreign Cheilostomata (miscellaneous). Annals and Magazine of Natural History, ser. 5, 10: 160–170, pls 7, 8.

Hondt J-L d' (1985) Contribution à la systématique des Bryozaires Eurystomes Apports récents et nouvelles propositions. Annales des Sciences Naturelles, Zoologie, Paris, 13 Série, 7: 1–12.

Hondt J-L d' & Mawatari SF (1986) Les *Alcyonidium* (Bryozoa, Ctenostomida) des côtes du Japon. Bulletin du Muséum National d'Histoire Naturelle, sér. 4, 8: 457–469.

Jebram D (1973) Stolonen-Entwicklung und Systematik bei den Bryozoa Ctenostomata. Zeitschrift für zoologische Systematik und Evolutionsforschung, 11: 1–48.

Johnston G (1838) A History of the British Zoophytes. W.H. Lizars, Edinburgh. xii + 341 pp., 44 pls.

Johnston G (1847) A History of the British Zoophytes. 2nd Edition. London: Van Voorst.

Jullien J (1882) Note sur une nouvelle division des Bryozoaires Cheilostomiens. Bulletin de la Société zoologique de France, 6: 271–285.

Jullien J (1888) Bryozoaires. Mission Scientifique du Cap Horn 1882–1883, 6(Zoologie 3): 1–92.

Lamarck JBPA. de M de (1816) Histoire naturelle des Animaux sans Vertèbres ... précédée d'une introduction offrant la détermination des caractéres essentiels de l'animal, sa distinction du végétal et des autres coorps naturels, enfin, exposition des principes fondamentaux de la zoologie. Vol.2. pp.1–568. Verdiére, Paris.

Lamouroux JVF (1813) Essai sur les genres de la famille des Thalassiophytes non articulées. Annales du Muséum Nationale d'Histoire Naturelle, 20: 267–293, pls 7–13.

Lamouroux JVF (1816) Histoire des Polypiers coralligènes flexibles, vulgairement nommés Zoophytes. F. Poisson, Caen, lxxxiv + 559 pp., 19 pls.

Levinsen GMR (1902) Studies on Bryozoa. Videnskabelige Meddelelser fra den Naturhistoriske Forening I Kjøbenhavn, 54: 1–31.

Levinsen GMR (1909) Morphological and Systematic Studies on the Cheilostomatous Bryozoa. Nationale Forfatteres Forlag, Copenhagen. vii + 431 pp., 24 pls.

Linnaeus C (1758) Systema Naturae per Regna Triae Naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. 10th edn. 1: 1–834. Holmiae: Laurentii Salvii.

Louis S & Menon NR (2009) *Biflustra perambulata* n. sp. (Cheilostomata: Bryozoa), a new alien species from Cochin Harbour, Kerala, India. Zootaxa, 2066, 59–68.

MacGillivray PH (1889). On some South Australian Polyzoa. Transactions of the Royal Society of South Australia, 12: 24–30.

MacGillivray PH (1895) A monograph of the Tertiary Polyzoa of Victoria. Transactions of the Royal Society of Victoria (n.s.), 4: 1–166.

Maplestone CM (1909) Polyzoa from the Gilbert Islands. Proceedings of the Royal Society of Victoria, 21: 410–419.

McCann LD, Hitchcock NG, Winston JE & Ruiz GM (2007) Non-native bryozoans in coastal embayments of the southern United States: new records for the Western Atlantic. Bulletin of Marine Science, 80(2): 319–342.

Marcus E (1937) Bryozoarios marinhos Brasileiros. I. Boletim da Faculdade de Filosofia, Ciencias e Letras, Universidade de São Paulo, Zoologia, 1: 3–224, pls 1–29.

Marcus E (1938) Bryozoarios marinhos Brasileiros. II. Boletim da Faculdade de Filosofia, Ciencias e Letras, Universidade de São Paulo, Zoologia, 2: 1–105, pls 1–29.

Mawatari S (1953) On *Electra angulata* Levinsen, one of the fouling bryozoans in Japan. Miscellaneous Reports Research Institute for Natural Resources, Tokyo, 12: 5–10, pl. 1.

Metcalfe K, Gordon DP & Hayward E (2007) An amphibious bryozoan from living mangrove leaves—*Amphibiobeania* new genus (Beaniidae). Zoological Science, 24: 563–570.

Nikulina EA (2007) *Einhornia*, a new genus for electrids formerly classified as the *Electra crustulenta* group (Bryozoa, Cheilostomata). Schriften des Naturwissenschaftlichen Vereins für Schleswig-Holstein, 69: 29–40.

Nikulina EA (2010) Three new genera of Electridae (Bryozoa): *Arbopercula*, *Osburnea*, and *Arbocuspis*. Schriften des Naturwissenschaftlichen Vereins für Schleswig-Holstein, 72: 25–28.

Nikulina EA & Schäfer P (2008) An evaluation of the monophyly of the genus *Electra* Lamouroux, 1816 (Bryozoa, Cheilostomata) with phylogenetic analyses of ribosomal genes. In: Hageman SJ, Key MM Jr & Winston JE (eds.), Bryozoan Studies 2007. Virginia Museum of Natural History Special Publication, 15: 177–185.

Norman AM (1903) Notes on the natural history of East Finmark. Polyzoa. Annals and Magazine of Natural History, (7) 11: 567–598.

Orbigny A. d' (1851) Paléontologie française, Terrains Crétacés, V, Bryozoaires [1], pp.1–188. Victor Masson, Paris.

Ortmann A (1890) Die Japanische Bryozoenfauna. Bericht über die von Herrn Dr. L. Döderlein in Jahre 1880–81, gemachten Sammlungen. Archiv für Naturgeschichte, 56: 1–74.

Ortmann A (1892) Die Koralriffe van Dar-es-Salaam und umgegend Zoologische Jahrbücher (Syst), 6: 631–670.

Osburn RC (1950) Bryozoa of the Pacific coast of America. Part 1, Cheilostomata-Anasca. Allan Hancock Pacific Expeditions, 14: 1–269.

Ostrovsky AN (2013) From incipient to substantial: evolution of placentotrophy in a phylum of aquatic colonial invertebrates. Evolution, 67(5):1368–82.

Pillai SRM (1978) A new species of *Hippoporina* (Ectoprocta, Ascophora) from Bombay coast. Current Science (Bangalore), 47: 61–63.

Robertson A (1921) Report of Bryozoa from the Bay of Bengal and other eastern seas. Records of the Indian Museum, 12: 33–65.

Ryland JS & Hayward PJ (1992) Bryozoa from Heron Island, Great Barrier Reef. Memoirs of the Queensland Museum, 32: 223–301.

Silén L (1941) Cheilostomata Anasca (Bryozoa) collected by Prof. Dr. Sixten Bock's expedition to Japan and the Bonin Islands 1914. Arkiv für Zoologi, 33A(12): 1–130, pls 1–9.

Silén L (1942) Carnosa and Stolonifera (Bryozoa) collected by Prof. Dr. Sixten Bock's expedition to Japan and the Bonin Islands 1914. Arkiv für Zoologi, 34A(8): 1–33.

Smitt FA (1868) Kritisk förteckning öfver Skandinaviens Hafs-Bryozoer, IV. Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar, 25: 3–320.

Stach L (1937) Reports of the McCoy Society for Field Investigation and Research. Lady Julia Percy Island. 13. Bryozoa. Proceedings of the Royal Society of Victoria, n.s., 49: 373–384, pl. 22.

Stoliczka F (1869) On the anatomy of *Sagartia schilleriana* and *Membranipora bengalensis*, a new coral and a bryozoan living in brackish water at Port Canning. Journal of the Asiatic Society of Bengal, 38: 28–63, pls. 11, 12.

Tilbrook KJ (1999) Description of *Hippopodina feegeensis* and three other species of *Hippopodina* Levinsen, 1909 (Bryozoa: Cheilostomatida). Journal of Zoology, London, 247: 449–456.

Tilbrook KJ (2006) Cheilostomatous Bryozoa from the Solomon Islands. Santa Barbara Museum of Natural History Monographs Number 4, Studies in Biodiversity Number 3, 386 pp.

Tilbrook KJ, Hayward PJ & Gordon DP (2001) Cheilostomatous Bryozoa from Vanuatu. Zoological Journal of the Linnean Society, London, 131(1): 35–108.

Vigneaux M (1949) Révision des Bryozoaires néogènes du Bassin d'Aquitaine et essai de classification. Mémoires de la Société géologique de France, 28: 1–153.

Winston JE (1982) Marine bryozoans (Ectoprocta) of the Indian River area (Florida). Bulletin of the American Museum of Natural History, 173: 99–176.

Winston JE (2005) Redescription and revision of Smitt's "Floridan Bryozoa" in the Collection of the Museum of Comparative Zoology, Harvard University. Virginia Museum of Natural History Memoir, 7: 1–150.