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ON SOME OCTOCORALLIA (CNIDARIA: ANTHOZOA: ALCYONACEA) FROM SINGAPORE, WITH A DESCRIPTION OF A NEW *CLADIELLA* SPECIES

Y. Benayahu
Department of Zoology, George S. Wise Faculty of Life Sciences, Tel Aviv University, Ramat Aviv, Tel Aviv 69978, Israel
Email: Yehudab@tauex.tau.ac.il (Corresponding author)

L. M. Chou
Department of Biological Sciences, Faculty of Science, National University of Singapore, 14 Science Drive 4, Singapore 117543
Email: dbsclm@nus.edu.sg

ABSTRACT. **–** Octocorallia (Cnidaria: Anthozoa) from Singapore were collected and identified in a survey conducted in 1999. Colonies collected previously, between 1993 and 1997, were also studied. The entire collection of ~170 specimens yielded 25 species of the families Helioporidae, Alcyoniidae, Paraclcyoniidae, Xeniidae and Briareidae. Their distribution is limited to six m depth, due to high sediment levels and limited light penetration. The collection also yielded *Cladiella hartogi*, a new species (family Alcyonacea), which is described. All the other species are new zoogeographical records for Singapore. A comparison of species composition of octocorals collected in Singapore between 1993 and 1977 and those collected in 1999 revealed that out of the total number of species, 12 were found in both periods, whereas seven species, which had been collected during the earlier years, were no longer recorded in 1999. Notably, however, six species that are rare on Singapore reefs were recorded only in the 1999 survey and not in the earlier ones. It is not yet clear whether these differences in species composition indeed imply changes over time in the octocoral fauna, or may reflect a sampling bias. The inclusion of octocorals in Singapore reef-monitoring programs will undoubtedly shed light on possible temporal changes in their species composition. The findings do indicate, however, that the fleshy octocoral fauna of Singapore is rather impoverished compared to other reefs in the region.

KEY WORDS. **–** Cnidaria, Octocorallia, Alcyonacea, new species, *Cladiella*, new records, coral reefs, Singapore.

INTRODUCTION

Singapore consists of a main island and over 60 small offshore islands with fringing and patch-reefs. The marine environment is an important resource that supports one of the world's busiest ports and one of the largest oil refineries (Chou, 2006). Close to 60% of the total coral reef areas of Singapore has been lost through foreshore land reclamation, while the remaining reefs are exposed to stress from the high sediment load (Chou, 1996; Dikou & van Woesik, 2006) and concerns have been raised regarding the conservation of these reefs (Todd & Chou, 2005; Chou & Tun, 2007). A mass bleaching event occurred in 1998 on a scale previously unknown (http://coralreef.nus.edu.sg/; Tun et al., 2004) affecting 50% to 90% of reef organisms, including *Sinularia* octocorals (family Alcyoniidae), which suffered particularly high mortality rates.

Taxonomic studies of the Singapore Octocorallia are relatively limited in number and deal mainly with gorgonians (sea fans and sea whips: see Fabricius & Alderslade, 2001). These studies were initiated by Verrill (1864) and Studer (1880), who recorded *Mopsella elongata* and *Juncella gemmacea*, respectively. Shann (1912) listed for Singapore 11 species, among which four were new ones, of the following families: Alcyoniidae (one species), Telestidae (one species), Nephthyidae (four species), Siphonogorgiidae (one species), Sclerogorgiidae (one species) and Melitodidae (three species). To date, Shann's study is the only taxonomic account to have dealt with the fleshy octocorals (families Alcyoniidae and Nephtheidae) from Singapore. Following a gap of 82 years, a preliminary survey of the gorgonian octocoral fauna of Singapore was published by Goh & Chou (1994), which revealed six families, comprising at least 11 genera and 21 species. That study concluded that the gorgonian taxonomy for the region is in a poor state and therefore species identification is uncertain. Based on these findings and also combined with

newly collected material, Goh & Chou (1996) published an annotated checklist of the gorgonians of Singapore, totaling 31 species of 12 genera and six families (Anthothelidae: *Solenocaulon*; Subergorgiidae: *Subergorgia*; Melithaeidae: *Melithaea, Mopsella* and *Acabaria*; Acanthogorgiidae: *Acanthogorgia*; Plexauridae: *Echinomuricea, Astrogorgia, Echinogorgia* and *Euplexaura*; and Ellisellidae: *Junceella* and *Ctenocella*. Notably, that study identified to species level only part of the specimens. Later, Ofwegen et al., (2000) dealt with species of the family Melithaeidae in Singapore and identified four species of the genera *Melithaea, Mopsella* and *Acabaria*, also with reference to Shann (1912). Several studies have dealt with other aspects of Singapore gorgonians other than their taxonomy, such as distribution (Goh & Chou, 1994), annual growth rate (Goh & Chou, 1995), zonation (Goh et al., 1997), associated fauna (e.g., Goh et al., 1999) and bioactivity (e.g., Koh et al., 2000, 2002). Recently, Goh et al. (2009) identified the following octocoral genera from Singapore: *Carijoa, Cladiella, Sinularia, Lobophytum, Sarcophyton, Stereonephthya* and *Nephthea*, and indicated the high abundance of the family Alcyoniidae and the lack of knowledge on the species diversity of the fleshy octocorals. Furthermore, that study demonstrated high levels of toxicity in extracts of *Sarcophyton* spp. and *Cladiella* spp. collected in Singapore reefs.

The present study deals with octocorals from Singapore of the families Helioporidae, Alyconiidae, Paralcyoniidae, Xeniidae and Briareidae. It provides for the first time a systematic list of octocorals of these families for the area and describes *Cladiella hartogi*, new species. It also compares the fleshy octocoral fauna recorded in the current survey (1999) to the previous ones (1993–1997).

MATERIALS AND METHODS

During Jul.1999 collections were conducted by us from the following sites: Pulau [=Island] Hantu; Pulau Satumu, Raffles Lighthouse; Terumbu Pempang Laut; Raffles Marina; Terumbu Pempang Tengah (artificial reef site); and The Sisters (Fig. 1). These sites were reached by boat. An examination of a variety of niches was carried out by scuba diving, and samples were obtained at a maximal depth of 4–6 m. At the artificial reef site at Terumbu Pempang Tengah, the survey included concrete modules and tyre structures and samples were obtained down to its maximal depth of 14 m. During the nine day-long survey, 14 dives were conducted, each lasted 60–80 minutes and approximately 90 samples were collected of the octocoral taxa found at the various sites. Prior to collection some of the colonies were

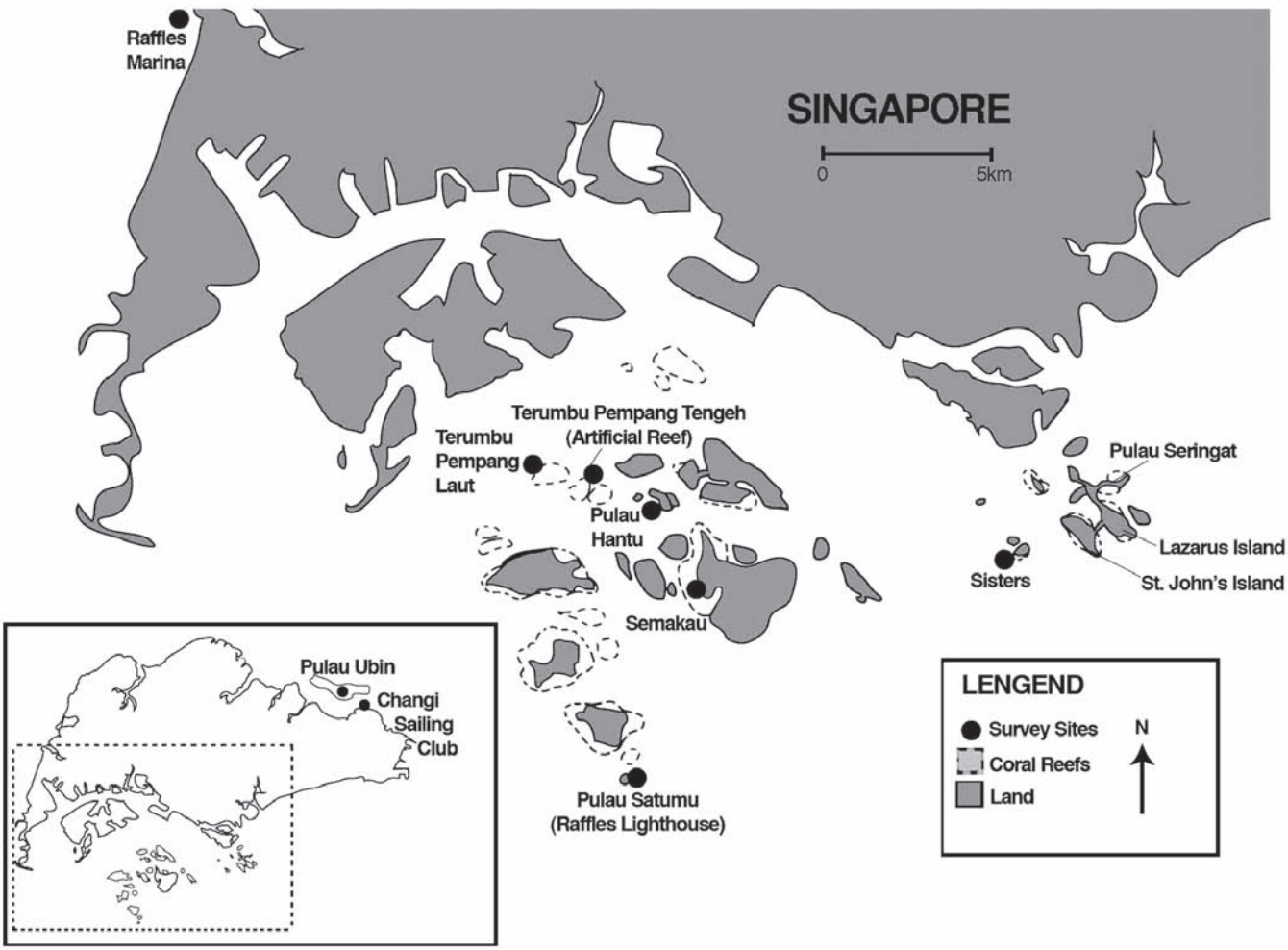

Fig. 1. Map of Singapore showing location of the study sites.

Table 1. List of species of Octocorallia of the orders Helioporacea Bock, 1938, and Alcyonacea (Lamouroux, 1816) from Singapore with indication of inventory numbers of Raffles Museum of Biodiversity Research (ZRC) and of Zoological Museum Tel Aviv University (ZMTAU Co), collection sites and date of collection. Previous ZRC numbers of material deposited at Tel Aviv University are given in square brackets.

Classification

Helioporidae Blainville, 1830

Genus *Heliopora* Moseley, 1786

Heliopora coerulea (Pallas, 1766)

6 colonies (ZRC 1999.2280), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 1 colony (ZMTAU Co 34544) [ZRC 1999.2282], Sisters, coll. Y. Benayahu, 19 Jul. 1999; 3 colonies (ZRC 1999.2282), Sisters, coll. Y. Benayahu, 19 Jul. 1999.

Alcyoniidae Lamouroux, 1912

Genus *Cladiella* Gray, 1869

Cladiella hartogi, new species

Holotype (ZRC 1999.2256), Terumbu Pempang Tengah, 2–4 m, coll. Y. Benayahu, 14 Jul.1999. Paratypes: 1 colony (ZRC 1999.1065), Pulau Hantu (north side of island), reef flat, coll. S. L. M. Teo & C. S. C. Lee, 30 May 1994; 1 colony (ZMTAU Co 34539) [ZRC 1999.2207], Pulau Hantu, 1 m, coll.Y. Benayahu, 6 Jul. 1999;1 colony and 2 fragments (ZRC1999.2207), Pulau Hantu, 1 m, coll. Y. Benayahu, 6 Jul.1999; 1 colony (ZMTAU Co 34540) [ZRC 1999.2221], Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul.1999; 1 colony (ZRC 1999.2221), Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul.1999; 1 colony (ZMTAU Co 34537) [ZRC 1999.2223], Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul.1999; 2 colonies (ZRC 1999.2223), Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul.1999; 1 colony (ZMTAU Co 34541) [ZRC 1999.2231], Pulau Hantu, 1–2 m, coll. Y. Benayahu, 9 Jul.1999; 2 colonies (ZRC1999.2231), Pulau Hantu, 1–2 m, coll. Y. Benayahu, 9 Jul.1999; 1 colony (ZMTAU Co 34536) [ZRC 1999.2232], Terumbu Pempang Laut, (patch reef), 2–6 m, coll. Y. Benayahu, 12 Jul.1999; 2 colonies (ZRC 1999.2232), Terumbu Pempang Laut, (patch reef), 2–6 m, coll. Y. Benayahu, 12 Jul.1999; 1 colony (ZRC 1999.2255), Terumbu Pempang Tengah, 2–6 m, coll. Y. Benayahu, 14 Jul.1999; 1 colony (ZMTAU Co 34535) [ZRC 1999.2262], Pulau Satumu (Raffles Lighthouse), 3-6 m, coll. Y. Benayahu, 15 Jul.1999; 1 colony (ZRC 1999.2262), Pulau Satumu (Raffles Lighthouse), 3-6 m, coll. Y. Benayahu, 15 Jul.1999; 1 colony (ZRC 1999.2266), Pulau Satumu (Raffles Lighthouse), 3-6 m, coll. Y. Benayahu, 15 Jul.1999; 1 colony (ZMTAU Co 34538) [ZRC 1999.2281], Sisters Reef, 2-3 m, coll. Y. Benayahu, 19 Jul., 1999; 2 colonies (ZRC 1999.2281), Sisters Reef, 2-3 m, coll. Y. Benayahu, 19 Jul., 1999.

Cladiella pachyclados (Klunzinger, 1887)

1 colony (ZRC 1999.1042), Pulau Semakau, coll. S.L.M. Teo & H. C. Tay, 7 Jun. 1995; 1 colony (ZRC 1999.1090), Pulau Semakau, west side of Is., coll. S.L.M. Teo, 20 Apr. 1995; 3 colonies (ZRC 1999.2259), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 1 colony (ZRC 1999.2267), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 3 colonies (ZRC 1999.2271), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 1 colony (ZRC 1999.2278), Pulau Satumu (Raffles Lighthouse), 15 Jul. 1999; 1 colony (ZMTAU Co 34542) [ZRC 1999.2279], Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999.

Genus *Lobophytum* von Marenzeller, 1886

Lobophytum crassum von Marenzeller, 1886

1 colony (ZRC 1996.480), Pulau Semakau, coll H. C. Tay & S.L.M. Teo, 19 Jun. 1995; 1 colony (ZRC 1996.481), Pulau Semakau, coll. 19 Jun. 1995; 1 colony (ZRC 1996.482), Pulau Semakau, coll. H. C. Tay & S.L.M. Teo, 19 Jun. 1995; 1 colony (ZRC 1999.1044(, Pulau Semakau, coll. S.L.M. Teo & H. C. Tay, 13 Jun. 1995; 1 colony (ZRC 1999.1062), Pulau Hantu, north-west side of Is., coll. S.L.M. Teo & C.S.C. Lee, 23 Jun. 1993; 1 colony (ZRC 1999.1067), Pulau Hantu, north side of Is., coll. S.L.M. Teo & C.S.C. Lee, 30 May 1994; 1 colony (ZRC 1999.1076), Pulau Hantu, north side of Is., coll. S.L.M. Teo & C.S.C. Lee, 6 Oct. 1994; 2 colonies (ZRC 1999.1077), Pulau Hantu, south east side of Is., coll. S.L.M. Teo, 5 Nov.1994; 3 colonies (ZRC 1999.1086), Pulau Semakau, west side of Is., coll. S.L.M. Teo & C.S.C. Lee, 8 Feb. 1993; 2 colonies (ZRC 1999.2233), Terumbu Pempang Laut, coll. Y. Benayahu, 12 Jul. 1999; 1 colony (ZRC 1999.2244), Terumbu Pempang Tengah, coll. S.L.M. Teo & H. C. Tay, 14 Jul. 1999; 2 colonies (ZRC 1999.2245), Terumbu Pempang Tengah, coll. Y. Benayahu, 14 July 1999; 2 colonies (ZMTAU Co 34545) [ZRC 1999.2246], Terumbu Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999.

Lobophytum pauciflorum (Ehrenberg, 1834)

1 colony (ZRC 1996.484), Pulau Hantu, coll. Juliana Chee. & S. K. Goh, 26 Sep. 1995; 1 colony (ZRC 1999.1053), Pulau Hantu, north west side of Is. coll. S.L.M. Teo & C.S.C. Lee, 9 Jan. 1993; 1 colony (ZRC 1999.1057), Pulau Hantu, south east side of Is., coll. S.L.M. Teo & C.S.C. Lee, 9 Jun. 1993; 2 colonies (ZMTA Co 34546) [ZRC 1999.1079], Pulau Hantu, south east side of Is., coll. S.L.M. Teo,16 Feb. 1995; 5 colonies (ZRC 1999.1079), Pulau Hantu, south east side of Is., coll. S.L.M. Teo,16 Feb. 1995; 1 colony (ZRC 1999.1091), Pulau Satumu (Raffles Lighthouse), coll. S.L.M. Teo, 18 May 1995; 3 colonies (ZRC 1999.1092), Pulau Satumu (Raffles Lighthouse), coll. S.L.M. Teo, 18 May 1995; 1 colony (ZRC 1999.1103), St. John's Is., south east side of Is., coll. C.S.C. Lee, 7 Oct. 1994; 2 colonies (ZRC 1999.2222), Pulau Hantu, coll. Y. Benayahu, 9 Jul. 1999; 3 colonies (ZRC 1999.2238), Terumbu Pempang Laut, coll. Y. Benayahu, 12 Jul. 1999; 1 colony (ZRC 1999.2263), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 1 colony (ZRC 1999.2269), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul.1999.

Table 1. Cont'd.

Classification
Lobophytum sarcophytoides Moser, 1919
2 colonies (ZRC 1999.1069), Pulau Hantu, north side of Is., coll. S.L.M. Teo & C.S.C. Lee, 30 May 1994; 4 colonies (ZRC 1999.1096), St.John's Is., north side of Is., S.L.M. Teo, 13 Jun. 1994; 1 colony (ZRC 1999.1097), St. John's Is., north side of Is., S.L.M. Teo, 13 Jun. 1994; 1 colony (ZMTAU Co 34547) [ZRC1999.2243], Terumbu, Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999.
Genus *Sarcophyton* Lesson, 1834
Sarcophyton crassocaule Moser, 1919
1 colony (ZRC 1996.496), Pulau Hantu, coll. Juliana Chee. & S. K. Goh, 22 Oct. 1995; 2 colonies (ZRC 1999.1075), Pulau Hantu, north side of Is., coll. S.L.M. Teo & C.S.C. Lee, 6 Oct. 1994; 3 colonies (ZRC 1999.1098), St. John's Is. north side of Is., coll. S.L.M. Teo, 13 Jun. 1994; 1 colony (ZRC 1999.2219), Pulau Hantu, coll. Y. Benayahu, 9 Jul. 1999; 1 colony, (ZRC 1999.2220), Pulau Hantu, coll. Y. Benayahu, 9 Jul., 1999; 1 colony (ZRC 1999.2234), Terumbu Pempang Laut, coll. Y. Benayahu, 12 Jul. 1999; 1 colony ZMTAU Co 34549 [ZRC 1999.2272], Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999.
Sarcophyton ehrenbergi von Marenzeller, 1886
1 colony (ZRC 1999.1061), Pulau Hantu, north west side of Is., coll. S.L.M. Teo & C.S.C. Lee, 23 Jun. 1993; 1 colony (ZRC 1999.1064), Pulau Hantu, north side of Is., coll. S.L.M. Teo, & C.S.C. Lee, 30 May 1994; 4 colonies (ZRC 1999.1094), St. John's Is., south east side of Is., coll. S.L.M. Teo, 23 Jun. 1993; 2 colonies (ZMTAU Co 34550) [ZRC 1999.2205], Pulau Hantu, coll. Y. Benayahu, 6 Jul.1999; 3 colonies (ZRC 1999.2218), Pulau Hantu, coll. Y. Benayahu, 9 Jul. 1999; 2 colonies (ZRC 1999.2239), Terumbu Pempang Laut, coll. Y. Benayahu, 12 Jul. 1999; 2 colonies (ZRC 1999.2253), Terumbu Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999; 3 colonies (ZRC 1999.2260), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 1 colony (ZRC 1999.2261), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 3 colonies (ZRC 1999.2275), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul.1999; 2 colonies (ZRC 1999.2277), Pulau Satumu (Raffles Lighthouse), 15 Jul. 1999.
Sarcophyton glaucum (Quoy & Gaimard, 1833)
1 colony (ZMTAU Co 34551) [ZRC 1999.1102], St. John's Is., south east side of Is., Coll. C.S.C. Lee, 7 Oct. 1994; 1 colony (ZRC 1999.1102), St. John's Is., south east side of Is., Coll. C.S.C. Lee, 7 Oct. 1994; 2 colonies (ZRC 1999.2270), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999.
Sarcophyton tenuispiculatum Thomson & Dean, 1931
1 colony (ZRC 1996.490) Pulau Hantu, coll. S.L.M. Teo, 26 Oct. 1995; 1 colony (ZMTAU Co 34553) [ZRC 1999.1078], Pulau Hantu, south east side of Is. coll. S.L.M. Teo, 5 Nov. 1994.
Sarcophyton trocheliophorum von Marenzeller, 1886
1 colony (ZRC 1999.1056), Pulau Hantu, south east side of Is., coll. S.L.M. Teo & C.S.C. Lee, 8 Mar.1993; 1 colony (ZRC 1999.2260), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu,15 Jul. 1999; 4 colonies (ZRC 1999.2227), Pulau Hantu, coll. Y. Benayahu, 9 Jul. 1999; 1 colony (ZRC 1999.2228), Pulau Hantu, coll. Y. Benayahu, 9 Jul. 1999; 1 colony (ZRC 1999.2235), Terumbu Pempang Laut, coll. Y. Benayahu, 12 Jul. 1999; 1 colony (ZMTAU Co 34552) [ZRC 1999.2283], Sisters, coll. Y. Benayahu, 19 July 1999; 1 colony (ZRC 1999.22830, Sisters, coll. Y. Benayahu, 19 July 1999.
Genus *Sinularia* May, 1898
Sinularia abrupta Tixier Durivault, 1970
1 colony (ZMTAU Co 34554) [ZRC 1999.2274], Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 1 colony (ZRC 1999.2274), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999.
Sinularia brassica May, 1898
1 colony, (ZRC 1996.478), Pulau Semakau, coll. H. C. Tay & S.L.M. Teo, 13 Jun. 1995; 2 colonies (ZRC 1999.1095), St. John's Is., south east side of Is., coll. L.J. Harrison, 23 Jul. 1993; 1 colony (1999.1099), St. John's Is., north side of Is., coll. S.L.M. Teo, 13 Jun. 1994; 1 colony (ZMTAU Co 34555) [ZRC 1999.2240], Terumbu Penpang Laut, coll. Y. Benayahu, 12 Jul. 1999; 2 colonies (ZRC 1999.2240), Terumbu Penpang Laut, coll. Y. Benayahu, 12 Jul. 1999.
Sinularia capillosa Tixier Durivault, 1970
1 colony (ZMTAU Co 34556) [ZRC 1996.483], Pulau Semakau, coll. H. C. Tay & S.L.M. Teo, 19 Jun. 1995; 1 colony (ZRC 1996.495), St. John's Is., coll. H. C. Tay & S.L.M. Teo, 28 Sept. 1995; 1 colony (ZRC 1999.1060), Pulau Hantu, south east side of Is., coll. S.L.M. Teo & C.S.C. Lee, 9 June 1993; 3 colonies (ZRC 1999.1068), Pulau Hantu, north side of Is., coll. S.L.M. Teo & C.S.C. Lee, 30 May 1994; 1 colony (ZRC 1999.1074), Pulau Hantu, north side of Is., coll. S.L.M. Teo & C.S.C. Lee, 6 Oct. 1994; 1 colony (ZRC 1999.1081), Pulau Hantu, south east side of Is., coll. S.L.M. Teo, 16 Feb. 1995; 1 colony (ZRC 1999.1089), Pulau Semakau, west side of Is., coll. S.L.M. Teo, 14 Jun. 1994; 1 colony (ZRC 1999.1100), St. John's Is., south east side of Is., coll. C.S.C. Lee, 7 Oct. 1994.
Sinularia compressa Tixier Durivault, 1945
1 colony (ZMTAU Co 34557) [ZRC 1999.2248], Terumbu Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999; 1 colony (ZRC 1999.2248), Terumbu Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999.
Sinularia depressa Tixier Durivault, 1970
1 colony (ZRC 1999.1071), Pulau Hantu, north side of Is., coll. S.L.M. Teo & C.S.C. Lee, 6 Oct. 1994; 1 colony (ZRC 1999.1073), Pulau Hantu, north side of Is., coll. S.L.M. Teo & C.S.C. Lee, 6 Oct. 1994; 1 colony (ZMTAU Co 34558) [ZRC 1999.1082], Pulau Hantu, south east side of Is., 16 Feb. 1995.

Table 1. Cont'd.

Classification

Sinularia erecta Tixier Durivault, 1945

1 colony (ZMTAU Co 34559) [ZRC 1999.2257], Terumbu Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999; 1 colony (ZRC 1999.2257), Terumbu Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999.

Sinularia exilis Tixier Durivault, 1970

1 colony, ZMTAU Co 34560 [ZRC 1999.2276], Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 1 colony (ZRC 1999.2276), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999.

Sinularia gibberosa Tixier Durivault, 1970

1 colony (ZRC 1999.1047), Pulau Hantu, north west end of Is., coll. S.L.M. Teo, K. Low, H. C. Tay, 12 Nov. 1996; 2 colonies (ZRC 1999.1059), Pulau Hantu, south east side of Is., coll. S.L.M. Teo & C.S.C. Lee, 9 Jun. 1993; 1 colony (ZRC 1999.1072), Pulau Hantu, north side of Is., coll. S.L.M. Teo & C.S.C. Lee, 6 Oct. 1994; 1 colony, (ZMTAU Co 34561) [ZRC 1999.1083], Pulau Hantu, south east side of Is., coll. S.L.M. Teo, 16 Feb. 1995; 1 colony (ZRC 1999.1083), Pulau Hantu, south east side of Is., coll. S.L.M. Teo, 16 Feb. 1995; 2 colonies (ZRC 1999.1084), Pulau Hantu, south east side of Is., coll. S.L.M. Teo, 16 Feb., 1995; 1 colony (ZRC 1999.1101), St. John's Is., south east side of Is. , coll. C.S.C. Lee, 7 Oct. 1994.

Sinularia hirta (Pratt, 1903)

1 colony (ZMTAU Co 34562) [ZRC 1999.1087], Pulau Semakau, west side of Is., coll. S.L.M. Teo & C.S.C. Lee, 10 Apr. 1993; 1 colony (ZRC 1999.1087), Pulau Semakau, west side of Is., coll. S.L.M. Teo & C.S.C. Lee, 10 Apr. 1993; 1 colony (ZRC 1999.2225), Pulau Hantu, coll. Y. Benayahu, 9 Jul. 1999.

Sinularia lochmodes Kolonko, 1926

1 colony (ZRC 1999.1058), Pulau Hantu, south east side of Is., coll. S.L.M. Teo & C.S.C. Lee, 9 May 1993; 3 colonies (ZRC 1999.1085), Pulau Semakau, west side of Is., coll. S.L.M. Teo & C.S.C. Lee, 8 Feb. 1993; 1 colony (ZRC 1999.2202), Raffles Marina, coll. Y. Benayahu, 6 Jun. 1999; 1 colony (ZMTAU Co 34563) [ZRC 1999.2206], Pulau Hantu, coll. Y. Benayahu, 6 Jul. 1999; 4 colony, (ZRC 1999.2242), Terumbu Pempang Laut, coll. Y. Benayahu, 12 Jul. 1999; 2 colonies (ZRC 1999.2250), Terumbu Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999; 1 colony (ZRC 1999.2251), Terumbu Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999; 1 colony (ZRC 1999.2254), Terumbu Pempang Tengah, coll. Y. Benayahu, 14 Jul. 1999; 2 colony (ZRC 1999.2265), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 3 colonies (ZRC 1999.2273), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999.

Sinularia microclavata Tixier Durivault, 1970

1 colony (ZMTAU Co 34564) [ZRC 1999.1088], Pulau Semakau, west side of Is., coll. Y. Benayahu, 14 Jun. 1994; 1 colony (ZRC 1999.1088), Pulau Semakau, west side of Is., coll. Y. Benayahu, 14 Jun. 1994.

Sinularia triangula Tixier Durivault, 1970

1 colony (ZMTAU Co 34565) [ZRC 1999.2237], Terumbu Pempang Laut, coll. Y. Benayahu, 12 Jul. 1999; 1 colony (ZRC 1999.2237), Terumbu Pempang Laut, coll. Y. Benayahu, 12 Jul. 1999.

Paralcyoniidae Gray, 1869

Genus *Studeriotes* Thomson & Simpson, 1909

Studeriotes spinosa Thomson & Dean, 1931

1 colony (ZMTAU Co 34566) [ZRC 1999.1048], Terumbu Pempang Tengah, coll. S.L.M. Teo & H.C. Tay, 17 Jun. 1996; 1 colony (ZRC 1999.1048), Terumbu Pempang Tengah, coll. S.L.H. Teo & H. C. Tay, 17 Jun. 1996.

Xeniidae Ehrenberg, 1828

Genus *Sansibia* Alderslade, 2000

Sansibia flava (May, 1898)

2 colonies (ZRC 1999.1050), Lazarus Is., coll. S.L.M. Teo, Juliana Chee. & S. K. Goh,5 Jul. 1996; 1 colony (ZRC 1999.1051), Pulau Seringat Kechil, coll. S.L.M. Teo, 25 May 1997; 1 colony (ZMTAU Co 34548) [ZRC 1999.1052], Pulau Seringat Kechil, coll. S.L.M. Teo, 23 Jul. 1997; 1 colony (ZRC 1999.1052), Pulau Seringat Kechil, coll. S.L.M. Teo, 23 Jul. 1997.

Briareidae Blainville, 1830

Genus *Briareum* Blainville, 1830

Briareum excavatum (Natting, 1911)

3 colonies (ZRC 1999.1045), St. John's Is., coll. S.L.M. Teo & H. C. Tay, 7 Feb. 1996; 1 colony (ZMTAU Co 34532) [ZRC 1999.2258], Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999; 2 colonies (ZRC 1999.2258), Pulau Satumu (Raffles Lighthouse), coll. Y. Benayahu, 15 Jul. 1999.

photographed *in situ*. Samples were fixed in 4% formalin in seawater overnight, then rinsed in freshwater and transferred to 70% alcohol. An additional ~90 octocoral colonies were obtained from the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research (RMBR), National University of Singapore, and were included in the current study. These colonies had been collected between 1993–1997, from some of the above-mentioned sites, and additionally from Pulau Ubin, St. John's Island, Changi Sailing Club (jetty), Pulau Semakau, Pulau Seringat Kechil and Lazarus Island (Fig. 1). These ZRC-RMBR samples lack data on collection depth. Duplicate material of the collection was deposited at the Zoological Museum, Tel Aviv University (ZMTAU) as indicated below followed by the original ZRC collection numbers of these colonies given in brackets.

Sclerites were obtained by dissolving the tissues in 10% sodium hypochlorite, and prepared for scanning electron microscopy as follows: the sclerites were carefully rinsed with double-distilled water, dried at room temperature, coated with gold, and then examined with a Jeol 840A electron microscope operated at 25 kV. Identification of species was in part facilitated by comparisons with permanent sclerite preparations of type material kept at the Zoological Museum, Department of Zoology, Tel Aviv University, Israel (ZMTAU). The specimens are deposited in the ZRC and duplicate material in ZMTAU. Some *Sinularia* colonies, mostly of the *leptoclados* group (see Verseveldt, 1980), and members of the family Nephtheidae are still being examined (Ofwegen & Benyahau, in prep.).

TAXONOMY

The examined material yielded 25 species of the five families Helioporidae, Alyconiidae, Paralcyoniidae, Xeniidae and Briareidae (Table 1), and *Cladiella hartogi*, new species.

Cladiella hartogi, new species

(Figs. 2–5)

Material examined. – Holotype and four microscope slides (ZRC1999.2256), Terumbu Pempang Tengah, 2–4 m, coll. Y. Benayahu, 14 Jul. 1999. Paratypes: 1 colony (ZRC1999.1065), Pulau Hantu (north side of island), reef flat, coll. S. L. M. Teo & C. S. C. Lee, 30 May 1994; 1 colony (ZMTAU Co 34539) [ZRC

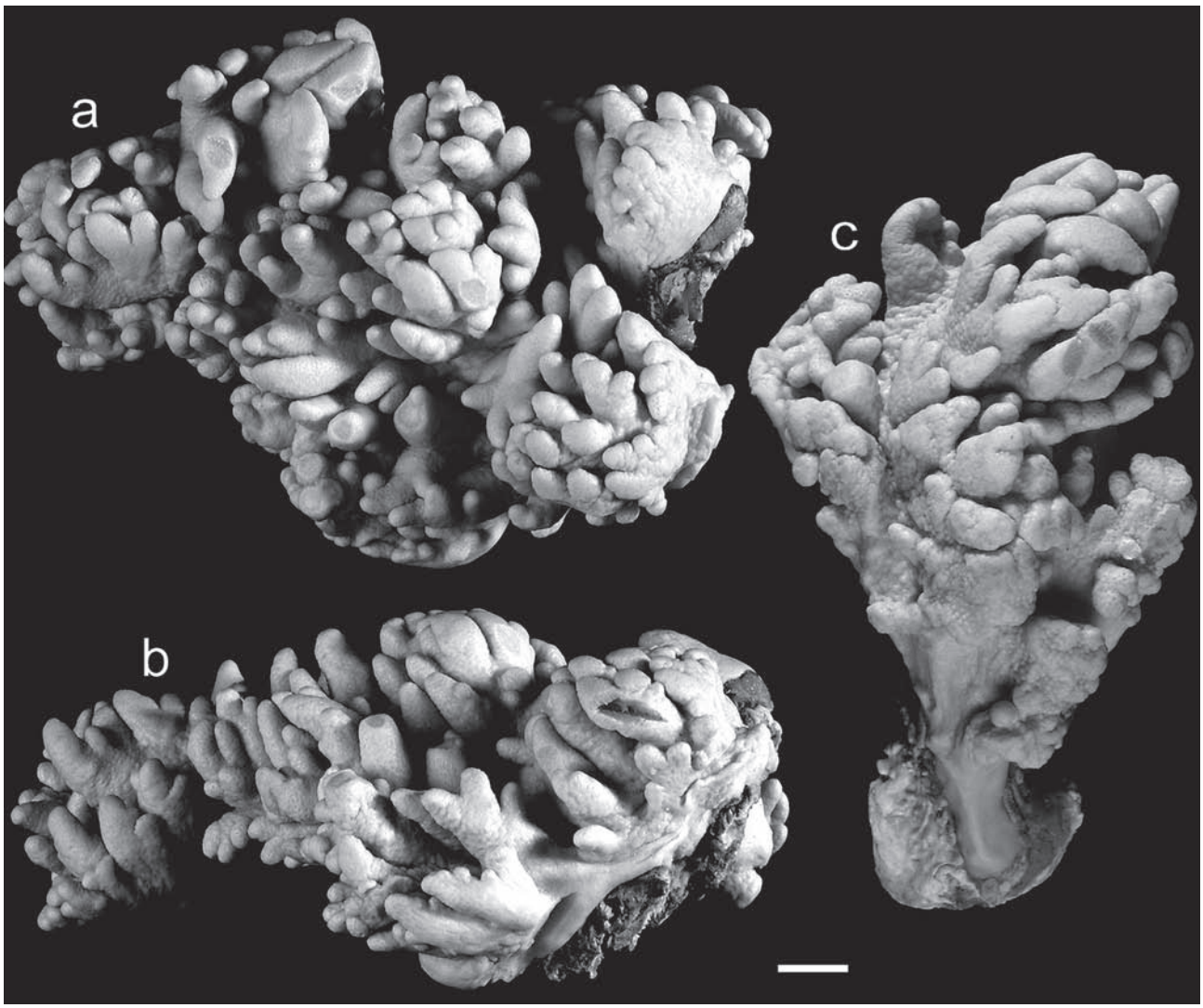

Fig. 2. *Cladiella hartogi* new species; holotype (ZRC 1999.2256): a, view of colony from above; b, side view of colony; c, paratype (ZRC 1999.2255). Scale bar 10 mm.

1999.2207], Pulau Hantu, 1 m, coll. Y. Benayahu, 6 Jul. 1999; 1 colony and 2 fragments (ZRC 1999.2207), Pulau Hantu, 1 m, coll. Y. Benayahu, 6 Jul.1999; 1 colony (ZMTAU Co 34540) [ZRC 1999.2221], Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul. 1999; 1 colony (ZRC 1999.2221), Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul. 1999; 1 colony (ZMTAU Co 34537) [ZRC 1999.2223], Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul. 1999; 2 colonies (ZRC 1999.2223), Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul. 1999; 1 colony (ZMTAU Co 34541) [ZRC 1999.2231], Pulau Hantu, 1–2 m, coll. Y. Benayahu, 9 Jul. 1999; 2 colonies (ZRC 1999.2231), Pulau Hantu, 1–2 m, coll. Y. Benayahu, 9 Jul. 1999; 1 colony (ZMTAU Co 34536) [ZRC 1999.2232], Terumbu Pempang Laut, (patch reef), 2–6 m, coll. Y. Benayahu, 12 Jul. 1999; 2 colonies (ZRC 1999.2232), Terumbu Pempang Laut, (patch reef), 2–6 m, coll. Y. Benayahu, 12 Jul. 1999; 1 colony (ZRC 1999.2255), Terumbu Pempang Tengah, 2–6 m, coll. Y. Benayahu, 14 Jul. 1999; 1 colony (ZMTAU Co 34535) [ZRC 1999.2262], Pulau Satumu (Raffles Lighthouse), 3–6 m, coll. Y. Benayahu, 15 Jul.1999; 1 colony (ZRC 1999.2262), Pulau Satumu (Raffles Lighthouse), 3–6 m, coll. Y. Benayahu, 15 Jul.1999; 1 colony (ZRC 1999.2266), Pulau Satumu (Raffles Lighthouse), 3–6 m, coll. Y. Benayahu, 15 Jul.1999; 1 colony (ZMTAU Co 34538) [ZRC 1999.2281], Sisters Reef, 2–3 m, coll. Y. Benayahu, 19 Jul., 1999; 2 colonies (ZRC 1999.2281), Sisters Reef, 2–3 m, coll. Y. Benayahu, 19 Jul. 1999.

Diagnosis. **–** The holotype is an encrusting colony with a maximum cross-section of 120 X 80 mm and a low base of four to eight mm (Fig. 2a, b). The colony has elongated lobes which split at their end or sides into lobules. The lobes and lobules are mostly arranged in groups, somewhat firm, partially bent and have a tapering tip. All polyps are retracted and only occasionally indicated by the tiny pits on the surface of the lobes and lobules.

The polyp sclerites vary in size (0.020–0.062 mm) and shape (Fig. 3a). The small ones are flat with irregular tubercles along their margins, while in the larger ones the tubercles are arranged at either end, separated by a bare waist and resembling dumb-bells. The lobe surface also features similar dumb-bells, 0.060–0.095 mm long. Some possess a coarse surface and tubercles, mostly conical with blunt tips (Fig. 3b). Other dumb-bells have pronounced, relatively high and warty tubercles (Fig. 3c), similar to those revealed in the lobe interior.

The surface of the base (Fig. 4a) and its interior (Fig. 4b) contain dumb-bells 0.050–0.090 mm long, with distinct waist and remarkably wide, tuberculate heads with high warts, up to 0.07 mm in diameter.

Colour. **–** The preserved colony is beige. Numerous zooxanthellae are found in the tissue.

Living features. **–** The expanded polyps are brown (Fig. 5a) and the colony surface is light gray (Fig. 5b). The colonies were occasionally found growing in patches.

Variation. **–** The 22 paratypes (see list above) differ only in size (i.e., ZRC 1999.2255: Fig. 2c), the smallest being with

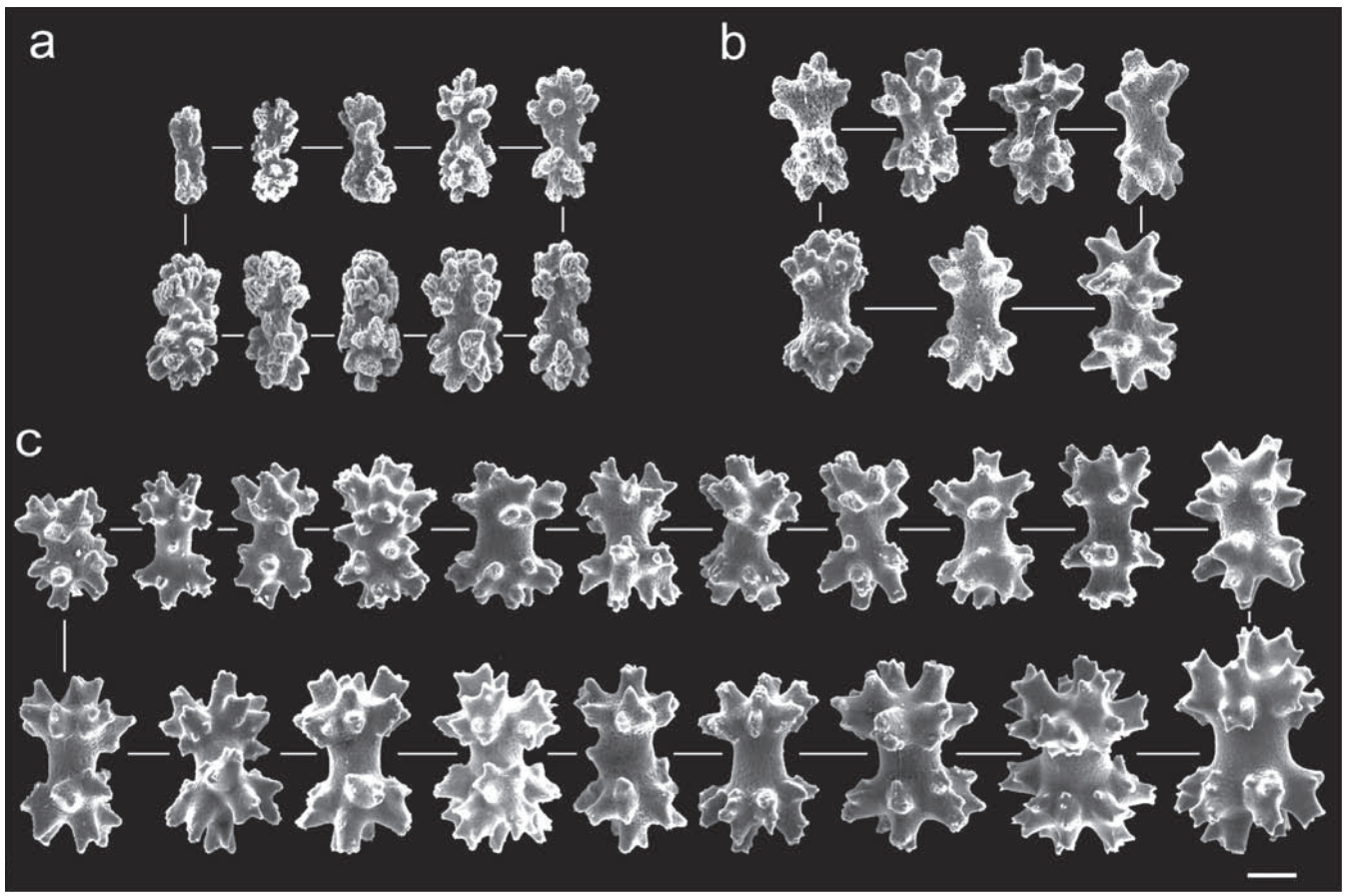

Fig. 3. *Cladiella hartogi* new species; holotype (ZRC 1999.2256): a, polyp sclerites; b, dumb-bells with course surface and tubercles from surface of lobes; c, dumb-bells with warty tubercles from surface and interior of lobes. Scale bar 0.020 mm.

a cross-section of 20 × 25 mm and all possess the same sclerites as the holotype.

Etymology. **–** The species is named after the late Drs. Jacobus Cornelis (Koos) den Hartog, former curator of the Coelenterata et al., National Museum of Natural History, Leiden, Netherlands, who passed away in October 2000. Koos greatly assisted Y. Benayahu during the latter's frequent visits to the octocoral collection in Leiden.

Remarks. **–** The genus *Cladiella* is moderately common in shallow Indo-Pacific coral reef habitats (Fabricius & Alderslade, 2001). Species of this genus have been collected in various regions, including the Red Sea (e.g., Verseveldt, 1965; Verseveldt & Benayahu, 1978; 1983); east coast Africa: Tanzania (Ofwegen & Benayahu, 1992); South Africa (Benayahu, 1993); Mozambique (e.g., Benayahu et al., 2003); Indian Ocean: Madagascar (Tixier-Durivault, 1966; Verseveldt, 1971); Seychelles (Verseveldt, 1976); Laccadives (Vennam & Ofwegen, 1996); Pacific Ocean: New Caledonia (Tixier-Durivault, 1970a; Verseveldt, 1974); Gambier (Verseveldt, 1977); Guam (Verseveldt, 1978; Benayahu, 1997); Ambon (Ofwegen & Vennam 1994); Bismark Sea (Ofwegen, 1996); East China Sea: Vietnam (Tixier-Durivault, 1970b); Ryukyu Archipelago (Benayahu, 2002 and references therein); Taiwan (Benayahu et al., 2004 and references therein). The only revision on octocorals of the genus *Cladiella* is by Tixier-Durivault (1948), who presented 44 nominal species. Since then, an additional 14 new species have been described: *C. aspera* Tixier-Durivault, 1970; *C.*

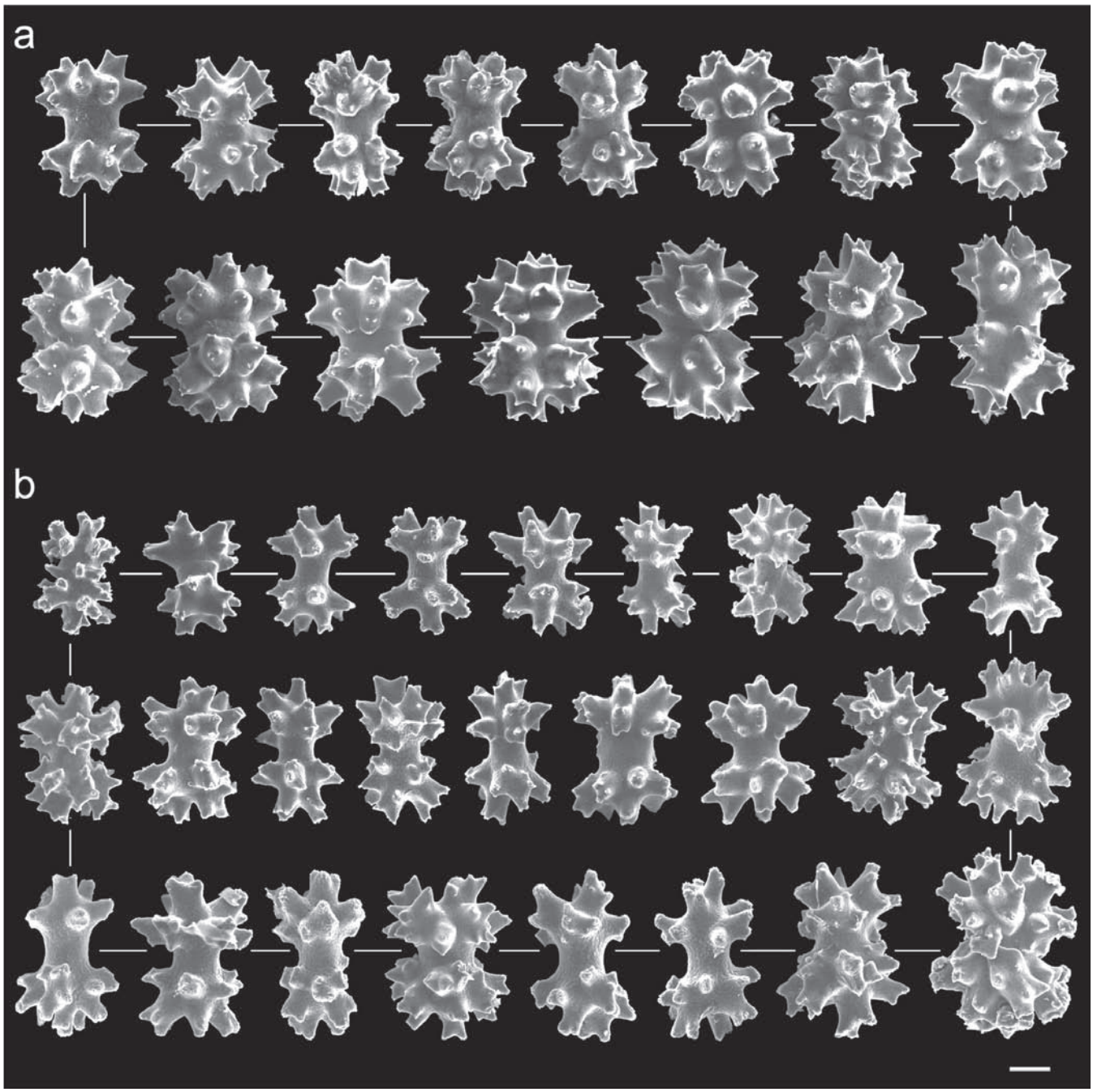

Fig. 4. *Cladiella hartogi* new species; holotype (ZRC 1999.2256): a, dumb-bells of surface of the base; b, dumb-bells of interior of base. Scale bar 0.020 mm.

densa Tixier-Durivault, 1970; *C. hirsuta* Tixier-Durivault, 1970; *C. multilobata* Tixier-Durivault, 1970; *C. ramosa* Tixier-Durivault, 1970; *C. rotundata* Tixier-Durivault, 1970; *C. scabra* Tixier-Durivault, 1970; *C. subtilis* Tixier-Durivault, 1970; *C. humesi* Verseveldt, 1974 (all from New Caledonia); *C. devaneyi* Verseveldt, 1977 (Rurutu Is., south of Tahiti); *C. arbusculoides* Verseveldt & Benayahu, 1978 (northern Red Sea); *C. steineri* Verseveldt, 1982 (Koh Si-chang, Thailand); *C. daphnae*; Ofwegen & Benyahau, 1992 (Tanzania) and *C. kashmani* Benayahu & Schleyer, 1996 (Sodwana Bay, South Africa). These findings indicate the diversity of the genus *Cladiella* throughout the entire Indo-Pacific reef systems, bringing its total number of nominal species to 58. Undoubtedly, there is need for a thorough taxonomic revision of *Cladiella* species. In the absence of such a revision, the description of *C. hartogi* sp. nov. was facilitated by the examination of relevant type material of all species designated by Tixier-Durivault (1948, 1970a) and in the subsequent publications (Verseveldt, 1974, 1977, 1982; Verseveldt & Benayahu 1978; Ofwegen & Benayahu, 1992; Benayahu & Schleyer, 1996).

The elongated and divided lobes (Figs. 2, 5) of *C. hartogi* new species and the shape and dimensions of its warty tuberculate dumb-bells (Figs. 3, 4) are considered by us as the diagnostic features of the species. The colony shape of several *Cladiella* species resembles, to a certain extent *C. hartogi* new species, but their sclerites differ from those of the newly-described species.

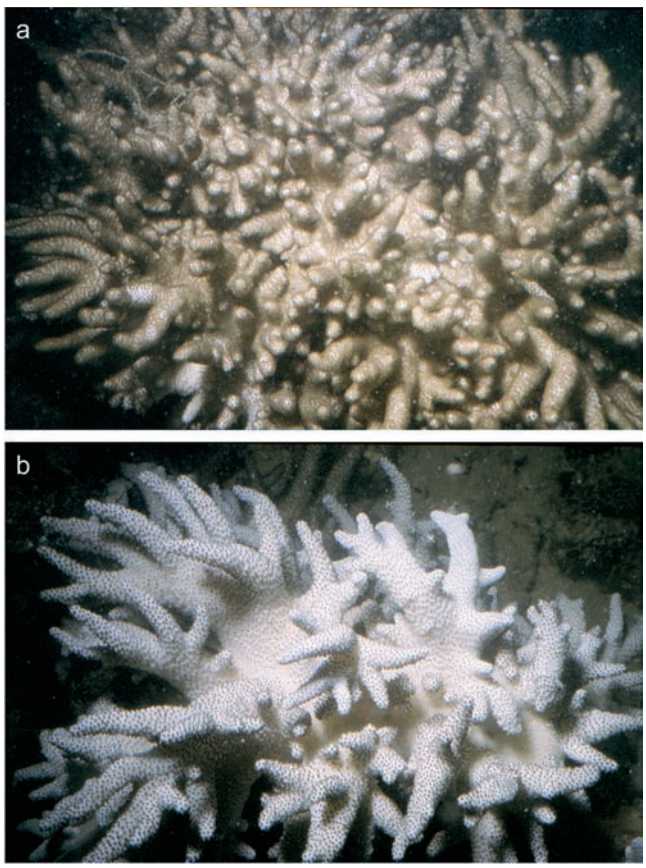

Fig. 5. Underwater photographs of colonies of *Cladiella hartogi* new species: a, with expanded polyps; b, with retracted polyps in their natural habitat.

The length of the dumb-bells of the following five *Cladiella* species falls within the size range of *C. hartogi* new species; however their head-diameter and tubercles differ. *C. laciniosa* (Tixier-Durivault, 1944) has dumb-bells up to 0.09 mm long, with head-diameter up to 0.05 mm, and covered by simple conical tubercles. *C. letourneuxi* (Tixier-Durivault, 1944) has dumb-bells up to 0.08 mm long, mostly with a narrow waist, which is often a mere line, their head-diameter up to 0.055 mm, and possessing conical tubercles. *Cladiella* (Tixier Durivault, 1944) has dumb-bells, up to 0.08 mm long, head-diameter up to 0.05 mm, and covered by conical or pointed tubercles. *C. pulchra* (Tixier Durivault, 1944) has non-retracted polyps, and thus differs from *C. hartogi* new species (see Fig. 2); its dumb-bells are up to 0.09 mm long, head-diameter up to 0.04 mm, and it possesses densely placed low-rounded tubercles. *C. suezensis* (Tixier Durivault, 1944) has dumb-bells up to 0.10 mm long, head-diameter up to 0.08 mm, and is mostly covered with elongate-pointed tubercles.

The colony shape of the following five *Cladiella* species resemble that of *C. hartogi* new species, but their sclerites differ. *C. hirsuta* Tixier-Durivault, 1970 has dumb-bells, up to 0.12 mm long, and head-diameter up to 0.08 mm. Unlike *C. hartogi* new species, the polyp sclerites of *C. hirsuta* are platelets, often with two transparent centers, pit-like, and resemble digit 8. *C. ramose* Tixier-Durivault, 1970 has dumb-bells up to 0.11 long, head-diameter up to 0.07 mm, and polyp sclerites with both platelets as above and rod-like ones. *C. humesi* (Verseveldt, 1974) has dumb-bells, up to 0.13 mm long, with waist occasionally reduced to a mere line, head-diameter up to 0.095 mm and possessing tubercles with spiny processes. *C. arbusculoides* Verseveldt & Benayahu, 1978 has dumb-bells up to 0.12 mm, with hemispherical heads featuring low undulating processes.

Based on the above comparisons, it is evident that *C. hartogi* new species has a unique suite of characters, both in terms of colony morphology and sclerites, and that it differs from all previously described congenerics.

DISCUSSION

The present study examined the octocoral fauna of Singapore and is the first one, since Shann (1912) to deal with the fleshy species. It should be noted that the recent study of Goh et al. (2009) provided only genera names, with no reference to any species. All of the species obtained in our study (Table 1) are either new (i.e. *C. hartogi*, new species) or new zoogeographical records for Singapore. The survey yielded 25 species distributed among seven genera and five families (Table 1). *Sinularia* was found to be the most specious genus on the studied reefs, with 12 species followed by *Sarcophyton* (five species), *Lobophytum* (two), *Cladiella* (two) and *Heliopora*, *Studeriotes*, *Sansibia* and *Briareum* (one each). Similar to many other Indo-Pacific reefs (Ofwegen, 2002), *Sinularia* species are prevalent on Singapore's reefs, but their diversity is lower compared, for example, to the reefs of South China Sea (32) and Indonesia (28) (Ofwegen

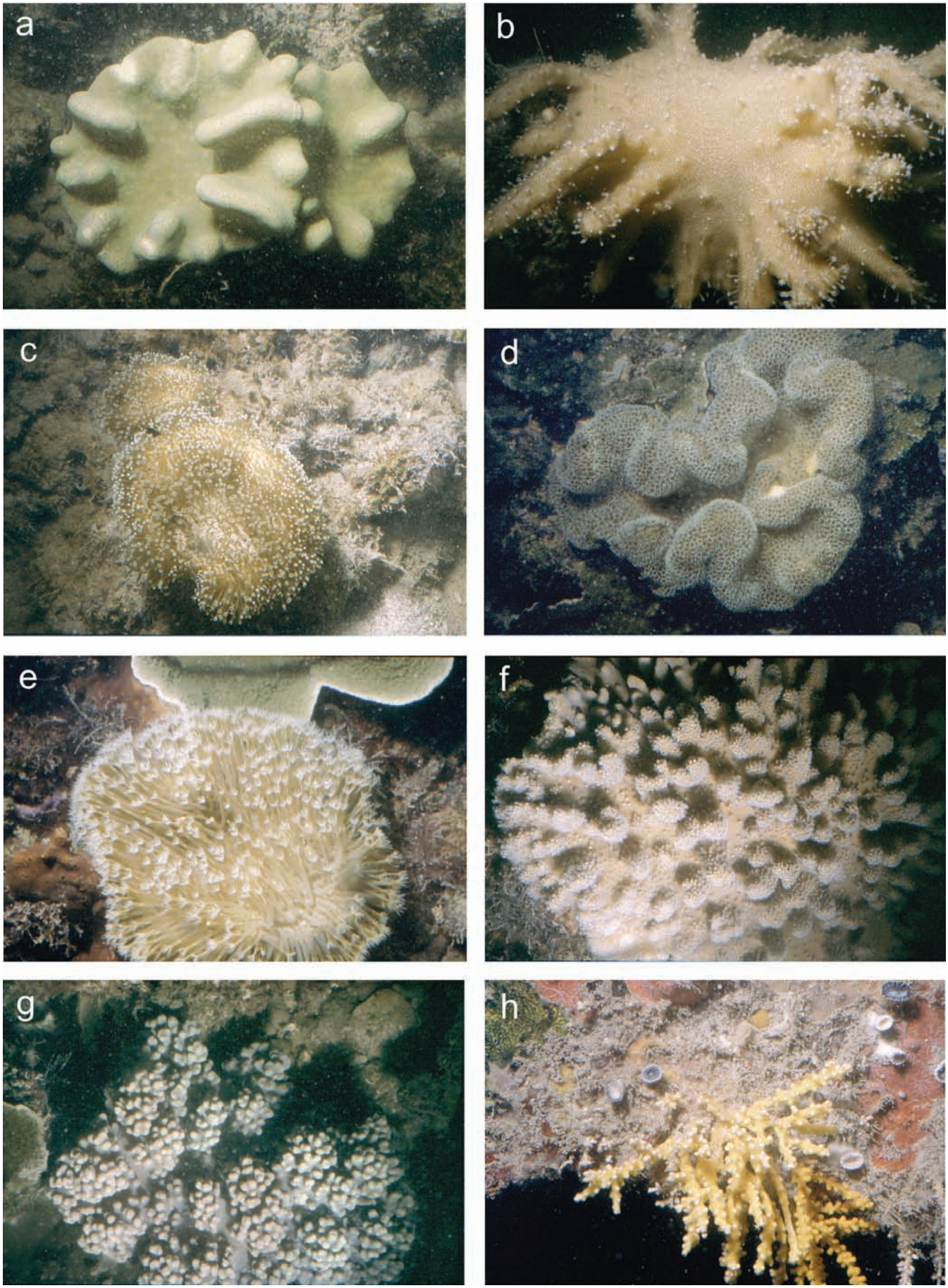

Fig. 6. Underwater photographs of Singapore octocorals a, *Lobophytum crassum* von Marenzeller, 1886; b, *L. pauciflorum* (Ehrenberg, 1834); c, *Sarcophyton crassocaule* Moser, 1919; d, *S. ehrenbergi* von Marenzeller, 1886; e, *Sarcophyton glaucum* (Quoy & Gaimard, 1833); f, *Sinularia erecta* Tixier Durivault, 1945; g, S. *lochmodes* (Kolonko, 1926) and h, *Carijoa* sp.

2002), but higher compared to Hong Kong (two) (Benayahu & Fabricius, 2010) and the Philippines (seven) (Ofwegen, 2002). Shann (1912) described *Sclerophytum* (= *Sinularia*) *pinnulatum* from Singapore, which was later synonymized by Verseveldt (1980) with *Sinularia capitalis* (Pratt, 1903). The examined material in this study did not contain this species. The nature of the Singapore Alcyoniidae fauna is also demonstrated by the relatively low number of species found in the genera *Cladiella*, *Lobophytum* and S*arcophyton* (Table 1), which in Indo-Pacific reefs typically contribute a much higher number of species (e.g., Ofwegen and Vennam, 1994; Benayahu, 1997, 2002; Benayahu et al., 2004). Notably, in Singapore, *Sansibia flava* (May, 1898) was the only species of the family Xeniidae (Table 1), although this family plays a much more significant role in both the East and South China Sea reef systems (e.g., Roxas, 1933; Benayahu et al., 2004; Benayahu, unpublished data). Thus, we suggest that the environmental conditions prevailing in Singapore have led to the paucity of Xeniidae, which require high-clarity water (Fabricius and McCorry, 2006). Notably, the collection data for the zooxanthellate octocorals found in the current study indicated that none of them were collected below 4-6 m, probably similarly due to the water turbidity and the heavy sedimentation load in Singapore (Chou, 1996; Dikou & van Woesik, 2006; Goh et al., 2009). Hence, it is also not surprising that most of the species recorded in the current survey are typical shallow reef dwellers (i.e. Benayahu, 2002; pers. obser.), whose distribution in Singapore reefs to a deeper depth is hampered by the prevailing water quality. These species include, for example, *Lobophytum crassum* von Marenzeller, 1886 (Fig. 6a); *L. pauciflorum* (Ehrenberg, 1834) (Fig. 6b); *Sarcophyton crassocaule* Moser, 1919 (Fig. 6c); *S. ehrenbergi* von Marenzeller, 1886 (Fig. 6d); *S. glaucum* (Quoy & Gaimard, 1833) (Fig. 6e); *Sinularia erecta* Tixier Durivault, 1945 (Fig. 6f) and *S. lochmodes* (Kolonko, 1926) (Fig. 6g). The azooxanthellate octocoral, genus *Carijoa* (Fig. 6h) was collected from Pulau Hantu, Changi Sailing Club and Terembu Pempang Tengah (artificial reef) down to 14 m, similarly to other regions (Benayahu, pers. obser.).

The current study examined octocorals collected between 1993-1997, prior to the 1998 bleaching event (http://coralreef.nus.edu.sg/; Tun et al., 2004), and also following it, in 1999 (Table 1). These collections were qualitative and in part were conducted at the same reef sites (Table 1: e.g., Pulau Hantu; Pulau Satumu, Raffles Lighthouse). The 1999 survey was comprehensive and aimed at collecting as many taxa as possible. Out of the 25 species, 12 were obtained at the two time points (Table 1). Seven species that were collected prior to the bleaching were no longer recorded in 1999 [i.e., *Sarcophyton tenuiospiculatum* Thomson & Dean, 1931; *Sinularia capillosa* Tixier Durivault, 1970; *S. depressa* Tixier Durivault, 1970; *S. gibberosa* Tixier Durivault, 1970; *S. microclavata* Tixier Durivault, 1970; *Studeriotes spinosa* Thomson & Dean, 1931 and *Sansibia flava* (May, 1898)]. It is interesting to note the absence of *S. capillosa* and *S. gibberosa* in the 1999 collection, which based on the large number of samples at the ZRC collected prior to the event, had in the past been highly abundant. *Sinularia microclavata* Tixier Durivault, 1970 and *Sansibia flava* (May, 1898) were collected in the previous years from Pulau Seringat and Pulau Semakau, sites that were not surveyed in 1999. Six species were recorded only after the bleaching (1999 survey), including *Heliopora coerulea* (Pallas, 1766); *Sinularia abrupta* Tixier Durivault, 1970; *S. compressa* Tixier Durivault, 1945; *S. erecta*, Tixier Durivault, 1970; *S. exilis* Tixier Durivault, 1945 and *S. triangula* Tixier Durivault, 1970 (Table 1). These latter species were somewhat scarce on the reefs and, based on their relatively large colony size at the time of collection, we assume that they had probably survived the bleaching event but for some reason were not recorded in the past collections. The lack of quantitative monitoring data on octocorals does not allow interpretation of the above findings as a result of the catastrophic 1998 bleaching event (Tun et al., 2004; Goh et al., 2009).

Because the octocorals of Singapore have experienced degradation and loss due to both natural and anthropogenic pressures (Chou, 1996; Dikou & van Woesik, 2006; Goh et al., 2009), it is imperative to include them in a long-term monitoring programme in the region, and to expand such a programme to nearby sites. Undoubtedly, octocoral diversity is indicative of the state of the reef and changes in their species composition may illuminate the changing state of the health of the reef.

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