

## NEW SPECIES OF THE GENUS *SINULARIA* (OCTOCORALLIA: ALCYONACEA) FROM SINGAPORE, WITH NOTES ON THE OCCURRENCE OF OTHER SPECIES OF THE GENUS

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**ABSTRACT.** – A new species of the genus *Sinularia*, *S. choui*, featuring *leptoclados*-type clubs, is described and depicted from Singapore coral reefs. *S. acuta* Manuputty & Ofwegen, 2007, featuring similar clubs, is discussed. Three other species of this genus with such clubs are listed: *S. maxima* Verseveldt, 1971; *S. molesta* Tixier-Durivault, 1970 and *S. verseveldti* Ofwegen, 1996. *S. polydactyla* (Ehrenberg, 1834) is also listed. All these species are new zoogeographical records for Singapore. The total *Sinularia* citation fauna of Singapore currently comprises of 18 species.

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

### INTRODUCTION

A recent paper by Benayahu & Chou (2010) summarised the current status of knowledge of Singapore's Octocorallia. That study examined a diverse collection from these reefs, which yielded 25 species of the families Alcyoniidae (21 species), Briareidae (1), Helioporidae (1), Paralcyoniidae (1) and Xenidae (1), all found to be new zoogeographical records for Singapore. It also yielded a new species, *Cladiella hartogi* Benayahu & Chou, 2010, that was described and depicted.

The genus *Sinularia* May, 1898 has been found to be the most speciose among Singapore's octocorals (Benayahu & Chou, 2010), similar to other Indo-Pacific regions (e.g., overview: Ofwegen, 2002; Okinawa: Benayahu, 2002; Taiwan: Benayahu et al., 2004; Moluccas, Indonesia: Manuputty & Ofwegen, 2007; Palau: Ofwegen, 2008; Vietnam: Dautova et al., 2010). Among the ~165 morphospecies of *Sinularia*, one of the largest groups of species features *leptoclados*-type clubs (Verseveldt, 1980). These sclerites received this name since they are typically found in *S. leptoclados* (Ehrenberg, 1834), one of the first described species of the genus and also considered to be common. Using the octocoral-specific mitochondrial *msh1* gene, McFadden et al. (2009) constructed a molecular phylogeny for *Sinularia*, proposing five major clades and subclades, among which a relatively high number of species have been assigned to clade 5c, with *leptoclados*-

type clubs. Thus, in this case the congruence between the classical taxonomy and molecular phylogeny further substantiates the validity of the *leptoclados*-clade as a major one among the genus. In anticipation of resolving species boundaries of this clade, especially among look-alikes, conclusions concerning the identification of some *Sinularia* colonies from Singapore were postponed (Benayahu & Chou, 2010: 6). Since then, further progress in the study of species belonging to this clade (e.g., Ofwegen, 2008; McFadden et al. 2009; Dautova et al., 2010) has facilitated identification of the respective specimens collected from the Singapore reefs as shown below.

### MATERIAL AND METHODS

During Jul.1999, collections were conducted by the first author at Pulau [=Island] Hantu, Pulau Satumu and Terumbu Pempang Tengah (artificial reef site) in Singapore. For details of collection procedures and map see Benayahu & Chou (2010). Additional *Sinularia* colonies were obtained from the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research (RMBR), National University of Singapore, and are included in the current study. These colonies had been collected between 1993–1997 from Pulau Hantu, St. John's Island and Pulau Semakau (see also Benayahu & Chou, 2010: Fig. 1). It should also be noted that since all material had been initially preserved in formalin it was not suitable for DNA analysis. The ZRC-RMBR

Table 1. List of species of Octocorallia of the order Alcyonacea (Lamouroux, 1816), genus *Sinularia* May, 1898 from Singapore, with indication of inventory numbers of the Raffles Museum of Biodiversity Research (ZRC) and of the Zoological Museum Tel Aviv University (ZMTAU Co), collection sites and dates of collection. Previous ZRC numbers of material deposited at Tel Aviv University are given in square brackets.

Classification
Alcyoniidae Lamouroux, 1912
Genus <i>Sinularia</i> May, 1898
<i>Sinularia acuta</i> Manuputty & Ofwegen, 2007
1 colony (1999.1043), Pulau Semakau, coll. S.L.M. Teo & T.H. Choong, 12 Jun.1995; 1 colony (1999.1054), Pulau Hantu, southeast side of Is., reef flat, coll. S.L.M. Teo & C.S.C. Lee, 8 Mar.1993; 1 colony (ZRC 1999.1080), Pulau Hantu, southeast side of Is., coll. S.L.M. Teo, 16 Feb.1995; 1 colony (ZMTAU Co 35104) [ZRC 1999.2224], Pulau Hantu, 1–4 m, coll. Y. Benayahu, 15 Jul.1999; 1 colony (ZRC 1999.2229), Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul.1999; 1 colony (1999.2268), Pulau Satumu (Raffles Lighthouse), 3–6 m, coll. Y. Benayahu, 15 Jul.1999.
<i>Sinularia choui</i> , new species
Holotype (ZRC 1999.2249) and four microscopic slides deposited at TAU (ZMTAU Co 35103), Terumbu Penang Tengah, 2–4 m, coll. Y. Benayahu, 14 Jul.1999.
<i>Sinularia maxima</i> Verseveldt, 1971
1 colony (ZMTAU Co 35105), 1 colony [ZRC 1999.1066], Pulau Hantu, north side of Is., reef flat, coll. S.L.M. Teo & C.S.C. Lee, 30 May 1994; 1 colony (ZRC 1999.1070); Pulau Hantu, coll. S.L.M. Teo & C.S.C. Lee, 6 Oct.1994.
<i>Sinularia molesta</i> Tixier-Durivault, 1970
2 colonies (ZRC 1999.1100), St. John's Is. south-east side of Is., coll. C.S.C. Lee, 7 Oct.1994; 2 colonies (ZRC 1999.2226), Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul.1999; 1 colony (ZMTAU Co 35106), 1 colony [ZRC 1999.2264], Pulau Satumu (Raffles Lighthouse), 3–6 m, coll. Y. Benayahu, 15 Jul.1999.
<i>Sinularia polydactyla</i> (Ehrenberg, 1834)
1 colony (1999.1063), Pulau Hantu, north-west side of Is., coll. S.L.M. Teo & C.S.C. Lee, 23 Jun.1993.
<i>Sinularia verseveldti</i> Ofwegen, 1996
1 colony (ZMTAU Co 35107), 3 colonies [ZRC 1999.2217], Terumbu Pempang Tengah (artificial reef site), 2 m, coll. Y. Benayahu, 8 Jul.1999.

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 square 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 6480LV electron microscope operated at 10 kV. Identification of species was in part facilitated by comparisons with permanent sclerite preparations of type material kept at the Netherlands Center for Biodiversity Naturalis, Leiden (RMNH). The specimens were deposited in ZRC-RMBR and duplicate material in ZMTAU.

## TAXONOMY

The examined material yielded six *Sinularia* species (Table 1), including *Sinularia choui*, new species.

### *Sinularia choui*, new species (Figs. 1a–4)

**Material examined.** – Holotype (ZRC 1999.2249) and four microscope slides deposited at TAU (ZMTAU Co 35103), Terumbu Penang Tengah, 2–4 m, coll. Y. Benayahu, 14 Jul. 1999.

**Diagnosis.** – The holotype is a stalked colony, with a maximum cross-section of 2 × 4 cm and 5 cm high (Fig. 1a). The polypary consists in densely placed lobes that bear lobules with a rounded tip. Some of the polyps are partially retracted and visible on the surface of the lobules.

The polyps have a collaret and eight points. The point sclerites have poorly developed heads, up to 0.19 mm long (Fig. 2a). The collaret spindles are slightly bent, 0.13–0.24 mm long, featuring sparse tubercles on their surface (Fig. 2b).

The surface layer of the lobules has *leptocladus*-type clubs, 0.10–0.26 mm long, whose heads mostly feature pointed leaf-like processes (Fig. 2c). In addition, there are clubs, up to 0.24 mm long, with heads featuring a prominent warty ornamentation (Fig. 3a), and others that are even longer,

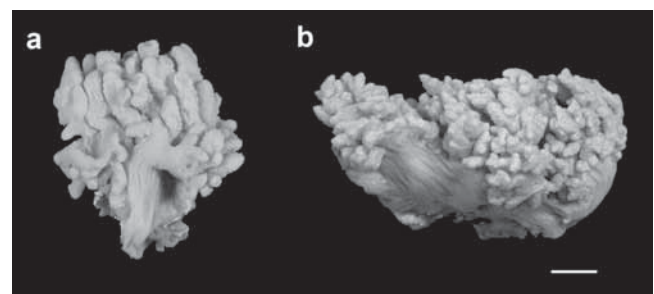


Fig. 1. *Sinularia* from Singapore; a, *Sinularia choui* new species; holotype (ZRC 1999.2249); b, *Sinularia acuta* Manuputty & Ofwegen, 2007 (ZRC 1999.2268). Scale bar 10 mm.

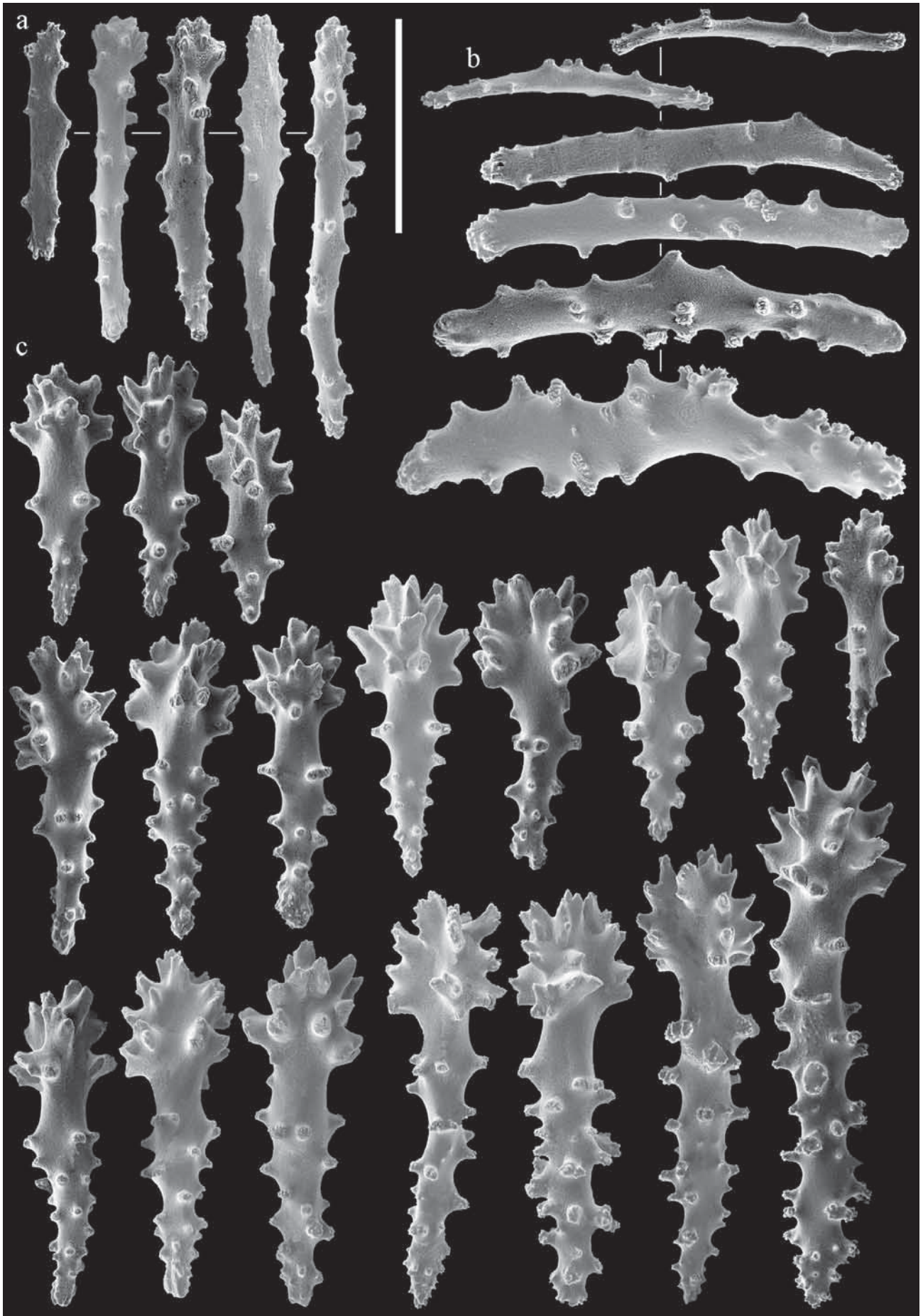


Fig. 2. *Simularia choui* new species; holotype (ZRC 1999.2249): a-b, polyp sclerites; a, point-clubs; b, collaret spindles; c, clubs of surface layer of lobules with leaf-like processes. Scale bar 0.10 mm.



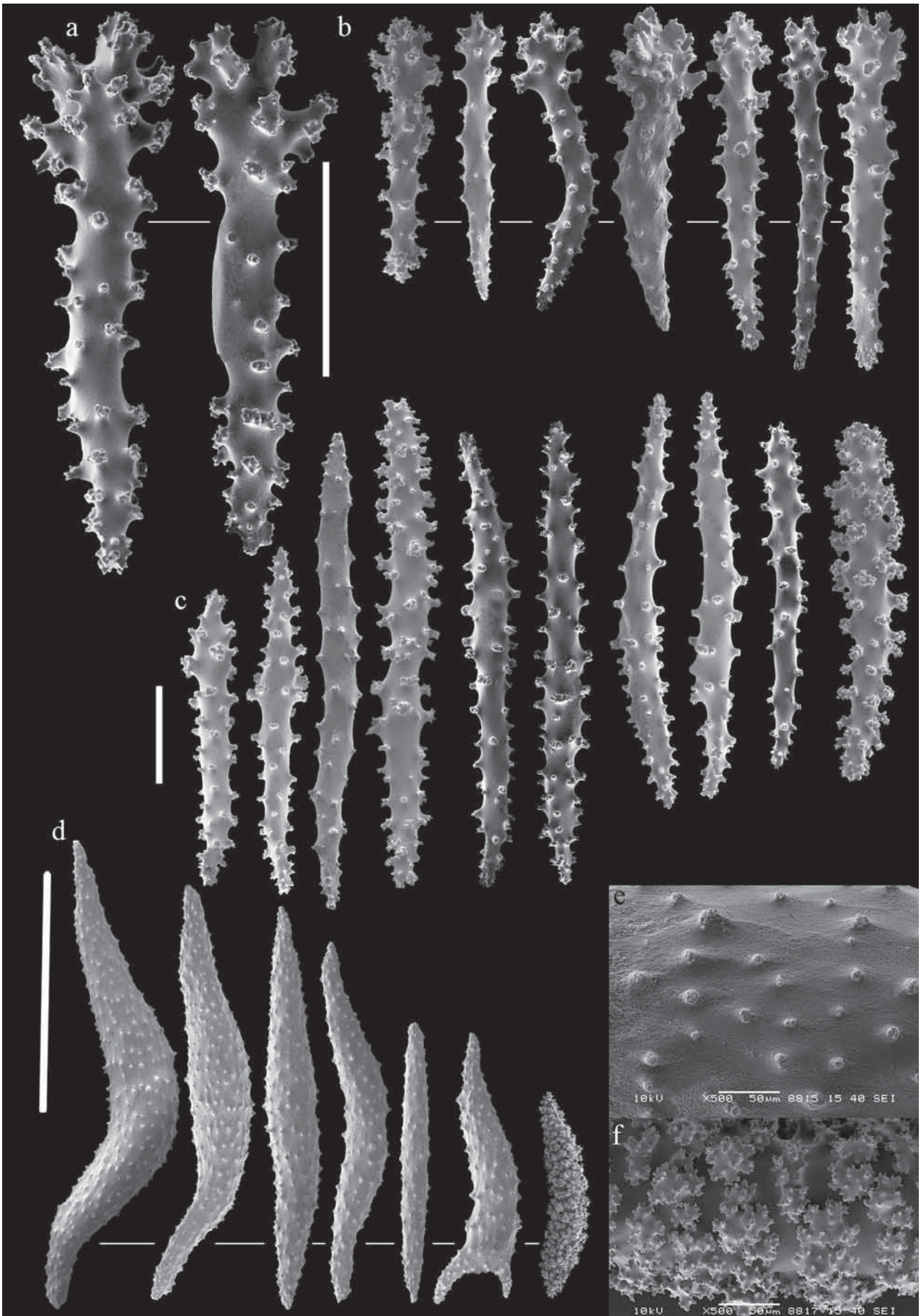


Fig. 3. *Sinularia choui* new species; holotype (ZRC 1999.2249): a–c, sclerites of surface layer of lobules; a, clubs with head featuring warty ornamentation; c, spindles; d, spindles of interior of lobules; e–f, tubercles on spindles. Scale bar at a and c 0.10 mm; that at a only applies to a, that at c applies to b–c; scale bar at d 1 mm only applies to d.

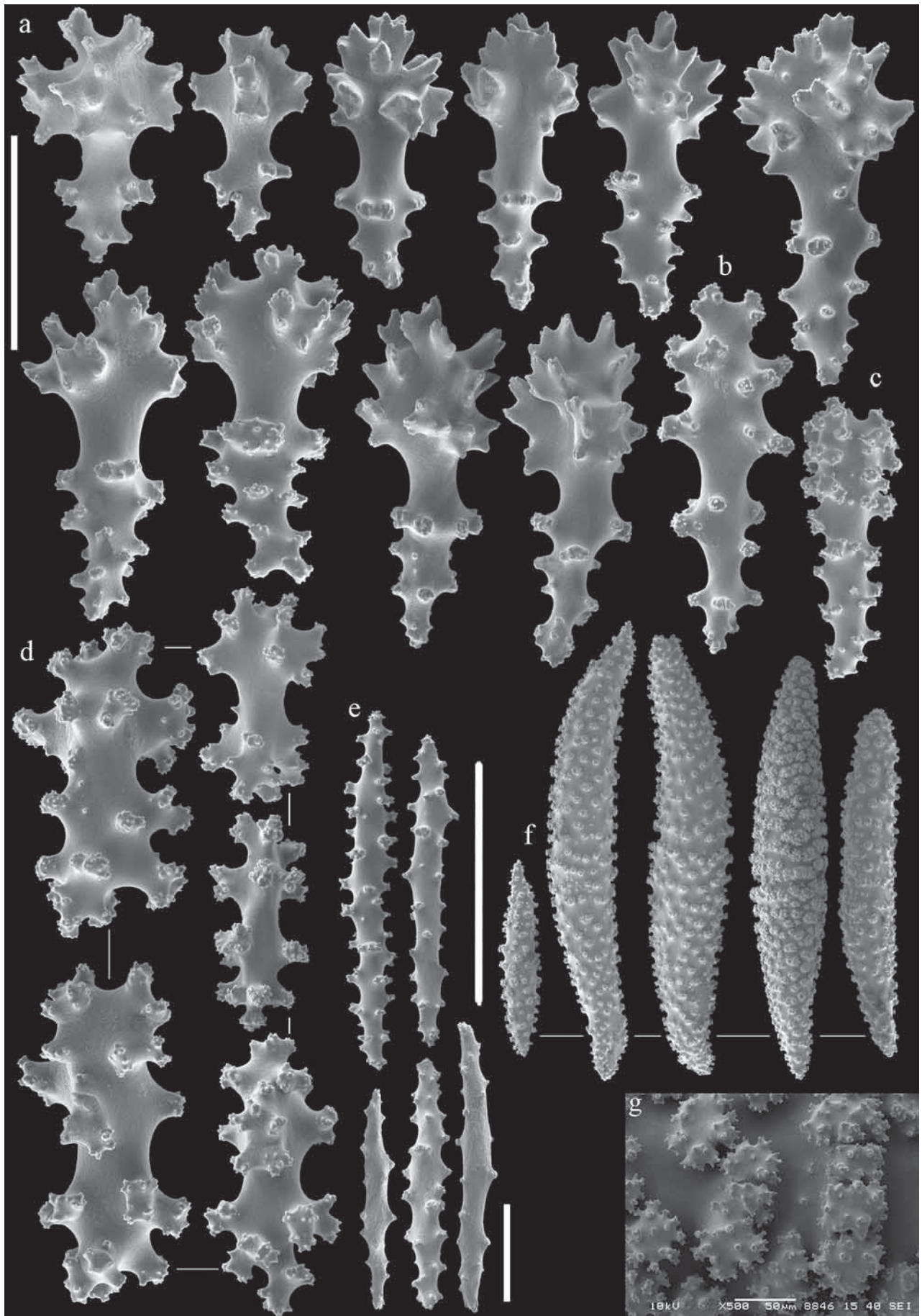


Fig. 4. *Simularai choui* new species; holotype (ZRC 1999.2249): a–e, sclerites of surface layer of colony base, a–e; a, clubs with leaflike processes; b–c, clubs with head featuring warty ornamentation; d, capstans; e, spindles; f, spindles of interior of base; g, tubercles on spindle. Scale bar at a and e 0.10 mm; that at a applies to a–d; that of e only applies to e; scale bar at f 1 mm.



up to 0.38 mm (Fig. 3b). The surface of the lobes has spindles, up to 0.51 mm long, with warty tubercles that are occasionally more common at one end of the spindle than the other (Fig. 3c).

The clubs with leaf-like processes on the surface layer of the colony base are 0.10–0.17 mm long (Fig. 4a). They have wider handles and are shorter compared to those of the lobules' surface. Some of these clubs, up to 0.30 mm long, feature heads with a warty ornamentation (Fig. 4b, c). In addition, there are capstan-like sclerites, 0.10–0.16 mm long (Fig. 4d). The spindles of the surface of the base are shorter than those of the surface of the lobes, up to 0.37 mm long (Fig. 4e).

The interior of the lobules has spindles, up to 1.95 mm long, some bent and with a side branch (Fig. 3d). Most of the spindles have sparsely dispersed small tubercles (Fig. 3e), but a few have more densely located and larger ones (Fig. 3f). The spindles in the interior of the base are up to 1.90 mm long (Fig. 4f) with a dense tubercular sculpture (Fig. 4g).

**Colour.** – The preserved holotype is light cream.

**Etymology.** – The species name honours Prof. L. M. Chou, National University of Singapore, a prominent coral reef scientist, in appreciation of his initiative to conduct a soft coral survey in Singapore and in recognition of his immense contribution to the study of the Singapore reefs.

**Remarks.** – Based on the presence of *leptocladus*-type clubs, collaret and point sclerites we assigned *S. choui* to clade 5C of McFadden et al. (2009). Within this clade, *S. pumila* Dautova et al., 2010 reveals two types of clubs in the surface layer of the lobes, with head either featuring pointed leaf-like processes or a warty ornamentation. In *S. choui* the clubs are larger than in *S. pumila*: the leafy ones reach up to 0.26 mm compared to 0.15 mm; the warty ones, 0.38 mm compared to 0.26 mm, respectively. Similarly, in *S. choui* most of the clubs of the surface layer of the base are longer than 0.10 mm (Fig. 4a), whereas in *S. pumila* they are 0.10 mm long or less (Dautova et al. 2010: Fig. 18). Hence, we conclude that *S. choui* has unique sclerite features, and does not resemble any congeneric species already described.

***Sinularia acuta* Manuputty & Ofwegen, 2007**  
(Figs. 1b, 5–7)

*Sinularia acuta* Manuputty & Ofwegen, 2007: 193 (Ambon); Ofwegen, 2008: 635–636 (Palau).

**Material examined.** – 1 colony (1999.1043), Pulau Semakau, coll. S.L.M. Teo & T.H. Choong, 12 Jun.1995; 1 colony (1999.1054), Pulau Hantu, south-east side of Is., reef flat, coll. S.L.M. Teo & C.S.C. Lee, 8 Mar.1993; 1 colony (ZRC 1999.1080), Pulau Hantu, south-east side of Is., coll. S.L.M. Teo, 16 Feb.1995; 1 colony (ZMTAU Co 35104) [ZRC 1999.2224], Pulau Hantu, 1–4 m, coll. Y. Benayahu, 15 Jul.1999; 1 colony (ZRC 1999.2229), Pulau Hantu, 1–4 m, coll. Y. Benayahu, 9 Jul.1999; 1 colony (1999.2268), Pulau Satumu (Raffles Lighthouse), 3–6 m, coll. Y. Benayahu, 15 Jul.1999.

**Remarks.** – The discussed colonies from Singapore resemble the holotype of *S. acuta*, except for ZRC 1999.2268, which shows certain differences. For comparison, both the colony and sclerites of ZRC 1999.2268 are presented here (Figs. 1b, 5–7). The colony shape (Fig. 1b) corresponds to the description of the holotype (Manuputty & Ofwegen, 2007: Fig. 2a). The sclerites of the polypary fit those of the holotype, including the polyp point (Fig. 5a) and crown (Fig. 5b), the clubs of the surface layer of the lobes (Fig. 5c, d) and its spindles (Fig. 5e) (see Manuputty & Ofwegen, 2007: Fig. 3). Similarly, the sclerites of the surface layer of the base, including the clubs (Fig. 6a, b) and spindles (Fig. 6c), correspond to the holotype (Manuputty & Ofwegen, 2007: Fig. 4). However, the spindles of the interior of the lobules of ZRC 1999.2268 are mostly branched (Fig. 7a), as opposed to those of the other examined colonies (see above) and the holotype (Manuputty & Ofwegen, 2007: Fig. 4c). The tubercular ornamentation of the spindles of all the colonies corresponds to the holotype (Fig. 7b, c, e, f). Notably, even the spindles in the interior of the base of ZRC 1999.2268 occasionally feature a side branch (Fig. 7d). We consider the slender spindles of the holotype of *S. acuta*, which are up to 3.6 mm long, a diagnostic of the species. The spindles depicted in Fig. 7a, are indeed of this type, up to 4 mm long, yet branched. Such differences between the holotype of *S. acuta* and the discussed colony are considered to reflect intra-specific variation, as commonly found in other *Sinularia* species (e.g., Dautova et al., 2010).

## DISCUSSION

The present study has yielded a new species, *S. choui*, and another five new zoogeographical records of the genus *Sinularia* for Singapore's reefs. Along with the 12 previously reported species of this genus there (Benayahu & Chou, 2010), these findings bring to a total of 18 the number of *Sinularia* species of Singapore. Moreover, the current results increase to 31 the number of octocoral species there, of the families Alcyoniidae, Briareidae, Helioporidae, Paraclyoniidae and Xenidae, with the first one comprising 87% (27 species) of the total number. Although *Sinularia* species are prevalent on Singapore's reefs, their diversity is lower, for example, compared to the reefs of the South China Sea (32) and Indonesia (28) (Ofwegen, 2002); while the octocorals of the Philippines have not been sufficiently studied (see also Dautova et al., 2010), it can be anticipated that the *Sinularia* diversity there is also quite high. Regrettably, there is also a scarcity of information on *Sinularia* diversity from other reefs in the region, such as those of Malaysia, the Gulf of Thailand, Brunei, Borneo, etc. Consequently, the level of diversity of the genus *Sinularia* in Singapore cannot be evaluated within the relevant regional scale. At this stage, therefore, it can be cautiously concluded that the number of *Sinularia* species on the Singapore reefs is rather moderate; a conclusion that can also be applied to the diversity of other genera of the family Alcyonacea there, as reflected in the findings of Benayahu & Chou (2010).

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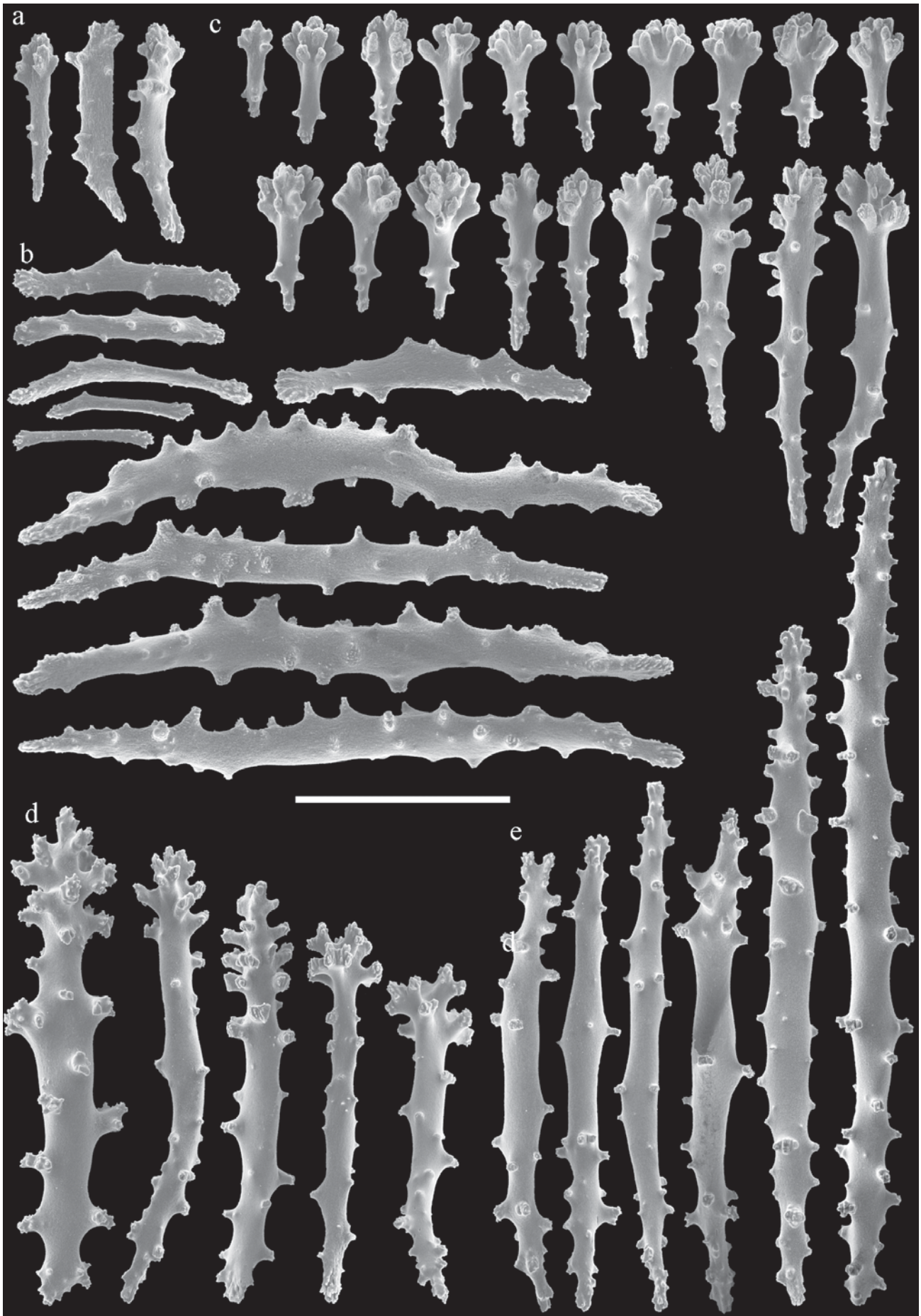


Fig. 5. *Simularia acuta* Manuputty & Ofwegen, 2007 (ZRC 1999.2268): a–b, polyp sclerites; a, point-clubs; b, collaret spindles; c–e, sclerites of surface layer of lobules; c–d, clubs; e spindles. Scale bar 0.10 mm.



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LITERATURE CITED

Benayahu, Y., 2002. Soft corals (Octocorallia: Alcyonacea) of the southern Ryukyu Archipelago: The families Tubiporidae, Clavulariidae, Alcyoniidae and Briareidae. *Galaxea JSRS*, **4**: 1–21.

Benayahu, Y., M.-S. Jeng, S. Perkol-Finkel & C.-F. Dai, 2004. Soft corals (Octocorallia, Alcyonacea) from Southern Taiwan. II. Species diversity and distributional patterns. *Zoological Studies*, **43**: 548–560.

Benayahu, Y. & L. M. Chou, 2010. On some octocorallia (Cnidaria: Anthozoa: Alcyonacea) from Singapore, with a description of a new *Cladiella* species. *The Raffles Bulletin of Zoology*, **58**: 1–13.

Dautova, T. N., L. P. van Ofwegen & O. V. Savinkin, 2010. New species of the genus *Sinularia* (Octocorallia: Alcyonacea)

from Nha Trang Bay, South China Sea, Vietnam. *Zoologische Mededelingen Leiden*, **84**: 47–92.

Ehrenberg, G. G., 1834. Beiträge zur physiologischen Kenntniss der Corallenthiere im allgemeinen, und besonders des Rothen Meeres, nebst einem Versuche zur physiologischen Systematik derselben. *Abhandl. K. Akademie der Wissenschaften, Berlin*, **1832**(1): 225–380.

Ofwegen, L.P. van, 1996. Octocorallia from the Bismarck Sea (Part II). *Zoologische Mededelingen Leiden*, **70**: 207–215.

Ofwegen, L. P. van, 2002. Status of knowledge of the Indo-Pacific soft coral genus *Sinularia* May, 1988 (Anthozoa, Octocorallia). *Proc. 9<sup>th</sup> Int. Coral Reef Symposium*, Bali 2000, **1**: 167–171.

Ofwegen, L.P. van, 2008. The genus *Sinularia* (Octocorallia: Alcyonacea) at Palau, Micronesia. *Zoologische Mededelingen Leiden*, **82**: 631–735.

Manuputty A. E. W. & L. P. van Ofwegen, 2007. The genus *Sinularia* (Octocorallia: Alcyonacea) from Ambon and Seram (Moluccas, Indonesia). *Zoologische Mededelingen Leiden*, **81**: 187–216.

McFadden, C.S., L.P. van Ofwegen, E. J. B. Beckman, Y. Benayahu & P. Alderslade. 2009. Molecular systematics of the specious Indo-Pacific soft coral genus, *Sinularia* (Anthozoa: Coelenterata). *Invertebrate Biology*, **128**: 303–323.

Tixier-Durivault, A., 1970. Les Octocoralliaires de Nouvelle-Calédonie. — *L'Expédition française sur les récifs coralliens de la Nouvelle-Calédonie sous l'égide de la fondation Singer-Polnac 1960-1963*, **4**: 171–350.

Verseveldt, J., 1971. Octocorallia from North-Western Madagascar (Part II). *Zoologische Verhandelingen Leiden*, **117**: 1–73.

Verseveldt, J., 1980. A revision of the genus *Sinularia* May (Octocorallia, Alcyonacea). *Zoologische Verhandelingen Leiden*, **179**: 1–128.

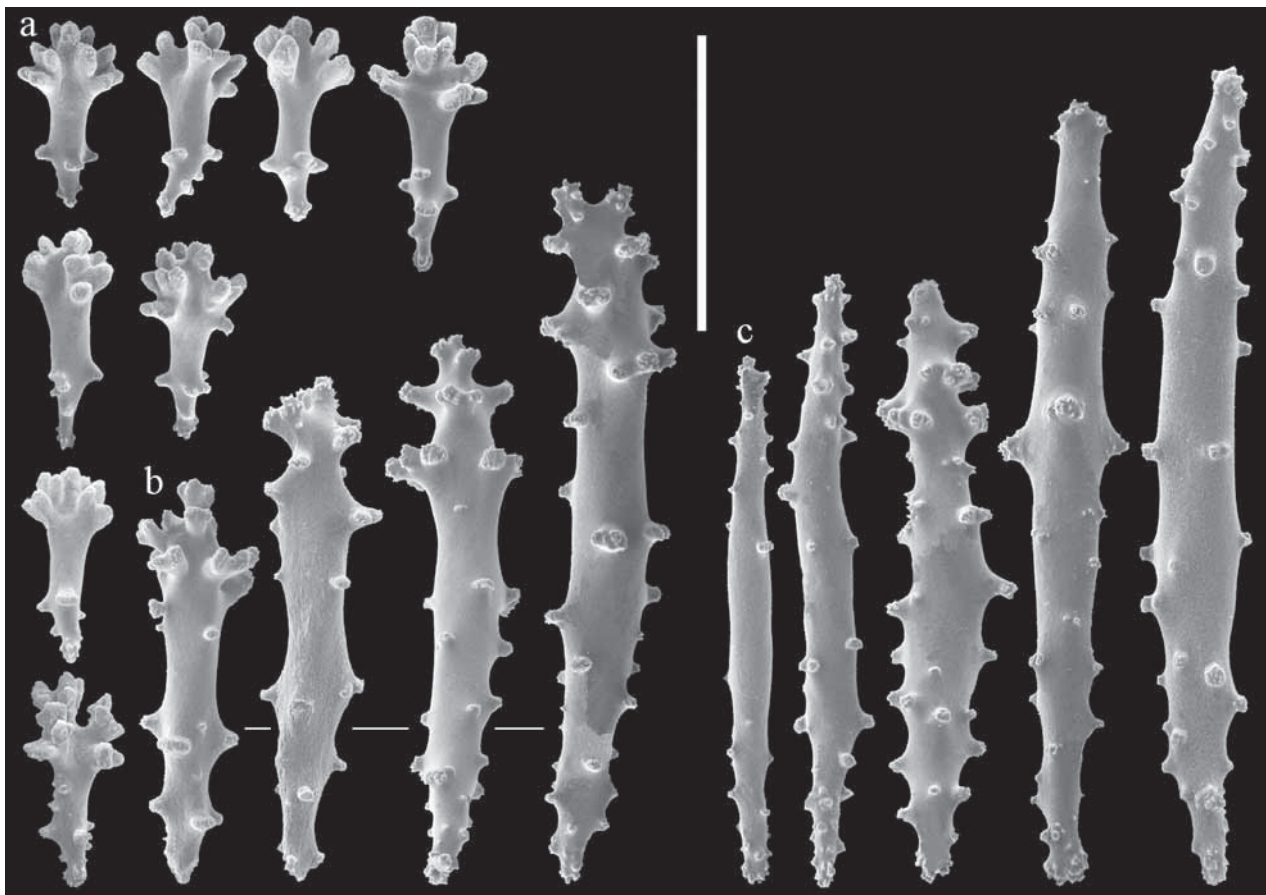


Fig. 6. *Sinularia acuta* Manuputty & Ofwegen, 2007 (ZRC 1999.2268): a–c. sclerites of surface layer of base; a–b, clubs; c, spindles. Scale bar 0.10 mm.



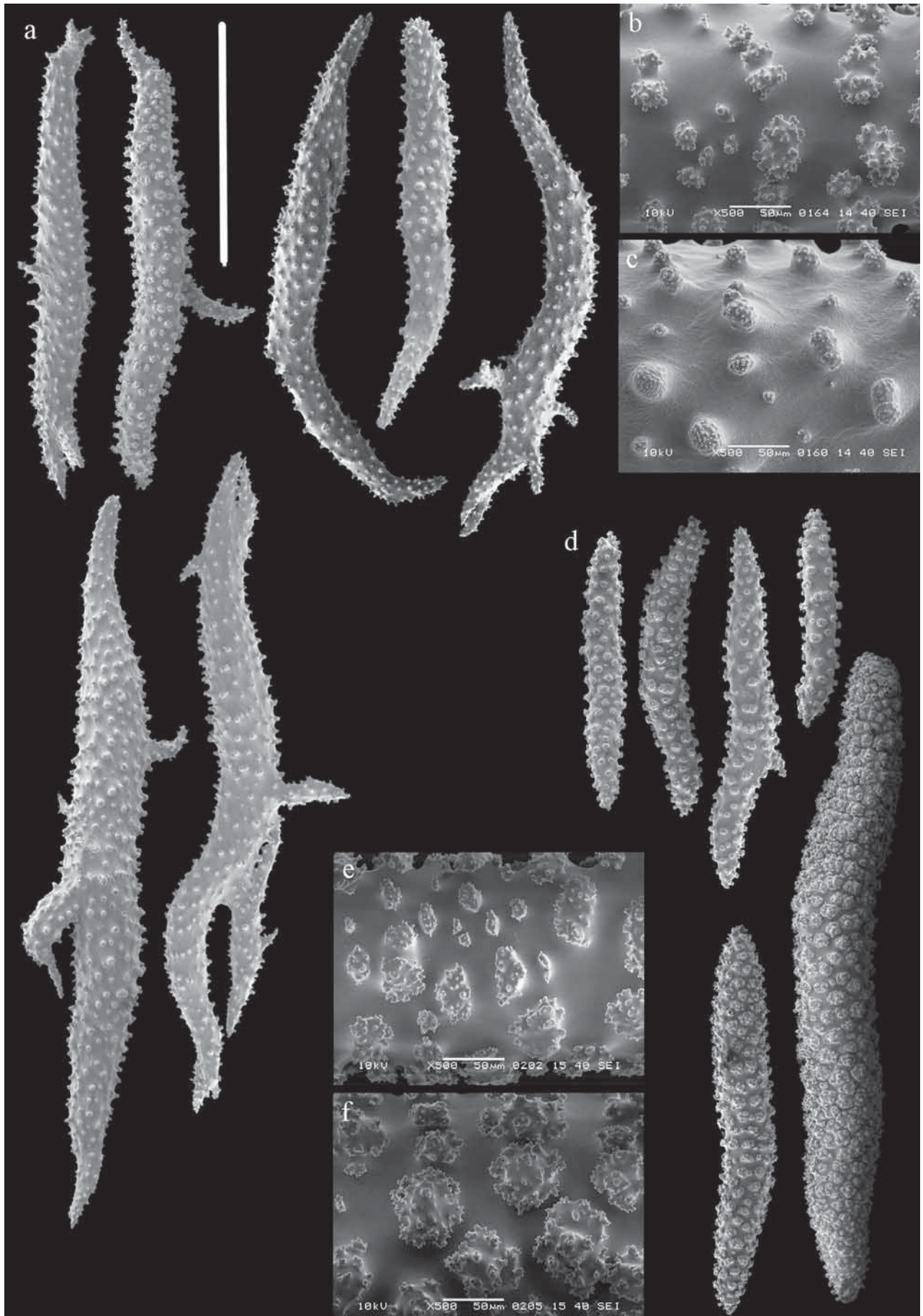


Fig. 7. *Simularia acuta* Manuputty & Ofwegen, 2007 (ZRC 1999.2268): a, spindles of interior of lobes; b–c, tubercles on spindles of interior of lobes; d, spindles of interior of colony-base; e–f, tubercles on spindles of interior of colony-base. Scale bar 1 mm at a, also applies to d.