

## New Species of Octocorals (Coelenterata: Anthozoa) from the Penghu Archipelago, Taiwan

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**Yehuda Benayahu and Leendert Pieter van Ofwegen (2011)** New species of octocorals (Coelenterata: Anthozoa) from the Penghu Archipelago, Taiwan. *Zoological Studies* 50(3): 350-362. As an outcome of an octocoral survey conducted on reefs in the Penghu Archipelago, Taiwan, 3 new species of the genera *Lobophytum* and *Sinularia* (family Alcyoniidae) are described: *L. hsiehi* sp. nov., *S. daii* sp. nov., and *S. soongi* sp. nov. *Lobophytum hsiehi* sp. nov. belongs to the mixed clade of *Sarcophyton* and *Lobophytum* nominal species with intermediate morphologies and was compared to all other species of that clade. The new *Sinularia* species are assigned to their respective clades and compared to species with similar sclerites. <http://zoolstud.sinica.edu.tw/Journals/50.3/350.pdf>

**Key words:** Octocorallia, *Lobophytum*, *Sinularia*, New species, Taiwan.

The octocoral fauna of Taiwan has been the subject of several taxonomic and ecological studies (see Benayahu et al. 2004). The 1st taxonomic studies there dealt with the fauna of the northeastern coast (Utinomi 1950a) and the southernmost part of the island (Utinomi 1950b 1951 1959). Benayahu and Perkol (2004) described a new species also from southern Taiwan (Nanwan Bay, Kenting National Park), and Benayahu et al. (2004) provided a species list, resulting from an octocoral survey conducted in the aforementioned area as well as at Green Is. (*Lutau* in Chinese), off the southeastern coast of Taiwan. From the results of the 1st octocoral survey conducted in the Penghu Archipelago (also known as the Pescadores), islands off the western coast of Taiwan in the Taiwan Strait, we herein describe new species of the genera *Lobophytum* and *Sinularia*.

### MATERIALS AND METHODS

Material was collected, by scuba diving, by Y.B. on 2 field trips conducted in July 2006 (7 d) and July 2009 (5 d). These 2 trips yielded 230 specimens of octocorals, encompassing the variety of taxa occurring at the explored sites (Benayahu et al. in prep.) and other new taxa yet to be described. All samples were preserved in 70% alcohol, and subsamples were removed and preserved in absolute alcohol and dimethyl sulfoxide (DMSO) for future molecular studies. In order to identify the material, sclerites from different parts of the colony (polyp, polyparium surface and interior, base surface, and interior) were obtained by dissolving tissues in 10% sodium hypochlorite, followed by careful rinsing in fresh water. Samples were then prepared for scanning electron microscopy (SEM) as follows: sclerites

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were carefully rinsed with double-distilled water, dried at room temperature, coated with gold, and examined with a Jeol 6480LV electron microscope (Jeol, Musashino 3-chome Akishima, Tokyo 196-8558, Japan), operated at 10 kV. Identification of species was facilitated by comparisons with permanent sclerite preparations of type material kept in the Zoological Museum, Department of Zoology, Tel Aviv Univ., Israel (ZMTAU) and the Netherlands Center for Biodiversity, Naturalis, formerly Rijksmuseum van Natuurlijke Historie, Leiden, the Netherlands (RMNH). The identified specimens were deposited at ZMTAU and RMNH as indicated below.

### SYSTEMATICS

#### *Lobophytum hsiehi* sp. nov.

(Figs. 1-4)

*Material examined:* ZMTAU Co 33629 holotype and 4 microscope slides, Penghu, Yupin (23°16.536'N; 119°30.154'E), 2-8 m, 30 July 2006; paratypes: ZMTAU Co 33579, Co 33582, Co 33593, Co 33594, Co 33599, Penghu, Chudra (24°41.437'N; 119°38.941'E), 2-8 m, 29 July 2006; ZMTAU Co 33605, Penghu, Gupo (23°42.859'N; 119°33.488'E), 2-8 m, 29 July 2006; ZMTAU Co 33609, Co 33620, Co 33628, Co 33638, Co 33641, Penghu, Yupin (23°16.536'N; 119°30.154'E), 2-8 m, 30 July 2006; ZMTAU Co 33671, Penghu, Chimei (23°11.762'N; 119°25.989'E), 2-8 m, 30 July 2006; ZMTAU Co 34628, Co 34634, Penghu, Sansui (23°30.573'N; 119°36.569'E), 7-11 m, 27 July 2009; ZMTAU Co 34687, Co 34676, Co 34679, Penghu, Mudo (23°48.079'N; 119°35.474'E), 7-9 m, 29 July 2009; ZMTAU Co 34688, Penghu, Tiehjen (23°42.824'N; 119°34.049'E), 7-9 m, 29 July 2009; ZMTAU Co 34694, Penghu, Wangan correct (23°20.913'N; 119°30.753'E), 8-10 m, 30 July 2009; ZMTAU Co 34663, Co 34670, Penghu, Sigeo (23°15.223'N; 119°36.680'E), 6-8 m, 28 July 2009; ZMTAU Co 34709, Co 34711, Co 34715, Penghu, Houdaitzai (23°21.683'N; 119°32.366'E), 6-7 m, 30 July 2009; Penghu; ZMTAU Co 34717, RMNH Coel. 39920, Co 34726, Penghu, Hugin 1 (23°28.994'N; 119°31.163'E), 12-16 m, 31 July 2009; ZMTAU Co 34687, Penghu, Mudo (23°48.079'N; 119°35.474'E), 7-9 m, 29 July 2009; ZMTAU Co 34688, Penghu, Tiehjen (23°42.824'N; 119°34.049'E), 7-9 m, 29 July 2009.

*Description:* Holotype an encrusting colony exhibiting a rather stiff texture, from which a part

was removed. Polypary with a maximum cross-section of 10.5 × 8 cm and a height of up to 2 cm (Fig. 1A); flattened and margins elevated. Polypary bearing several radially oriented ridges or crest-like lobes, including both short and longer ridges that radiate toward center of polypary. Most polyps retracted, while those that remain expanded are notable on surface of polypary. Polyps not containing sclerites.

Surface of polypary with clubs, 0.09-0.17 mm long (Fig. 2A). Head of such clubs often consisting of a central wart, while handle commonly with 2 zones of tubercles. Some clubs with a wide warty head (Fig. 2B).

Interior of polypary containing tubercular spindles, 0.18-0.32 mm long (Fig. 2C), and a few wider spindles with sparse tubercles, up to 0.41 mm long (Fig. 2D).

Surface of base with clubs of same type as those of surface of polypary, 0.09-0.17 mm long, but wider (Fig. 3A).

Interior of base containing similar sclerites to those of polypary interior. With numerous warty spindles, 0.18-0.32 mm long (Fig. 3B) and a few with sparse tubercles, up to 0.41 mm long (Fig. 3C).

*Color:* In alcohol, preserved holotype beige to light-brown.

*Living features:* Encrusting colonies growing on reef generally as aggregations (Fig. 4A), but occasionally individual colonies also found, not growing within a patch. Colonies flat, featuring irregular margins (Fig. 4B), and only small colonies (< 10 cm in diameter) more or less rounded and dish-shaped (Fig. 4A). Lobes of colonies varying in abundance and dimensions. Number of ridges and their length increase, depending on size of colony (Figs. 4A, C, D). In addition to ridges, some

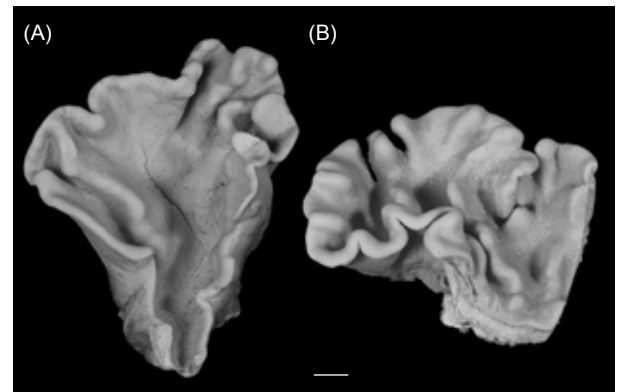


Fig. 1. *Lobophytum hsiehi* sp. nov. (A) Holotype (ZMTAU Co 33629); (B) paratype ZMTAU Co 33594. Scale bar = 10 mm.

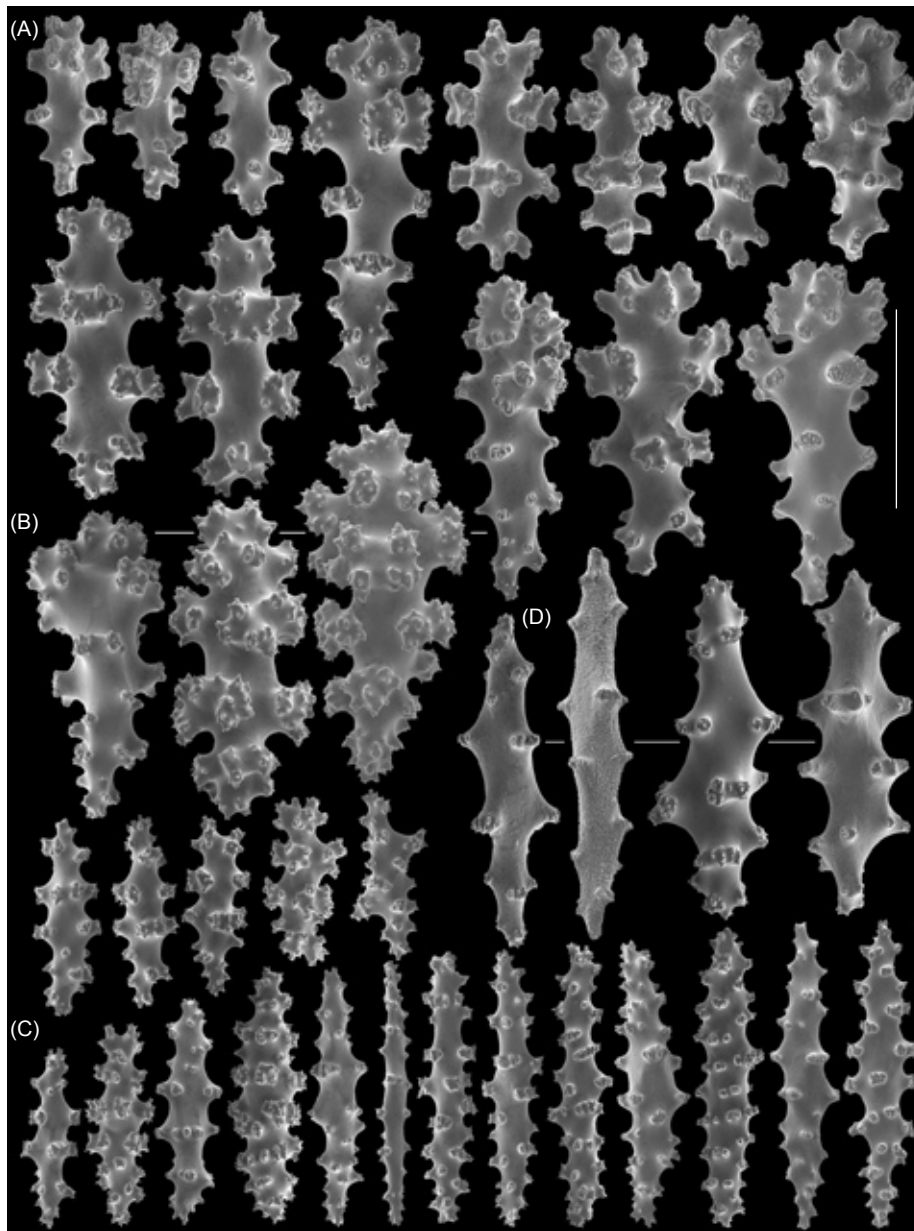
colonies featuring irregular lumps (Fig. 4C). When expanded, polyps brown, sometimes with greenish tint (Figs. 4A, B, E, F). Some colonies seemingly undergoing fission and therefore with irregular shapes (e.g., Figs. 4D, E).

**Etymology:** The species is named after Dr. H.J. Hsieh, Penghu Marine Biology Research Center, Taiwan Fisheries Research Institute Penghu, in appreciation of his enthusiastic help during the collection trips to Penghu and his continued friendship.

**Variability:** Preserved paratypes differing in

size and number and size of lobes (e.g., Fig. 1B). In some specimens, polypary with only rather small lumps, while in others, ridges sometimes with a wide base and tapering toward their distal part (Fig. 1).

**Remarks:** *Lobophytum hsiehi* sp. nov. belongs to the mixed clade of *Sarcophyton* and *Lobophytum* nominal species with intermediate morphologies (McFadden et al. 2006). Most species in this clade have a growth form in which the polypary is not distinct from the stalk, and the sclerites on the colony surface are club-shaped

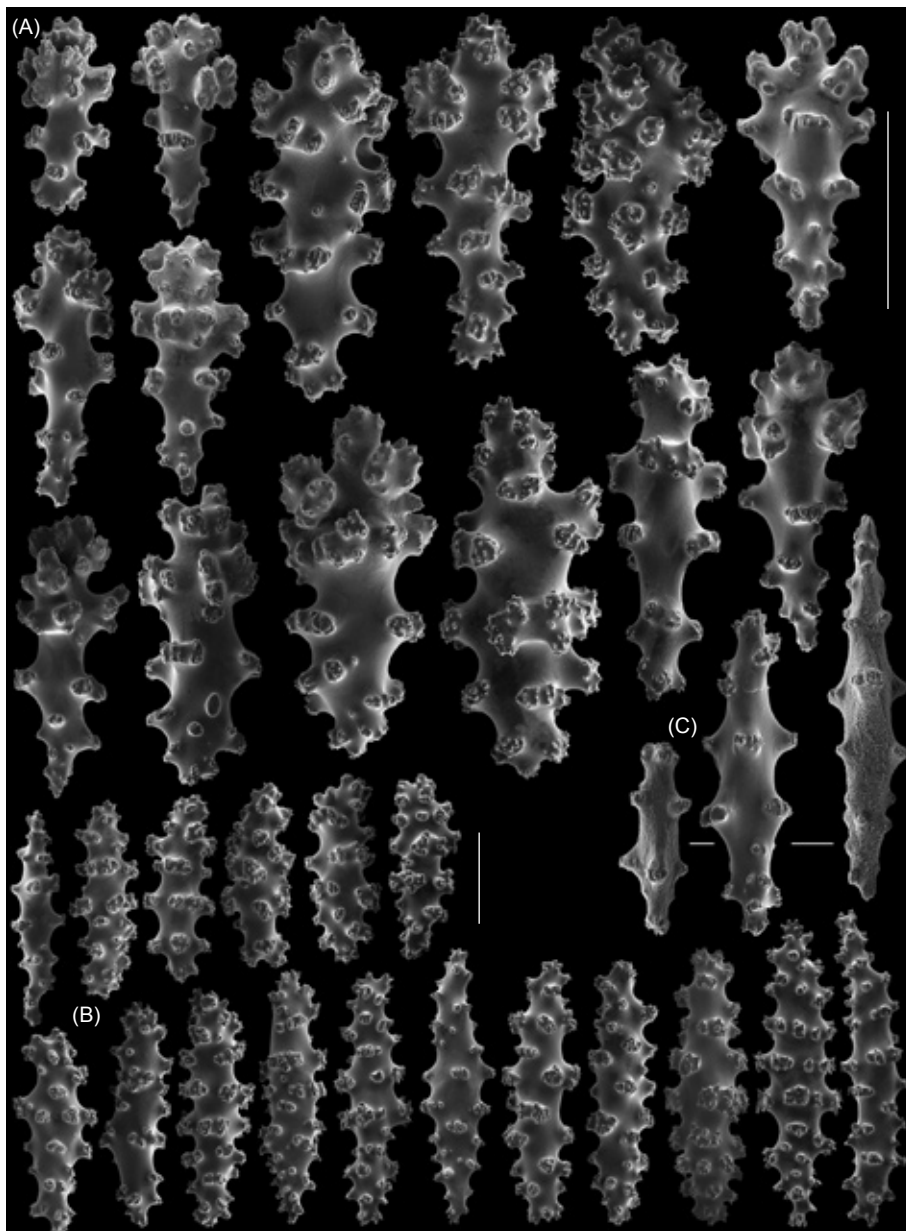


**Fig. 2.** *Lobophytum hsiehi* sp. nov., holotype (ZMTAU Co 33629). (A-D) Sclerites of the polypary; (A, B) clubs of the surface layer; (C, D) spindles of the interior. Scales 0.10 mm, that in A also applies to B, that in C also applies to D.

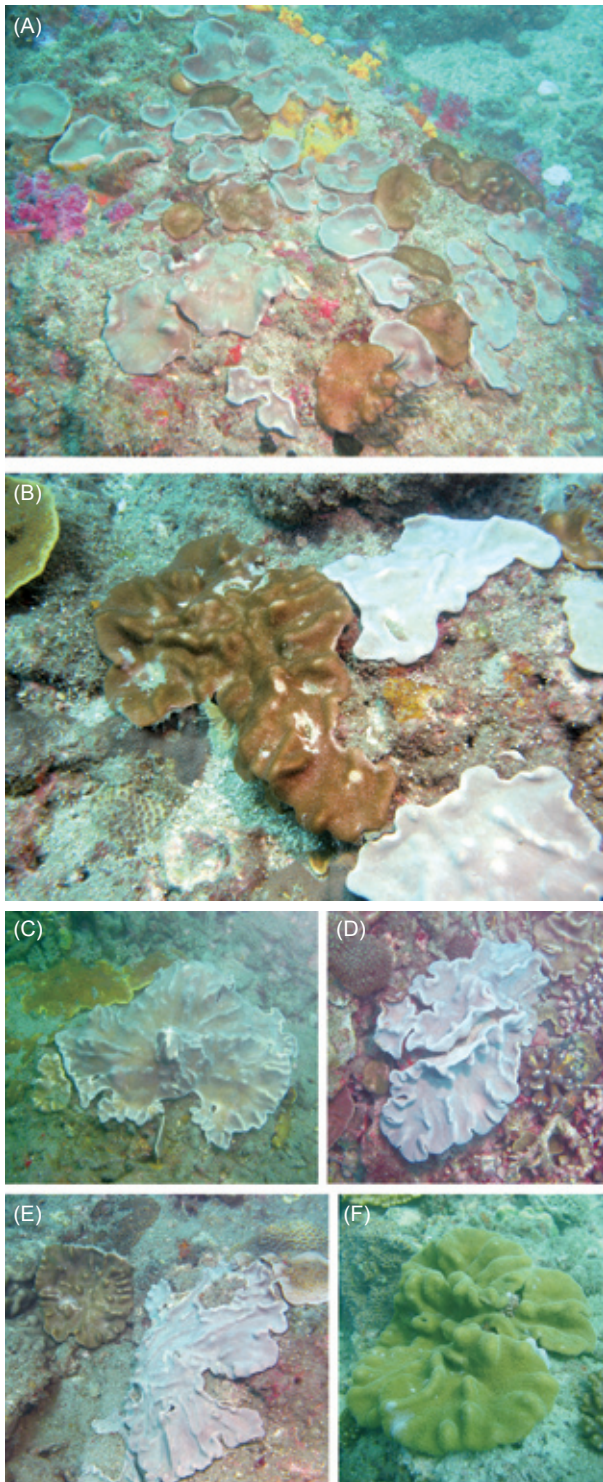
with a well-defined head. Similar to other species that belong to this clade, the newly described species has no polyp sclerites, a feature that is considered diagnostic for the mixed clade (McFadden et al. 2006). An *msh1* sequence of one of the paratypes (Co 33593) further indicated that *L. hsiehi* sp. nov. falls in the mixed clade (McFadden pers. comm.).

The growth form of *L. hsiehi* sp. nov. resembles those of *L. patulum* Tixier-Durivault, 1956 and *L. variatum* Tixier-Durivault, 1957 (for

details, see also Verseveldt 1983). In the interior of the base, *L. patulum* has capstans and oval sclerites, and *L. variatum* has wide rods and cylinders, and therefore they both markedly differ from the respective sclerites of *L. hsiehi* sp. nov. (Figs. 3B, C). The colony morphologies of *L. sarcophytoides* Moser, 1919 and *L. schoedei* Moser, 1919 feature folded edges of the disc that may fuse to form lobes or ridges (see Verseveldt 1982 1983, McFadden et al. 2006), and thus they differ from the newly described species (Fig. 1).



**Fig. 3.** *Lobophytum hsiehi* sp. nov., holotype (ZMTAU Co 33629). (A-C) Sclerites of the base; (A) clubs of the surface of the base; (B, C) spindles of the interior. Scale bars = 0.10 mm, that in A applies only to A, that in B also applies to C.



**Fig. 4.** Underwater photographs of *Lobophytum hsiehi* sp. nov. (A) Aggregation of colonies, note small dish-shaped colonies among larger ones; (B) large colonies with irregular margins and crest-like lobes, left colony with expanded polyps; (C) colony with radially oriented crest-like lobes and an irregular lump; (D) colonies with crest-like lobes and retracted polyps undergoing fission; (E) colony with expanded polyps (left) and retracted polyps (right), the latter undergoing fission; (F) colonies with expanded polyps.

Furthermore, in those 2 species, the spindles of the interior of the polypary and stalk are longer, up to 0.48 mm, compared to those of *L. hsiehi* sp. nov. (Figs. 2C, D). Although the type of *L. batarum* Moser, 1919 has not been found, it should be noted that the examination of specimens by Verseveldt (1983) and by us (see also Benayahu 2002) revealed spindles up to 0.50 mm long compared to 0.34 mm in *L. hsiehi* sp. nov. (this study). *Lobophytum venustum* Tixier-Durivault, 1957 features capstans in the interior of the colony, which are lacking in the newly described species (see also Ofwegen and Benayahu 1992). The colony shape and sclerites of *L. hsiehi* sp. nov. differ markedly from those of *S. ehrenbergi* Von Marenzeller, 1886; *S. flexuosum* Tixier-Durivault, 1966; and *S. mililatensis* Verseveldt and Tursch, 1979 (see Verseveldt 1982, McFadden et al. 2006). A more-recently described species, *L. mortoni* Benayahu and Ofwegen, 2009, is also included in the same mixed clade, but differs



**Fig. 5.** *Sinularia daii* sp. nov., holotype (ZMTAU Co 34665). Scale bar = 10 mm.

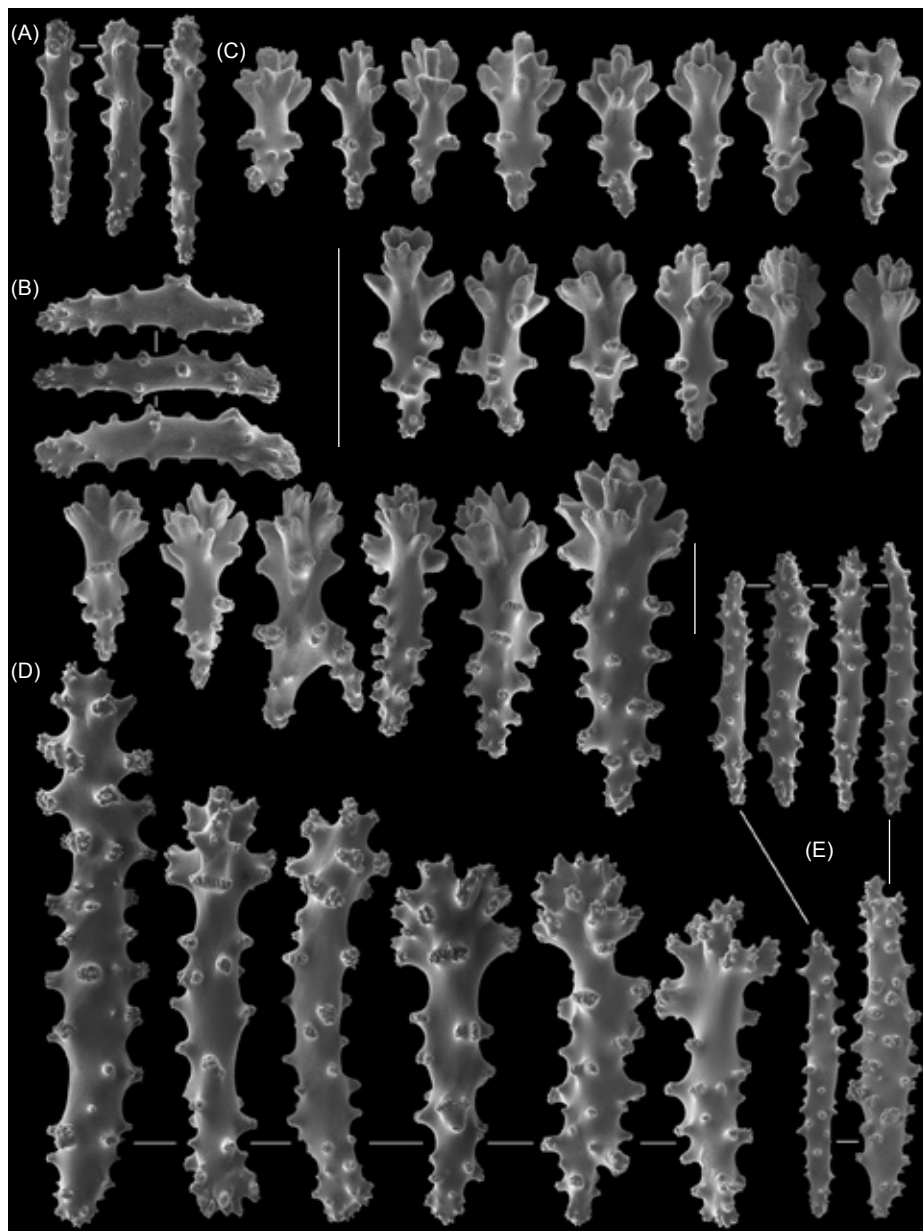
from *L. hsiehi* sp. nov. in possessing spindles in the interior of the base with zoned warts. It was therefore concluded that *L. hsiehi* sp. nov. differs from all of the previously described *Lobophytum* and *Sarcophyton* species that belong to the mixed clade (see McFadden et al. 2006, Benayahu and Ofwegen 2009), and it is consequently justified to assign *L. hsiehi* sp. nov. specimens to a new species.

***Sinularia daii* sp. nov.**

(Figs. 5-8)

*Material examined:* ZMTAU Co 34665, holotype and 4 microscope slides, Penghu, Sigee (23°15.223'N; 119°36.680'E), 6-8 m, 28 July 2009.

*Description:* Holotype an encrusting colony, from which a fragment was removed, with a maximum cross-section of 10 × 7 cm and height of up to 5 cm (Fig. 5). Polyparium consisting of short undivided lobes and longer ones that branch off, mostly only once, and bear lobules. Lobes



**Fig. 6.** *Sinularia daii* sp. nov., holotype (ZMTAU Co 34665). (A) Point clubs; (B) collaret spindles; (C-E) sclerites of surface layer of lobules; (C, D) clubs; (E) spindles. Scale bars = 0.10 mm, that in C also applies to A, B, and D; that in E only applies to E.

and lobules knob- to finger-shaped with tapering ends and tending to bend down towards surface of colony. Colony with a hard texture.

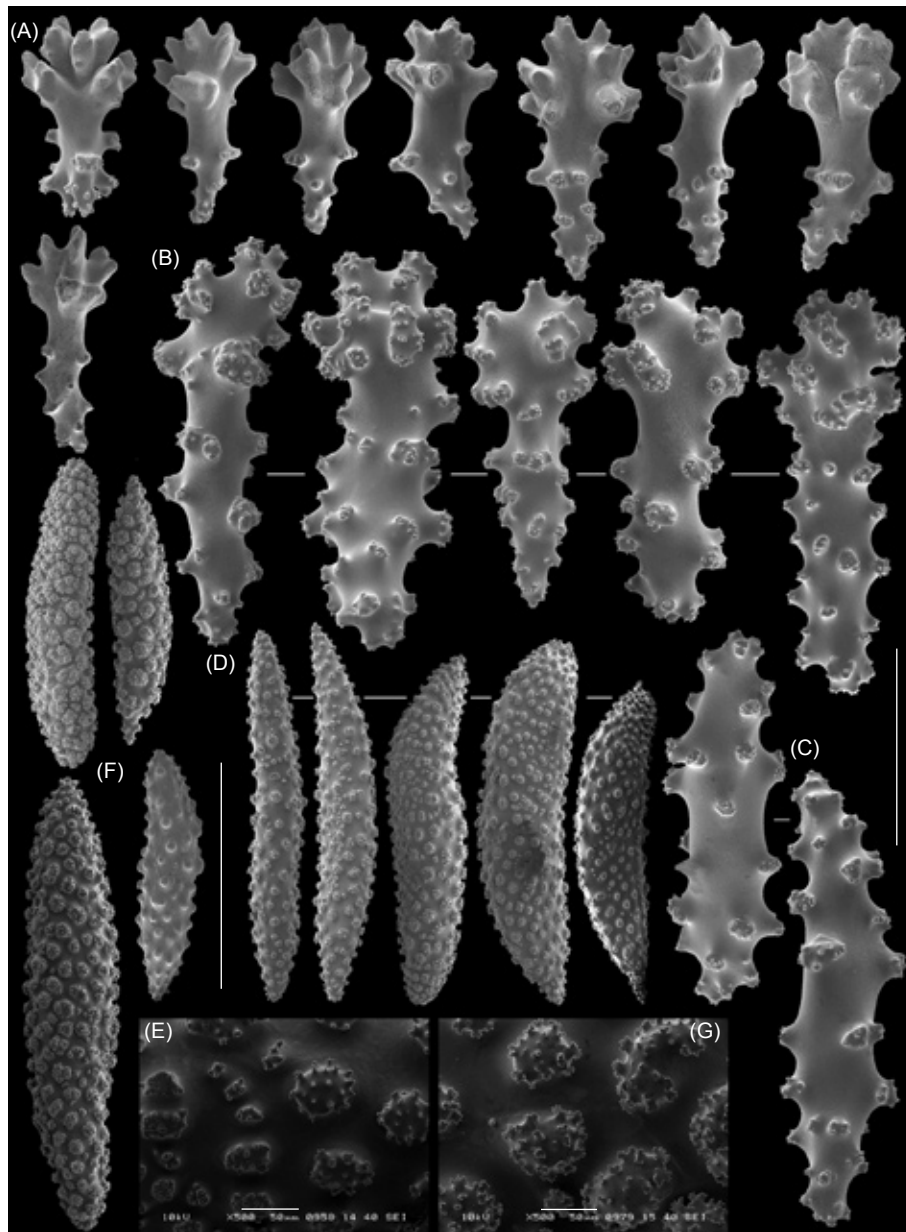
Polyps with a collaret and 8 points. Point sclerites with poorly developed club-heads, up to 0.12 mm long (Fig. 6A). Collaret consisting of slightly bent spindles, up to 0.13 mm long (Fig. 6B). Tentacles lacking rod sclerites.

Surface layer of lobules with *leptocladus*-type clubs, smallest at 0.08 mm long, but some longer, reaching 0.18 mm (Fig. 6C). Also with

longer clubs with warty heads and tubercles along handles, up to 0.28 mm long (Fig. 6D). In addition, with spindles with simple or warty tubercles, up to 0.36 mm long (Fig. 6E).

Surface layer of base of colony containing *leptocladus*-type clubs, similar to those of lobules, but wider, up to 0.13 mm long (Fig. 7A). Also with wide clubs with warty heads and tubercles on handle, up to 0.21 mm long (Fig. 7B). Spindles of surface layer of base up to 0.23 mm long (Fig. 7C).

Interior of lobules with spindles, up to 1.7 mm



**Fig. 7.** *Sinularia daii* sp. nov. holotype (ZMTAU Co 34665). (A-C) Sclerites of surface layer of base of colony; (A, B) clubs; (C) spindles; (D, F) spindles of interior; (D) lobules; (F) base; (E, G) tubercles on spindles; (E) interior lobules; (G) interior base. Scale in C, 0.10 mm, which also applies to A and B; scale in D, 1 mm, which also applies to F.

long (Fig. 7D), with simple tubercles of various sizes (Fig. 7E). Interior of base with slightly longer spindles, up to 2.0 mm (Fig. 7F), with larger warty tubercles (Fig. 7G).

**Color:** Preserved holotype dark brown; tips of lobules lighter.

**Living features:** Encrusting colony with branched lobes along periphery, while center undivided with spaced knob- to finger-shaped lobes (Fig. 8). Colony gray.

**Etymology:** The species is named after Prof. C.F. Dai, Institute of Oceanography, National Taiwan Univ., Taipei, Taiwan, in appreciation of his initiative to conduct octocoral studies in Taiwan, particular in Kenting National Park and on Green Is.

**Remarks:** *Sinularia daii* sp. nov. belongs to *Sinularia* clade 5c of McFadden et al. (2009): polyps with collaret and point sclerites and *leptoclados*-type clubs. *Sinularia daii* sp. nov. is characterized by large clubs, mostly > 0.10 mm long (Figs. 6C, 7A). *msh1* and cytochrome oxidase subunit I (*COI*) sequences of the holotype (Co 34665) further indicated that *S. daii* falls in that *leptoclados*-clade (McFadden pers. comm.).

Among *Sinularia* species that belong to this clade, *S. compacta* Tixier-Durivault, 1970 also has *leptoclados*-type clubs of similar lengths (Verseveldt 1980, Ofwegen 2001), but its colony shape greatly differs, featuring short, laterally flattened undivided lobes (Verseveldt 1980: pl. 14). *Sinularia pumila* Dautova et al., 2010 contains similar clubs, but the colony has weakly branched lobes. *Sinularia acuta* Manuputty and Ofwegen, 2007 has an arborescent colony shape



**Fig. 8.** Underwater photographs of *Sinularia daii* sp. nov. (holotype).

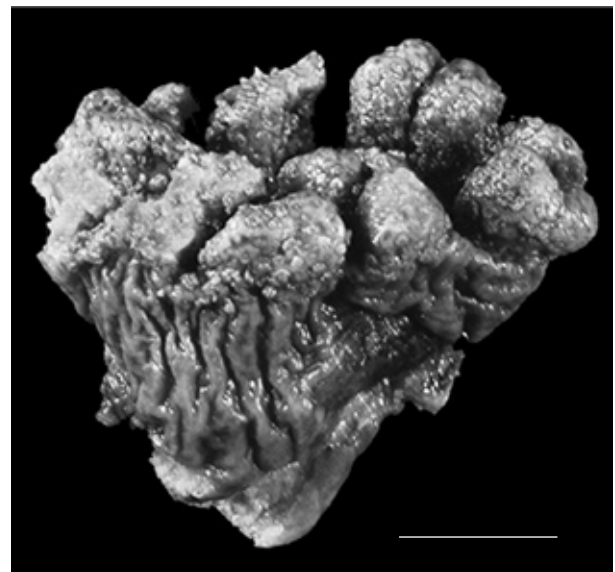
with a number of primary lobes that branch off and lobules with tapering ends, and therefore somewhat resembles *S. daii* sp. nov. (Figs. 5, 8). However, most of the *leptoclados*-type clubs of *S. acuta* are < 0.10 mm and thus differ from those of *S. daii* sp. nov. *Sinularia biscula* Ofwegen, 2008 resembles the present species most. It is also encrusting with lobes that split at the end or have lobules (Ofwegen 2008: fig. 75d). It also has similarly sized *leptoclados*-type clubs. However, it has more-developed polyp sclerites (Ofwegen 2008: fig. 8a, b). Additionally, in *S. biscula* the angle between the club-head and the handle is about 90° (Ofwegen 2008: fig. 8c), whereas in *S. daii* sp. nov. it is distinctly larger. Notably, this character was first introduced by Ofwegen (2001) and subsequently also used by Manuputty and Ofwegen (2007). We consider it useful for identifying species with *leptoclados*-type clubs. Therefore, it is evident that *S. daii* sp. nov. differs from all previously described *Sinularia* species of clade 5c.

#### ***Sinularia soongi* sp. nov.**

(Figs. 9-12)

**Material examined:** ZMTAU Co 33632, holotype and 4 microscope slides, Penghu, Yupin (23°16.536'N, 119°30.154'E), 2-8 m, 30 July 2006.

**Description:** Holotype part of a colony with maximum cross-section of 3.5 × 2 cm and height of 3 cm (Fig. 9). Its knob-like lobes laterally flattened,



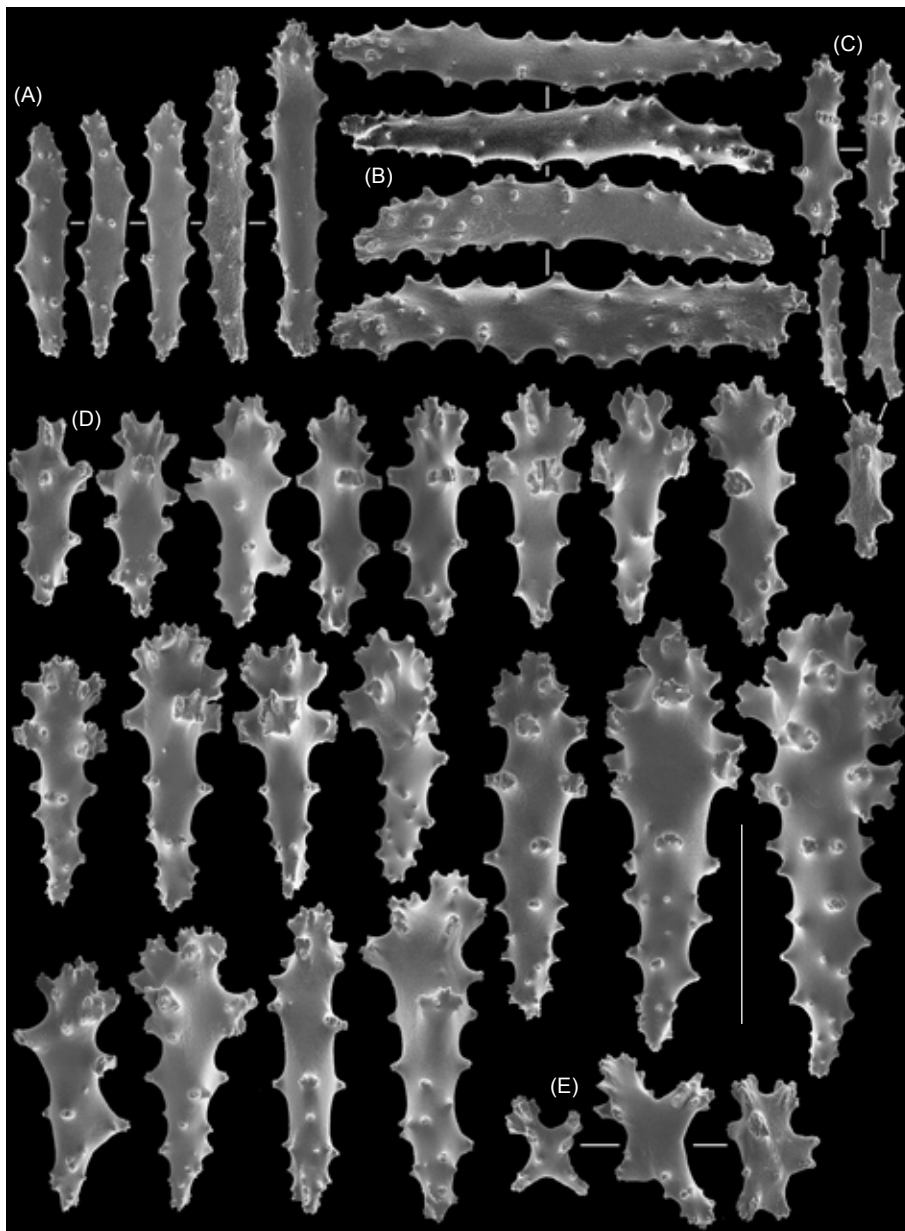
**Fig. 9.** *Sinularia soongi* sp. nov. holotype (ZMTAU Co 33632). Scale bar = 10 mm.



and seemingly with a stalk featuring longitudinal wrinkles.

Polyps with collaret and 8 points. Point sclerites up to 0.14 mm long (Fig. 10A), and almost straight collaret-spindles, up to 0.17 mm long, featuring sparse simple tubercles (Fig. 10B). Tentacular rods up to 0.07 mm long (Fig. 10C). Surface layer of lobules containing clubs, 0.09-0.25 mm long, most of which featuring a central wart (Fig. 10D). In addition, with some crosses, up to 0.09 mm long (Fig. 10E).

Surface layer of base of colony containing variety of sclerites (Figs. 11, 12A, B). With rods and capstans, 0.07-0.12 mm long, featuring warty tubercles at ends and along surface (Fig. 11A). Also with crosses up to 0.11 mm long (Fig. 11B). Clubs of surface layer of stalk, 0.15-0.23 mm long (Fig. 11C); wider than those of lobes with some featuring a central wart. Additionally, with tubercular spindles, up to 0.30 mm long (Fig. 11D), several are up to 0.40 mm long (Fig. 12A). Also with shuttles, up to 0.20 mm long (Fig. 12B).



**Fig. 10.** *Sinularia soongi* sp. nov. holotype (ZMTAU Co 33632). (A) Point sclerites; (B) collaret sclerites; (C) tentacular rods; (D, E) sclerites of surface layer of lobules; (D) clubs; (E) crosses. Scale bars = 0.10 mm.

Interior of lobes with spindles, up to 1.9 mm long (Fig. 12C), some featuring 1 or several side branches; all with rather sparsely scattered tubercles (Fig. 12D).

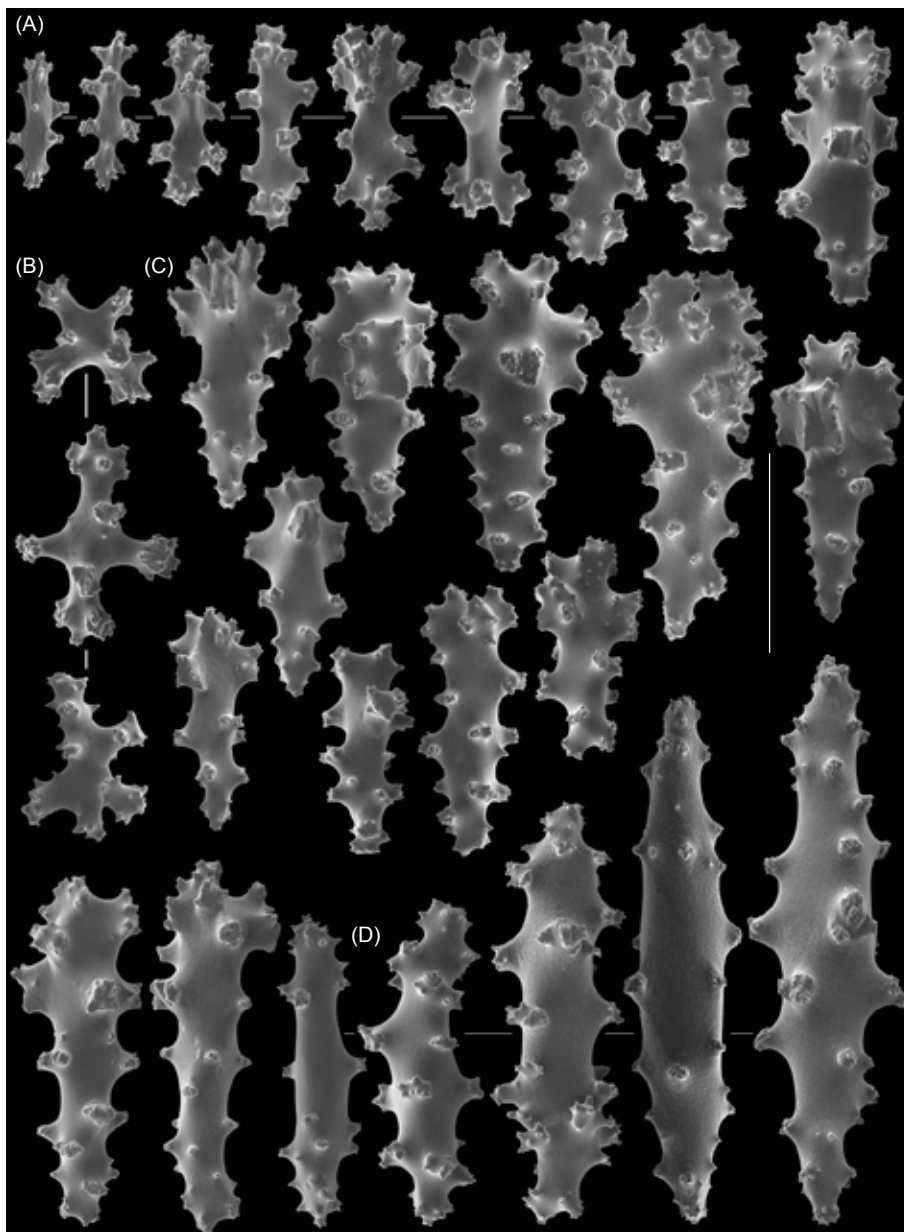
Interior of base with spindles of a wide size range, up to 1.7 mm long (Figs. 12E, F), with densely placed warty tubercles (Fig. 12G).

*Color:* Preserved holotype brown.

*Etymology:* The species is named after Prof. K. Soong, Institute of Marine Biology, National Sun Yat-sen Univ., Kaohsiung, Taiwan in appreciation

of his enthusiastic support for octocoral studies in Taiwan, particular in Penghu.

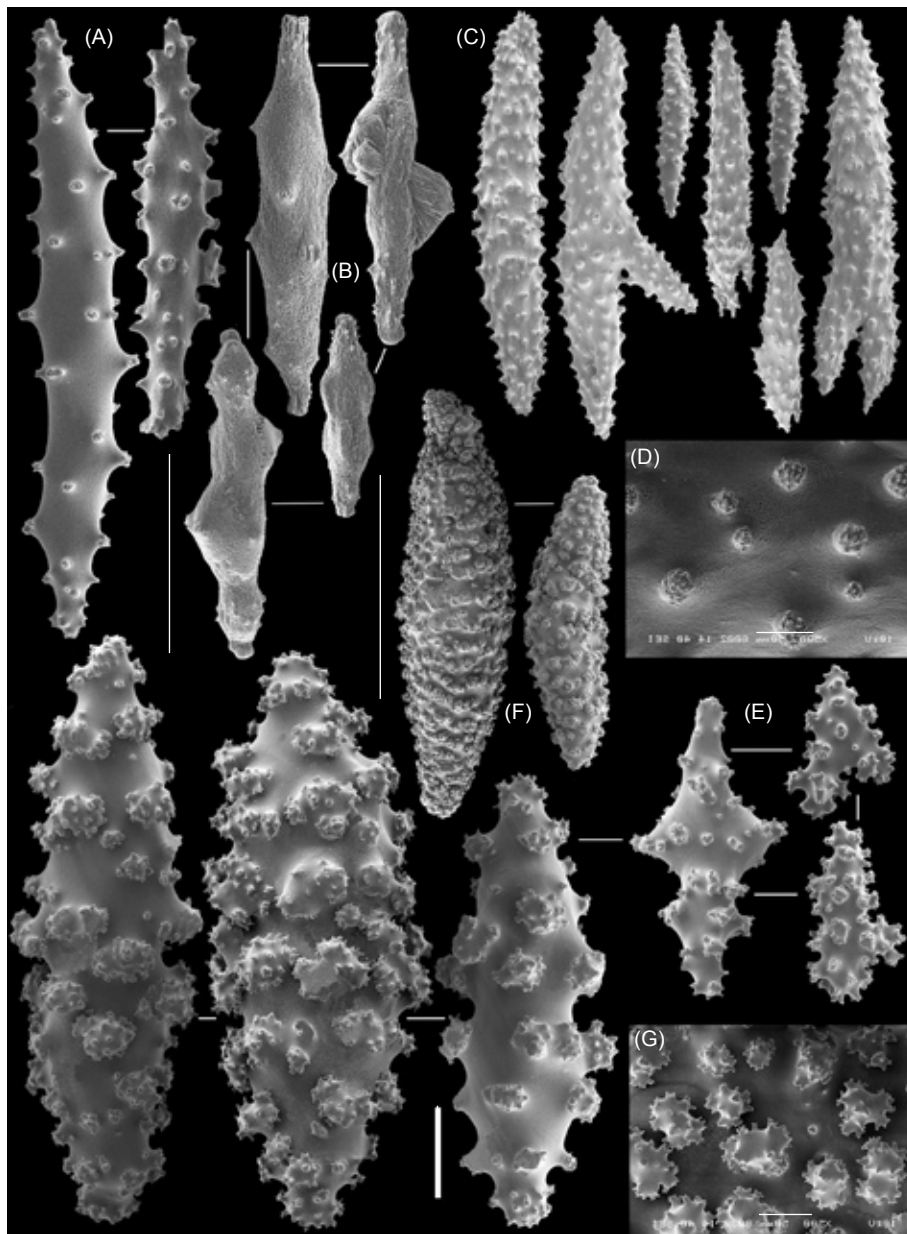
*Remarks:* *Sinularia soongi* sp. nov. belongs to *Sinularia* clade 2 of McFadden et al. (2009): polyps with collaret, points, and tentacle rods; clubs with an indistinct central wart because the central wart and 3 warts below it are juxtaposed. Notably, the holotype, which is part of a colony, seemed to have a stalk (Fig. 9). Other species in clade 2 with the stalked colony shape have distinctly shorter clubs on the surface of the lobules than *S. soongi*



**Fig. 11.** *Sinularia soongi* sp. nov. holotype (ZMTAU Co 33632). (A-D) Sclerites of surface layer of base; (A) rods and capstans; (B) crosses; (C) clubs; (D) spindles. Scale bar = 0.10 mm.

sp. nov. In *S. grandilobata* Verseveldt, 1980, the clubs are up to 0.10 mm long, and in *S. capricornis* Dautova et al., 2010 they are up to 0.18 mm long, compared to up to 0.25 mm in the newly described species (Fig. 10D). Species with the encrusting growth form in clade 2 include *S. parva* Tixier-Durivault, 1970 which has clubs up to 0.30 mm and some even 0.40 mm long (see Verseveldt 1980). Similarly, *S. muqebblae* Verseveldt and Benayahu, 1983 has clubs up to 0.32 mm long, with a narrow

head, and a slender, pointed handle compared to those of *S. soongi* sp. nov. Therefore, sclerites of *S. soongi* sp. nov. differ from both previously described stalked and encrusting *Sinularia* clade 2 species. Notably, *S. soongi* sp. nov. revealed a *COI* sequence that is quite similar to that of *S. capricornis*, and probably also to *S. grandilobata* and to the encrusting species, *S. loyai* Verseveldt and Benayahu, 1983, all of clade 2 (McFadden pers. comm.). It is thus concluded that *S. soongi*



**Fig. 12.** *Sinularia soongi* sp. nov. holotype (ZMTAU Co 33632). (A, B) Sclerites of surface layer of polypary; (A) spindles; (B) shuttles; (C, E, F) spindles of the colony; (C) interior of lobules; (E, F) interior of base; (D, G) tubercles on spindles. Scale bars = 0.10 mm, that in A applies to A and B; scale in E only applies to E; scale in F, 1 mm, also applies to C and F.

sp. nov. differs from all previously described species of clade 2.

## DISCUSSION

The present study provides a further contribution to the knowledge of octocorals of Taiwan, adding to that of Benayahu and Perkol (2004) and Benayahu et al. (2004). We applied classical taxonomy for species identification, and consequently the new species were assigned to their respective clade within the genera *Lobophytum* and *Sinularia*. These findings were further confirmed by molecular analyses of the *msh1* sequence for *L. hsiehi* sp. nov., *msh1* and *COI* sequences for *S. daii* sp. nov., and *COI* sequence for *S. soongi* sp. nov. (McFadden pers. comm.). This approach also improves our ability to discriminate species boundaries and facilitated description of the new species (see also McFadden et al. 2009). The suite of characters exhibited by each of the newly described species justifies their assignment as such. It is anticipated that future examination of all species of each of the *Lobophytum* and *Sinularia* clades will facilitate production of proper identification keys for these octocorals.

Prior to the current survey, the octocoral fauna of Penghu reefs had not been studied. The discovery of the new species is thus an indication of the need to further explore these reefs, which are experiencing extreme environmental conditions such as a chilling event (Hsieh et al. 2008). The occurrence of the newly described octocoral species on Penghu reefs (this study), along with an additional ~25 species (Benayahu et al. in prep.), indicates the presence of unique species assemblages there that differ from those of the relatively better-explored southern Taiwanese reefs (Benayahu et al. 2004). Further studies in the East China Sea should reveal whether the currently described new species are endemic to the Penghu region or have wider distributions.

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