

A Report on Coralliidae (Cnidaria: Octocorallia) Specimens Collected from the Emperor Seamounts with Descriptions of Three New Species

Masanori Nonaka^{1,3} and Takeshi Hayashibara²

¹Okinawa Churashima Foundation Research Center, Motobu-cho, Okinawa 905-0206, Japan

E-mail: m-nonaka@okichura.jp

²Seikai National Fisheries Research Institute, Ishigaki, Okinawa 907-0451, Japan

³Corresponding author

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Investigations were carried out on 22 deep-water octocoral specimens in the family Coralliidae sampled from the Emperor Seamounts during 2009 to 2012. The specimens were collected from 350–1100 m deep, mostly from the southernmost region of the Emperor Seamounts. Colonies were identified by visual and microscopic observation of standard morphological characters (colony size, diameters of colony base and branches, diameter and height of autozoid mound, thickness of coenenchyme and sclerite sizes, etc.) along with supporting information from molecular DNA analysis. Half of the 22 specimens were identified as *Pleurocorallium* cf. *pusillum* (Kishinouye, 1903), suggesting that the species called “Mid” that was once harvested dominantly in this area was this species. The remaining 11 specimens were identified as genus *Hemicorallium* Gray, 1867. These were identified as belonging to the following species: one previously described species [*H. laauense* (Bayer, 1956)], three similar species [*H. cf. abyssale* (Bayer, 1956), *H. cf. regale* (Bayer, 1956), *H. cf. sulcatum* (Kishinouye, 1903)] and three new species (*H. kaiyo* sp. nov., *H. muzikae* sp. nov. and *H. tokiyasui* sp. nov.).

Key Words: Coralliidae, the Emperor Seamounts, *Hemicorallium*, *Pleurocorallium*.

Introduction

Species in the family Coralliidae (Octocorallia: Alcyonacea) are known as precious corals, because their colorful and hard axial skeletons have been valuable for use as jewelry, medicine and other products for nearly 5000 years (Grigg 1984). The original precious coral—*Corallium rubrum* (Linnaeus, 1758)—was initially collected from the Mediterranean Sea (Grigg 1974). Other species of precious coral have been collected from Japanese waters for about 200 years (Kosuge 1993).

The first taxonomic report on Pacific Coralliidae corals was written over 150 years ago, by Dana (1846), describing *Pleurocorallium secundum* (Dana, 1846). Japanese Coralliidae species were next described by Ridley (1882) and Kishinouye (1902, 1903a, b, c, 1904, 1905). In 1956, Bayer described a number of species of Coralliidae from Hawaiian waters, and provided a key to the known species of Indo-Pacific *Corallium* (Bayer 1956). Pasternak (1981) described *P. porcellanum* (Pasternak, 1981) and *Hemicorallium boshuense* (Kishinouye, 1903) in the Marcus-Necker Sea Mounts near Hawaii. Bayer and Cairns (2003) established the genus *Paracorallium* Bayer and Cairns, 2003 in the family Coralliidae, and transferred seven described species to this genus. Using their 2003 revised generic system, Nonaka and Muzik (2010) reviewed the past studies of Indo-Pacific

species of Coralliidae. Tu et al. (2012) described two new species from Taiwan, and Nonaka et al. (2012) described two new species from Japan. Ardila et al. (2012), using molecular analyses, recognized *Paracorallium* as a junior synonym of *Corallium* Cuvier, 1798 and proposed to use the genus *Hemicorallium* Gray, 1867, for species having tentacles with long rod sclerites, cylindrical autozoid mounds and smooth axes. Figueroa and Baco (2014) concluded that *Paracorallium* should be subsumed into *Corallium* and resurrected the genus *Pleurocorallium* Gray, 1867. Tu et al. (2015b) revised the three genera of Coralliidae: *Corallium* (having strong longitudinally grooved axes with pits usually raindrop-shaped especially near branch tips), *Hemicorallium* (having tentacles with long rod sclerites, cylindrical autozoid mounds and smooth axes) and *Pleurocorallium* (having hemispherical autozoid mounds and axes without raindrop-shaped pits). Recently, Tu et al. (2016) described one new species from Hawaii and four from New Caledonia, and suggested *Pleurocorallium kishinouyei* (Bayer, 1996) was a junior synonym of *P. porcellanum*. They concluded that there were 7 species in the genus *Corallium*, 18 species in *Hemicorallium* and 17 species in *Pleurocorallium*, for a total of 42 species in the family Coralliidae (Tu et al. 2016).

The Emperor Seamount Chain (Fig. 1) extends about 2500 km south from the meeting of the Aleutian Trench and the Chishima-Kamchatka Trench, connecting to the Hawaiian Ridge that extends southeastward about 3500 km (Sugi-

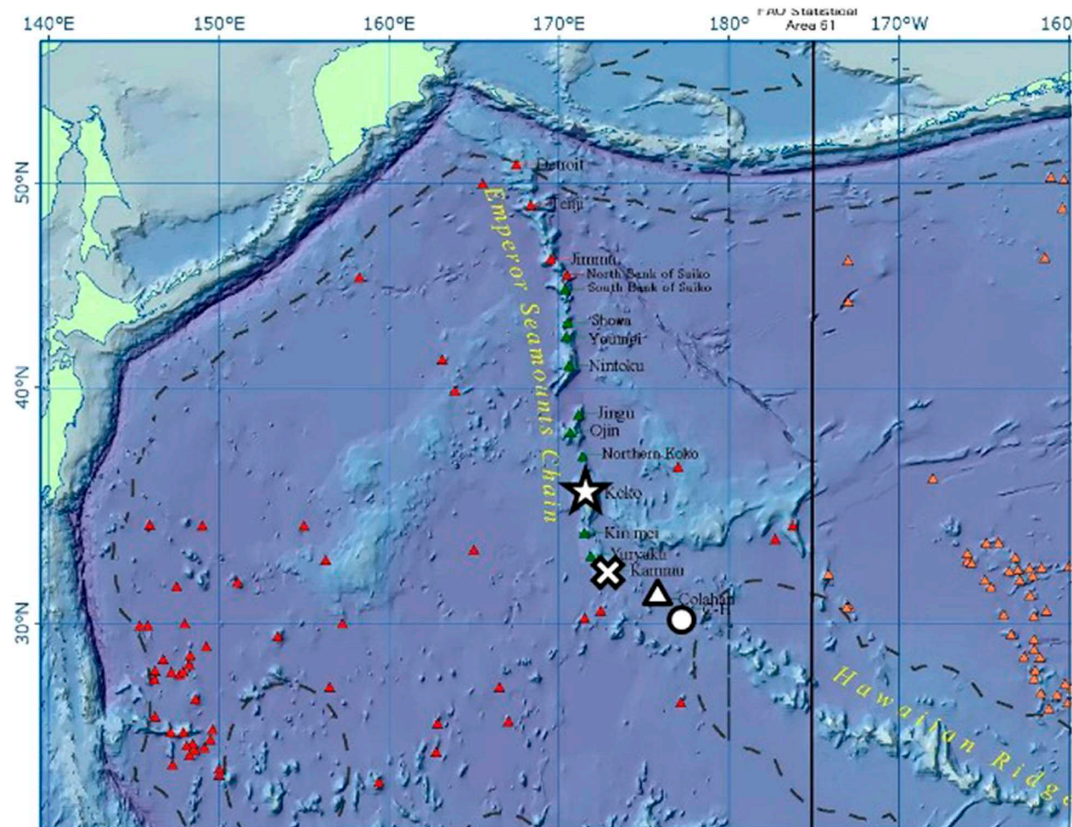


Fig. 1. Regions of 2009–2012 collections of the Coralliidae colonies in the Emperor Seamounts Chain. Star, Koko Seamount; cross, Kanmu Seamount; triangle, Colahan Seamount; circle, C-H Seamount.

Table 1. List of specimens described in this study.

Specimen	Species	Sampling data				
		Date	Site	Latitude	Longitude	Depth (m)
NSMT-Co 1717	<i>Pleurocorallium</i> cf. <i>pusillum</i>	31 May 2009	Kanmu S. Mt.	32°15'10"N	172°43'70"E	350–800
NSMT-Co 1718	<i>Pleurocorallium</i> cf. <i>pusillum</i>	22 May 2009	Kanmu S. Mt.	32°14'48"N	172°45'36"E	350–800
NSMT-Co 1719	<i>Pleurocorallium</i> cf. <i>pusillum</i>	27 Apr 2009	Kanmu S. Mt.	32°14'87"N	172°45'72"E	350–750
NSMT-Co 1720	<i>Pleurocorallium</i> cf. <i>pusillum</i>	25 Mar 2009	Kanmu S. Mt.	32°14'50"N	172°45'56"E	550–610
NSMT-Co 1721	<i>Pleurocorallium</i> cf. <i>pusillum</i>	25 Mar 2009	Kanmu S. Mt.	32°14'50"N	172°45'56"E	550–610
NSMT-Co 1722	<i>Pleurocorallium</i> cf. <i>pusillum</i>	2 Sep 2009	Koko S. Mt.	35°38'80"N	171°00'20"E	404–591
NSMT-Co 1723	<i>Pleurocorallium</i> cf. <i>pusillum</i>	16 Sep 2010	Kanmu S. Mt.	32°21'30"N	172°31'10"E	563–595
NSMT-Co 1724	<i>Pleurocorallium</i> cf. <i>pusillum</i>	18 May 2010	Koko S. Mt.	35°39'80"N	171°02'90"E	446–523
NSMT-Co 1725	<i>Pleurocorallium</i> cf. <i>pusillum</i>	25 May 2010	Koko S. Mt.	34°59'71"N	171°58'34"E	372
NSMT-Co 1726	<i>Pleurocorallium</i> cf. <i>pusillum</i>	28 May 2010	Koko S. Mt.	34°52'23"N	171°54'25"E	415–427
NSMT-Co 1727	<i>Pleurocorallium</i> cf. <i>pusillum</i>	16 Jun 2011	Koko S. Mt.	35°33'64"N	171°15'26"E	336–410
NSMT-Co 1728	<i>Hemicorallium</i> cf. <i>abyssale</i>	4 Jun 2010	C-H S. Mt.	30°21'68"N	177°32'83"E	1121
NSMT-Co 1729	<i>Hemicorallium</i> cf. <i>abyssale</i>	26 Jul 2012	C-H S. Mt.	30°20'92"N	177°34'13"E	861–942
NSMT-Co 1730	<i>Hemicorallium</i> <i>laauense</i>	27 May 2009	Kanmu S. Mt.	32°14'87"N	172°45'72"E	350–800
NSMT-Co 1731	<i>Hemicorallium</i> <i>laauense</i>	30 Jul 2009	Koko S. Mt.	35°41'50"N	171°01'40"E	535–579
NSMT-Co 1732	<i>Hemicorallium</i> <i>laauense</i>	9 Aug 2012	Koko S. Mt.	35°37'30"N	171°04'71"E	477–480
NSMT-Co 1733	<i>Hemicorallium</i> cf. <i>regale</i>	24 Jun 2011	Colahan S. Mt.	31°02'24"N	175°54'99"E	605–682
NSMT-Co 1734	<i>Hemicorallium</i> cf. <i>sulcatum</i>	20 Aug 2009	Koko S. Mt.	35°39'90"N	171°01'00"E	521–569
NSMT-Co 1735	<i>Hemicorallium</i> cf. <i>sulcatum</i>	9 Aug 2012	Koko S. Mt.	35°37'30"N	171°04'71"E	477–480
NSMT-Co 1737	<i>Hemicorallium</i> <i>kaiyo</i> sp. nov.	14 Jun 2011	Koko S. Mt.	35°39'16"N	170°25'35"E	409–942
NSMT-Co 1738	<i>Hemicorallium</i> <i>muzikae</i> sp. nov.	2 Aug 2012	Colahan S. Mt.	31°02'40"N	175°55'43"E	682–712
NSMT-Co 1736	<i>Hemicorallium</i> <i>tokiyasui</i> sp. nov.	4 Sep 2009	Koko S. Mt.	35°38'50"N	171°01'40"E	414

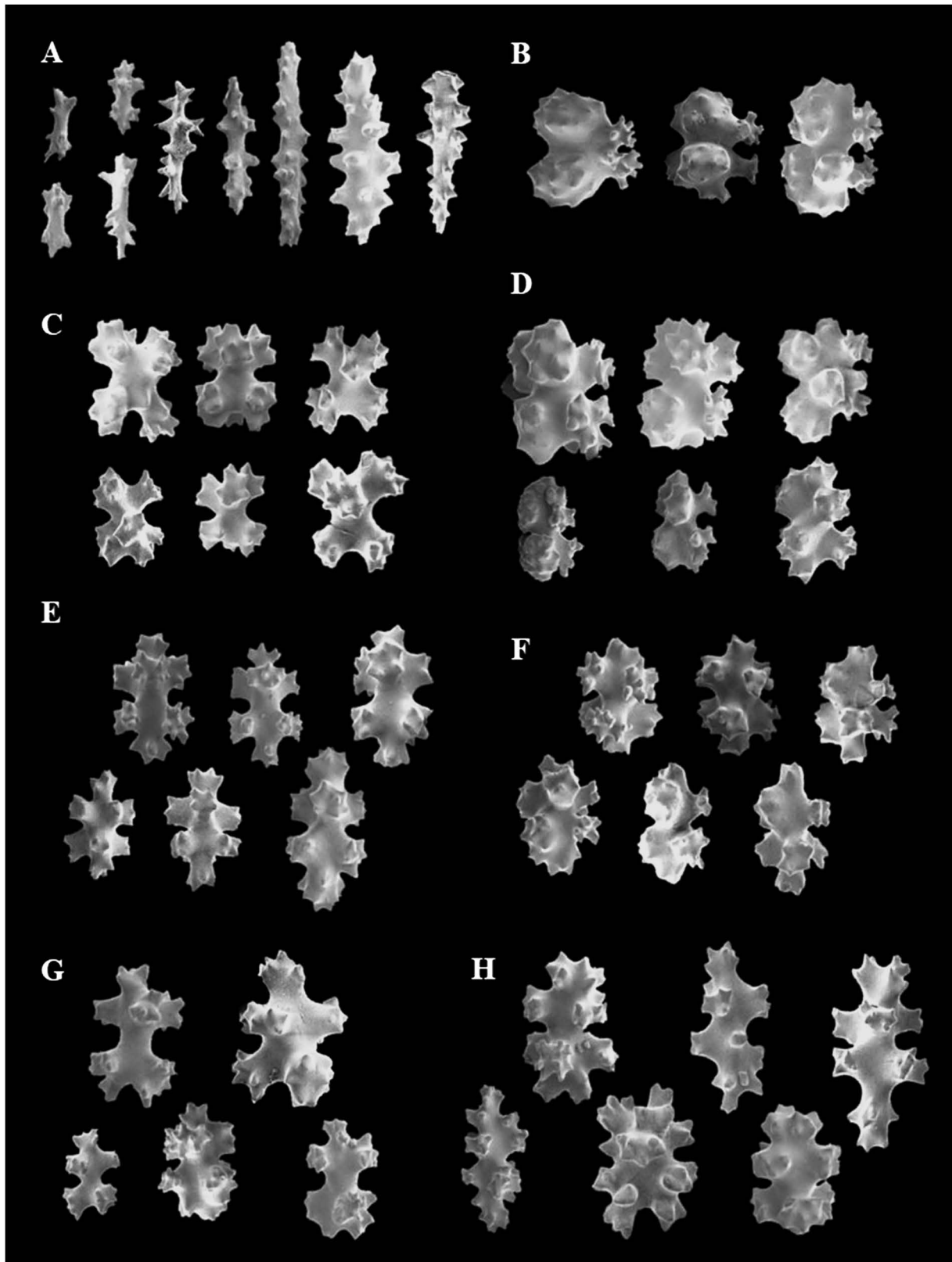


Fig. 2. Special terms used in this study for sclerites in the Coralliidae. A, Rods; B, double-clubs; C, 6-radiates (symmetric); D, 6-radiates (asymmetric); E, 8-radiates (symmetric); F, 8-radiates (asymmetric); G, 7-radiates; H, multi-radiates.

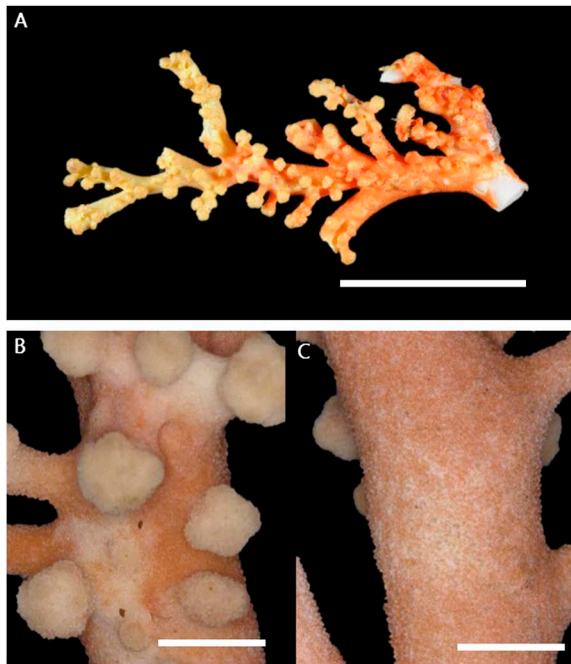


Fig. 3. *Pleurocorallium* cf. *pusillum*, NSMT-Co 1717. A, Whole specimens; B, autozoid clusters; C, opposite-side surface. Scale bars: A, 50 mm; B, C, 5.0 mm.

yama 2005). In 1965, a large coral bed was discovered on the Milwaukee Banks (Koko Seamount), a part of the Emperor Seamount Chain, 750 km northwest of the Midway Islands (Grigg 1974, 2002). For several years, over 100 fishing boats harvested the corals (known as “Mid”) from the area, removing several hundred tons of precious coral (Grigg 1984). Baco et al. (2019) recently reported on the recovery of the marine resources in this area over the past 30–40 years. Nevertheless, there have been no taxonomic studies of the target species there. Grigg (1984) reported tentatively that *C. secundum* was found from 350–475 m deep, and also an undescribed species of *Corallium* from 1000–1500 m deep, but he provided no descriptions of their morphological characters.

The 22 specimens of Coralliidae examined in this study (Table 1) were sampled from 2009 to 2012 by the Fisheries Research Agency (FRA) of Japan, during investigations for the conservation of deep-water benthic ecosystems in the Emperor Seamounts (Miyamoto et al. 2017).

Materials and Methods

Colonies were collected from 350–1100 m in depth, mainly from the southernmost region of the Emperor Seamounts, including Koko, Kammu, Colahan and C-H Seamounts (Fig. 1; Table 1). Samples were photographed along with a cm scale, and preserved in 99.5% ethanol. They were deposited in the National Museum of Nature and Science, Tokyo (NSMT).

The specimens were observed by naked eye and digital microscope (Keyence VHX). Measurements of colony size,

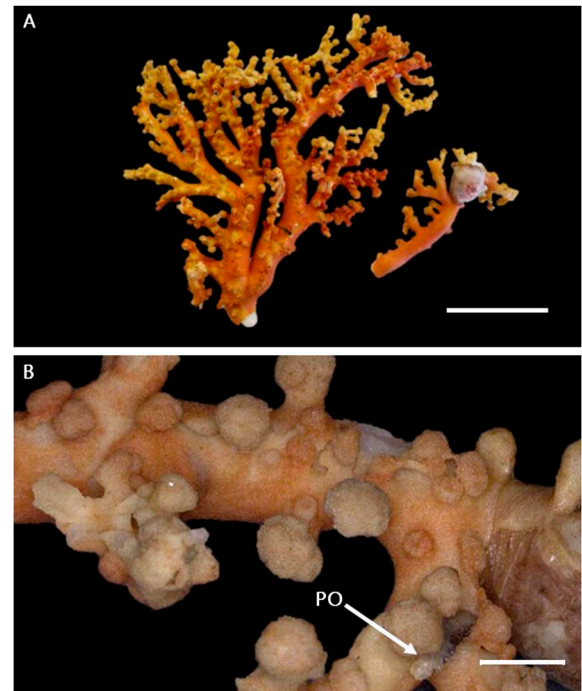


Fig. 4. *Pleurocorallium* cf. *pusillum*, NSMT-Co 1718. A, Whole specimens; B, autozoid clusters. Abbreviation: PO, commensal polychaete. Scale bars: A, 50 mm; B, 5.0 mm.

diameters of colony base and branches, diameter and height of autozoid mounds (contracted autozoid covered with coenenchyme) and thickness of coenenchyme, etc., were made with measurement software, accessorized with the Keyence VHX, and Image J software. Small pieces of coenenchyme were removed by hand with a dissecting needle from the four colony parts (tentacles, autozoid mounds, branch tips and colony base) for sclerite examination. For scanning electronic microscope examination, sclerites were separated and cleaned using 5% sodium hypochlorite solution (household bleach), and details of sclerites were observed with Keyence VE-8800.

The sclerites were classified according to standard taxonomic convention (Bayer 1956; Bayer et al. 1983). They were distinguished from each other by the number of their projections, for example 6-radiates (Fig. 2C, D), 7-radiates (Fig. 2G) and 8-radiates (Fig. 2E, F). With more than eight projections, the sclerites were called multi-radiates (Fig. 2H). Sharp sclerites with undeveloped projections were called “rods” (Fig. 2A). In addition, for this study, 6-radiates and 8-radiates were subdivided into the following two types; “symmetric” and “asymmetric” (Fig. 2C–F). Asymmetric 6-radiates (Fig. 2D) were intermediate between symmetric 6-radiates (Fig. 2C) and double-clubs (Fig. 2B). Double-clubs were identified by clearly having “two handles”. In addition to the sclerites shown in Fig. 2, crosses, 5-radiates and other shapes were found. All sclerites were shown in the pie charts (e.g., Figs 9, 11), but not common ones (less than 10%) of them were excluded from the tables (Tables 3–7). All sclerites were photographed by SEM and length and widths measured with SEM accessory software. Important taxonomic characters such as dimensions of

Table 2. Summary of measurements of taxonomic characters for each specimen examined. Measurements reported are the average \pm standard deviation (N=number of measurements) in mm. Statistical data represents measurements of 5 or more samples; for fewer than 5, measurements are reported as “about.”

Specimen	Species	Diameter of autozoid	Height of autozoid	Diameter of siphonozooids	Coenenchyme thickness	Diameter of warts	Interval between axial grooves
NSMT-Co 1717	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.58 \pm 0.14 (N=73)	0.50 \pm 0.06 (N=6)	0.07 \pm 0.01 (N=13)	—	about 0.18	about 0.36
NSMT-Co 1718	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.54 \pm 0.14 (N=92)	about 0.50	0.07 \pm 0.02 (N=13)	—	0.20 \pm 0.02 (N=28)	0.38 \pm 0.04 (N=5)
NSMT-Co 1719	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.49 \pm 0.11 (N=33)	0.47 \pm 0.04 (N=8)	0.08 \pm 0.03 (N=11)	0.28 \pm 0.06 (N=7)	0.21 \pm 0.04 (N=7)	about 0.32
NSMT-Co 1720	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.52 \pm 0.19 (N=56)	about 0.59	—	about 0.35	0.30 \pm 0.12 (N=8)	0.36 \pm 0.04 (N=5)
NSMT-Co 1721	<i>Pleurocorallium</i> cf. <i>pusillum</i>	about 1.65	—	about 0.12	—	—	—
NSMT-Co 1722	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.69 \pm 0.16 (N=6)	about 0.49	about 0.06	—	—	—
NSMT-Co 1723	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.59 \pm 0.16 (N=29)	about 0.78	about 0.07	about 0.27	0.26 \pm 0.03 (N=7)	—
NSMT-Co 1724	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.53 \pm 0.15 (N=34)	0.75 \pm 0.20 (N=8)	about 0.08	0.27 \pm 0.03 (N=7)	0.25 \pm 0.03 (N=24)	—
NSMT-Co 1725	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.49 \pm 0.13 (N=62)	about 0.61	0.07 \pm 0.02 (N=57)	0.30 \pm 0.05 (N=6)	0.21 \pm 0.03 (N=47)	about 0.29
NSMT-Co 1726	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.46 \pm 0.22 (N=18)	about 0.59	—	—	0.20 \pm 0.02 (N=24)	about 0.23
NSMT-Co 1727	<i>Pleurocorallium</i> cf. <i>pusillum</i>	1.51 \pm 0.16 (N=26)	about 0.63	0.05 \pm 0.01 (N=57)	—	0.18 \pm 0.03 (N=5)	—
NSMT-Co 1728	<i>Hemicorallium</i> cf. <i>abyssale</i>	1.55 \pm 0.19 (N=31)	1.76 \pm 0.43 (N=5)	0.03 \pm 0.01 (N=6)	—	0.29 \pm 0.06 (N=19)	about 0.33
NSMT-Co 1729	<i>Hemicorallium</i> cf. <i>abyssale</i>	1.66 \pm 0.19 (N=14)	1.25 \pm 0.32 (N=8)	0.04 \pm 0.01 (N=14)	0.10 \pm 0.03 (N=6)	0.51 \pm 0.28 (N=20)	about 0.28
NSMT-Co 1730	<i>Hemicorallium</i> <i>laauense</i>	1.38 \pm 0.11 (N=102)	1.14 \pm 0.19 (N=8)	about 0.07	about 0.15	0.23 \pm 0.05 (N=23)	—
NSMT-Co 1731	<i>Hemicorallium</i> <i>laauense</i>	1.36 \pm 0.14 (N=18)	—	—	—	0.21 \pm 0.03 (N=10)	—
NSMT-Co 1732	<i>Hemicorallium</i> <i>laauense</i>	1.32 \pm 0.17 (N=32)	1.04 \pm 0.20 (N=16)	0.06 \pm 0.01 (N=6)	—	about 0.3	about 0.18
NSMT-Co 1733	<i>Hemicorallium</i> cf. <i>regale</i>	1.24 \pm 0.13 (N=14)	about 1.36	about 0.06	—	—	—
NSMT-Co 1734	<i>Hemicorallium</i> cf. <i>sulcatum</i>	1.25 \pm 0.19 (N=21)	about 1.04	about 0.06	—	about 0.26	about 0.34
NSMT-Co 1735	<i>Hemicorallium</i> cf. <i>sulcatum</i>	1.24 \pm 0.15 (N=16)	1.09 \pm 0.19 (N=5)	about 0.06	—	about 0.19	—
NSMT-Co 1737	<i>Hemicorallium</i> <i>kaiyo</i> sp. nov.	1.06 \pm 0.13 (N=23)	1.00 \pm 0.19 (N=9)	—	0.08 \pm 0.03 (N=14)	—	about 0.34
NSMT-Co 1738	<i>Hemicorallium</i> <i>muzikae</i> sp. nov.	1.08 \pm 0.09 (N=31)	0.99 \pm 0.20 (N=11)	0.08 \pm 0.03 (N=5)	0.13 \pm 0.02 (N=24)	about 0.23	about 0.32
NSMT-Co 1736	<i>Hemicorallium</i> <i>tokiyasui</i> sp. nov.	1.00 \pm 0.12 (N=52)	1.10 \pm 0.26 (N=14)	about 0.06	0.06 \pm 0.02 (N=17)	0.20 \pm 0.02 (N=11)	—

contracted autozooids, coenenchyme thickness and sclerite sizes were measured many times, but only the size range (average \pm standard deviation) is reported in the descriptions and tables. Identifications by morphology for each species follow original descriptions and the taxonomic keys by Bayer (1956), Nonaka et al. (2012) and Tu et al. (2016).

For molecular data, DNA was extracted from the tissues of 22 ethanol-preserved samples (Table 1) by using a

DNeasy Blood & Tissue Kit for animals (QIAGEN, Tokyo, Japan). The intergenic region between mitochondrial ND6-COI region (IGR1) was used for this study, because it is a good marker for species level identification in Coralliidae (Tu et al. 2015b). Polymerase chain reaction (PCR) amplifications were carried out using the primer pairs for IGR1 as in Tu et al. (2015b), with the following thermal cycle conditions: 1 cycle of 2 min. at 94°C and 30 cycles of 10 sec.



Fig. 5. *Pleurocorallium* cf. *pusillum*, NSMT-Co 1718. A, Burrow of a commensal polychaete; B, surface with coenenchyme and denuded axis. Scale bars: 1.0 mm.

at 98°C, 30 sec. at 65°C, and 30 sec. at 74°C. The amplified PCR products were checked by 2.0% agarose gel electrophoresis. The amplified DNA fragments were sequenced in both directions by FASMAC Co. Ltd. (Kanagawa, Japan).

New sequences obtained were deposited in GenBank using the NCBI web site (<https://www.ncbi.nlm.nih.gov>). The nucleotide sequences of the IGR1 gene from samples were separately aligned by NCBI and Clustal Omega (<http://www.ebi.ac.uk/Tools/msa/clustalo>). Phylogenetic reconstruction on the resulting IGR1 alignment was carried out using three methods: Neighbor-Joining (NJ), Maximum Likelihood (ML) and Bayesian inference (BI). Neighbor-Joining (NJ) and Maximum Likelihood (ML) tree was reconstructed by MEGA 7.0.14 software (<https://www.megasoftware.net>) under the T92+G (Tamura 3-parameter+Gamma distribution) model with 1000 bootstrap replications. The best evolutionary models for the dataset were determined using the "Find best DNA model" tool of MEGA 7.0.14. The Bayesian inference (BI) analyses were performed on the same dataset using MrBayes version 3.1.2. The Markov-Chain Monte-Carlo (MCMC) process was run with four chains for 3000000 generations, with trees being sampled every 100 generations. The first 7500 trees were discarded as burn-in. Genetic pairwise distances (uncorrected p-distances) were calculated for IGR1 sequences using MEGA 7.0.14.

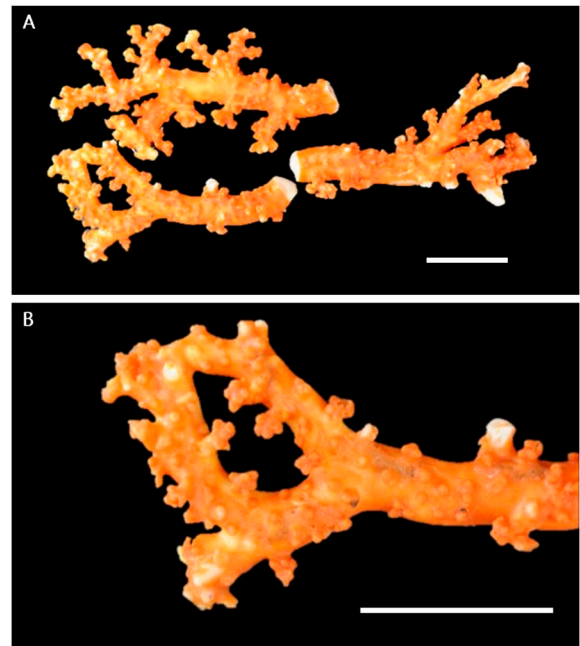


Fig. 6. *Pleurocorallium* cf. *pusillum*, NSMT-Co 1724. A, Specimen branches; B, branch tip with anastomoses. Scale bars: 30 mm.

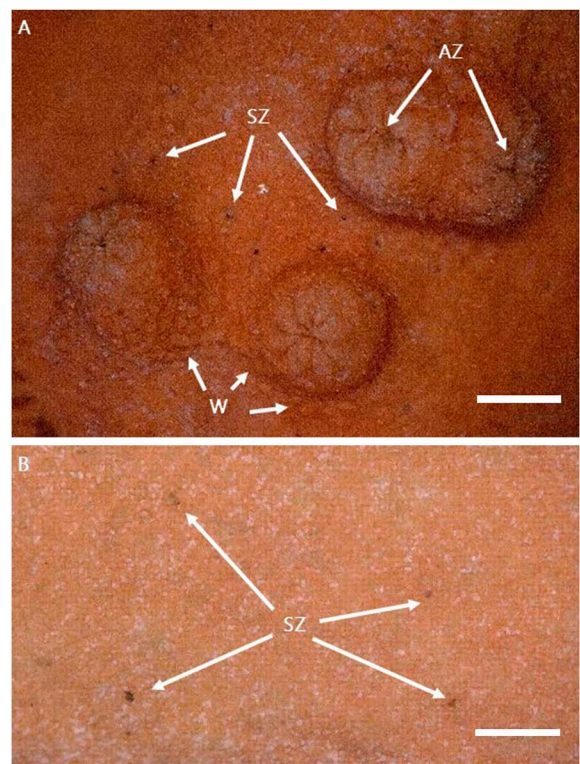


Fig. 7. The distribution of autozooids and siphonozooids of *Pleurocorallium* cf. *pusillum*. A, Autozooid side of NSMT-Co 1725; B, opposite side of NSMT-Co 1718. Abbreviations: AZ, autozooids; SZ, siphonozooid; W, wart. Scale bars: 1.0 mm.

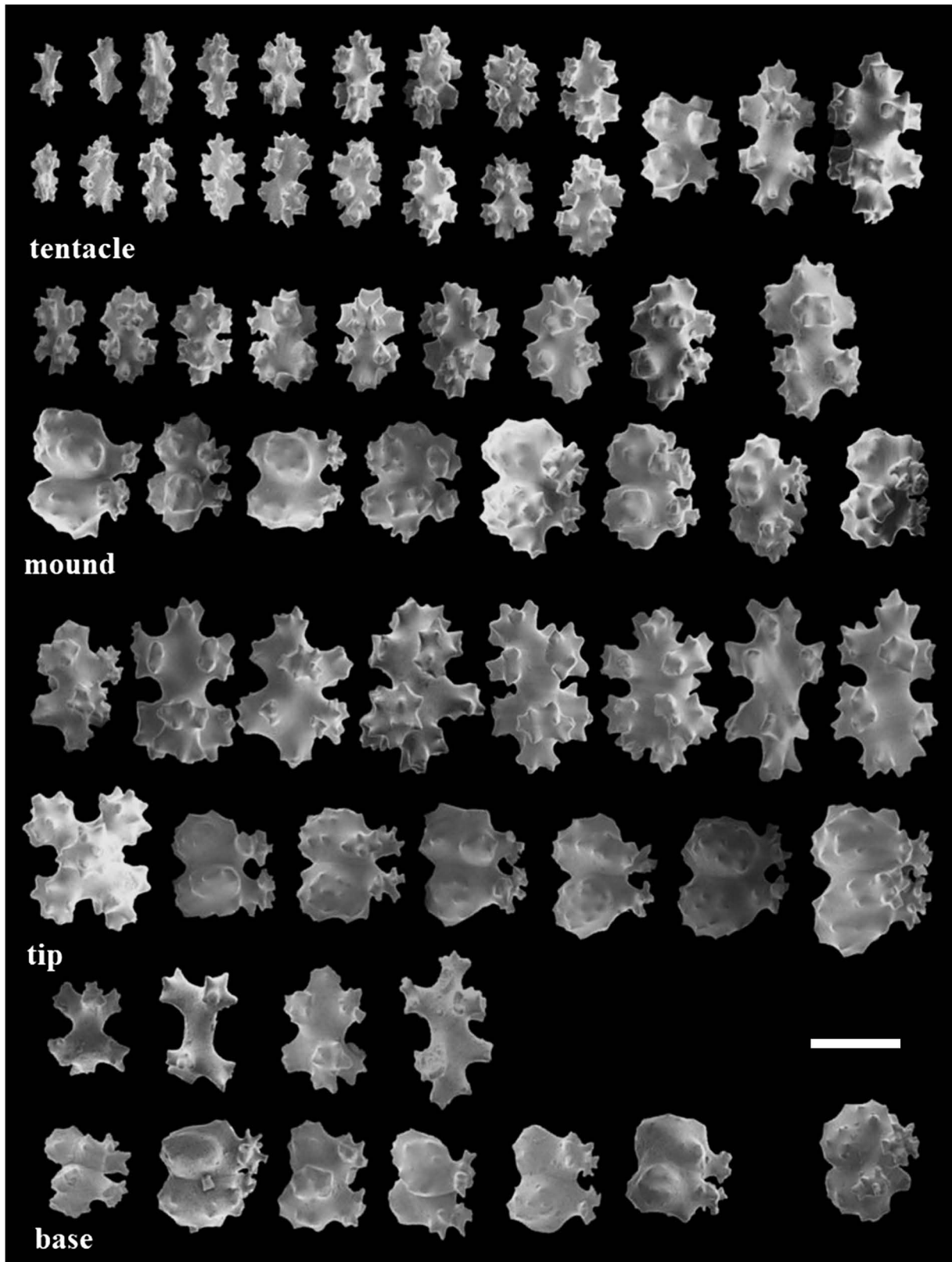


Fig. 8. *Pleurocorallium cf. pusillum*, NSMT-Co 1717. Sclerites: from tentacles, autozooid mounds, branch tip and colony base. Scale bar: 0.05 mm.

Systematic Descriptions

Pleurocorallium cf. pusillum (Kishinouye, 1903c)

(Figs 3–13; Tables 2, 3)

Corallium pusillum Kishinouye, 1903c: 372 (in Japanese); Kishinouye 1904: 29, pl. 5, figs 3, 4, pl. 7, fig. 4 (in Japanese); Kishinouye 1905: 27–28, pl. 5, figs 3, 4, pl. 7, fig. 4; Kukenthal 1924: 50; Bayer 1956: 76 (in key); Imahara 1996: 28 (in list); Nonaka and Muzik 2010: 95–96, figs 17–19; Tu et al. 2012: 5 (in key); Nonaka et al. 2012: 5 (in key); Nonaka and Muzik 2012: 79 (in key), table 1.

Pleurocorallium pusillum: Tu et al. 2015b: 181 (in list); Tu et al. 2016: 1036 (in key), table II; Nonaka and Muzik 2016: 16 (in list).

Material examined. NSMT-Co 1717, Kanmu Seamount, 350–800 m, 31 May 2009; NSMT-Co 1718, Kanmu Seamount, 350–800 m, 22 May 2009; NSMT-Co 1719, Kanmu Seamount, 350–750 m, 27 April 2009; NSMT-Co 1720, Kanmu Seamount, 550–610 m, 25 March 2009; NSMT-Co 1721, Kanmu Seamount, 550–610 m, 25 March 2009; NSMT-Co 1722, Koko Seamount, 404–591 m, 2 September 2009; NSMT-Co 1723, Kanmu Seamount, 563–595 m, 16 September 2010; NSMT-Co 1724, Koko Seamount, 446–523 m, 18 May 2010; NSMT-Co 1725, Koko Seamount, 372 m, 25 May 2010; NSMT-Co 1726, Koko Seamount, 415–427 m, 28 May 2010; NSMT-Co 1727, Koko Seamount, 336–410 m, 16 June 2011 (Table 1).

Diagnosis. Colony is in one plane with a few anastomoses. Branching in an asymmetrically dichotomous manner, at acute to right angles. Contracted autozooids making hemispherical mounds, distributed on only one side of the colony, about 1.5 mm in diameter and 0.6 mm in height, sometimes forming clusters of over four or five on the twigs. Coenenchyme is about 0.3 mm thick, with small but distinct warts. Almost orange in color, and yellowish on branchlets. Some commensal polychaete burrows with I or T-shaped openings are found on the surface. Axis is stout, no pits underneath autozooids, surface with longitudinally grooved, white in color. Tentacles contain small (about 0.05 mm long) 8-radiates and rods, coenenchyme contains mainly double-clubs, 6-radiates, 8-radiates and multi-radiates. 8-radiates are about 0.09 mm long.

Description of the 11 specimens examined. Colony form. The specimens include large branches (NSMT-Co 1718, NSMT-Co 1719, NSMT-Co 1722, NSMT-Co 1723, Fig. 4A), and small fragments (NSMT-Co 1717, NSMT-Co 1720, NSMT-Co 1721, NSMT-Co 1724, NSMT-Co 1725, NSMT-Co 1726, NSMT-Co 1727, Figs 3A, 6A). The colonies branch in one plane in an asymmetrically dichotomous manner, with a few anastomoses (NSMT-Co 1724; Fig. 6B). Angles of branching are acute to right. Almost all colonies are wider than tall, curving backward (opposite the side with autozooids). The branchlets are thick and rounded. The thickest part is more than 4 mm in diameter, and the thinnest is about 2 mm in diameter. The cross sections of main

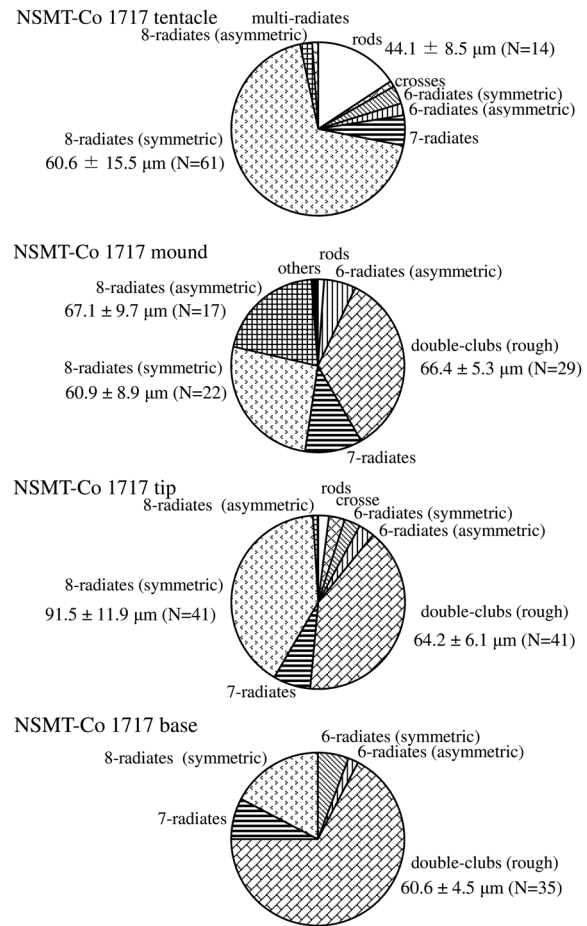


Fig. 9. *Pleurocorallium cf. pusillum*, NSMT-Co 1717. Composition of sclerites from each part sampled.

branches are rounded.

Polyps. The autozooids are retracted into the coenenchyme, making hemispherical mounds. These mounds are distributed on only one side of the colony (Fig. 3B, C) and sometimes make clusters of over four or five (Figs 3B, 4B). They are denser on the branchlets than on the base of the colony (Fig. 4A). They are 1.46–1.69 mm in diameter and 0.47–0.78 mm high (Table 2). Siphonozooids are invisible to the naked eye (Fig. 7), forming minute pits 0.05–0.12 mm in diameter (Table 2), distributed randomly on the both sides (Fig. 7).

Axis. The surface of the axis is faintly longitudinally grooved (Fig. 5B), at 0.23–0.38 mm intervals (Table 2). Removal of autozooid mounds in order to collect the sclerites from the tentacles and the autozooids confirmed that there are no rounded pits on the surface of the axis at the position of the autozooids.

Coenenchyme. The coenenchyme is 0.27–0.35 mm thick (Table 2) and the longitudinal axial grooves are not visible through it (Figs 5B, 7). There are small and inconspicuous warts 0.18–0.30 mm in diameter (Table 2) distributed mainly on the sides of autozooids (Fig. 7A). Some commensal polychaete burrows with I or T-shaped openings are found on the surface of the autozooids (Figs 4B, 5A).

Color. The dry coenenchyme is red to orange and yellow-

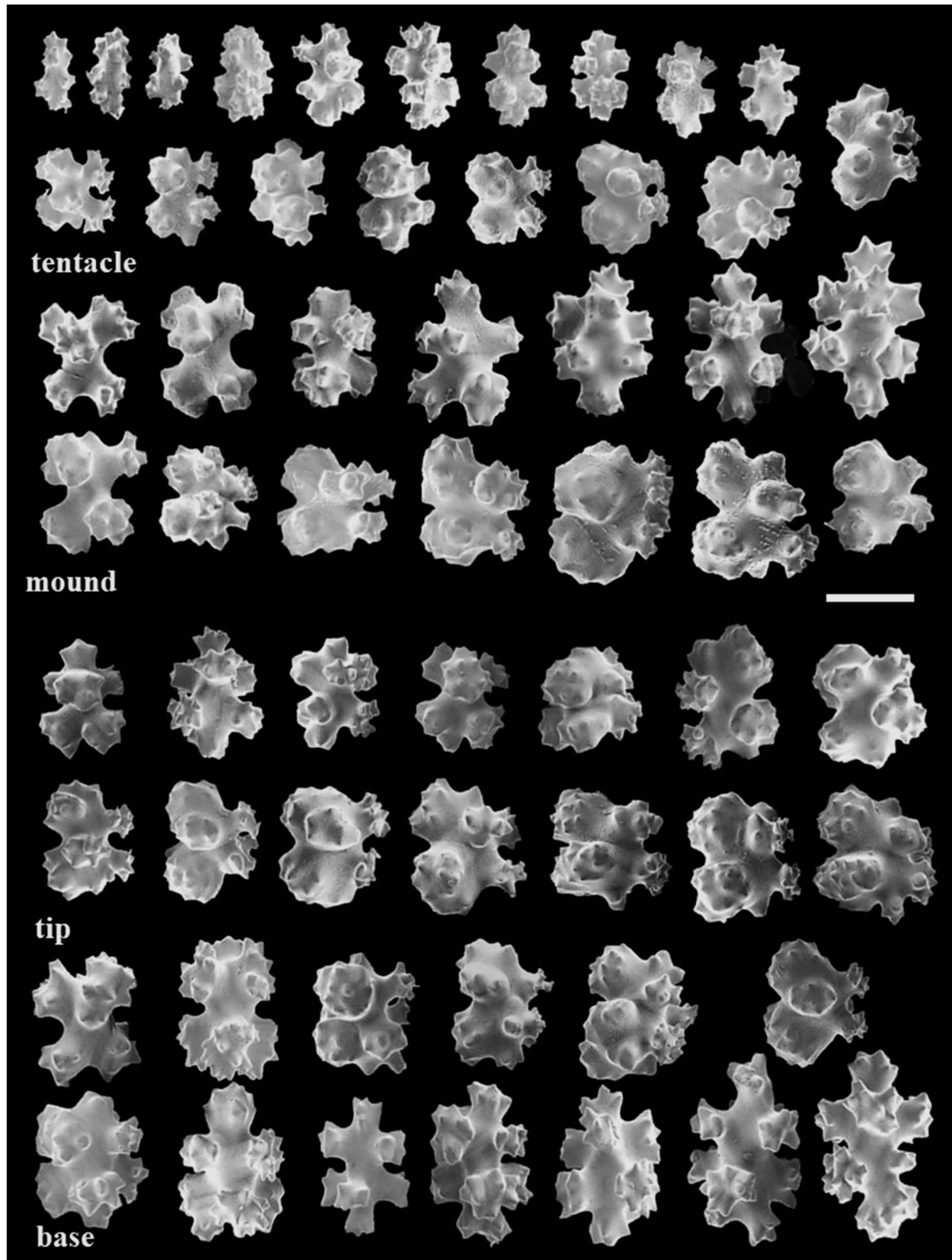


Fig. 10. *Pleurocorallium cf. pusillum*, NSMT-Co 1724. Sclerites: from tentacles, autozoid mounds, branch tips and colony base. Scale bar: 0.05 mm.

ish on branchlets (Figs 3–7). The axis is white (Fig. 5B).

Sclerites. The tentacles contain mainly small symmetric 8-radiates (ranging from 13–69%; 0.046–0.065 mm long, 0.027–0.042 mm wide), multi-radiates (12–39%; 0.047–0.056 mm long, 0.026–0.034 mm wide) and a few rods, asymmetric 6-radiates, 7-radiates and asymmetric 8-radiates (Figs 8–13; Table 3).

The autozoid mounds contain mainly symmetric 8-radiates (21–47%; 0.061–0.092 mm long, 0.038–0.060 mm width), asymmetric 6-radiates (12–32%; 0.062–0.070 mm long, 0.051–0.061 mm wide) and double-clubs with a rough surface (16–38%; 0.061–0.075 mm long, 0.049–0.061 mm wide). A few 7-radiates and asymmetric 8-radiates are present (Figs 8–13; Table 3).

The branch tips contained mainly double-clubs with a rough surface (19–66%; 0.062–0.075 mm long, 0.053–0.060 mm wide), asymmetric 6-radiates (20–51%; 0.061–0.069 mm long, 0.050–0.057 mm wide) and symmetric 8-radiates (18–45%; 0.072–0.094 mm long, 0.047–0.056 mm wide), and a few 7-radiates and asymmetric 8-radiates (Figs 8–13; Table 3).

The coenenchyme on the base of the colony also contains mainly double-clubs with a rough surface (11–67%; 0.057–0.070 mm long, 0.049–0.060 mm wide), asymmetric 6-radiates (10–54%; 0.056–0.070 mm long, 0.044–0.055 mm wide), and symmetric 8-radiates (11–40%; 0.070–0.092 mm long, 0.044–0.057 mm wide). There are also a few 7-radiates and asymmetric 8-radiates (Figs 8–13; Table 3). in the basal coenenchyme.

The average size of the symmetric 8-radiates is similar from all three parts (autozoid mounds, branchlets and base) of the colonies (Table 3).

Remarks. Some species belonging to genus *Pleurocorallium*, such as *P. borneense* (Bayer, 1950), *P. carusrubrum* (Tu, Dai, and Jeng, 2012), *P. clavatum* Tu, Dai, and Jeng, 2016, *P. konojoi* (Kishinouye, 1903), *P. niveum* (Bayer, 1956), *P. norfolkicum* Tu, Dai, and Jeng, 2016, *P. porcellanum*, *P. pusillum* (Kishinouye, 1903), *P. occultum* (Tu, Altuna, and Jeng, 2015) are also known to have autozoid-clusters as well as the present specimens. Of these nine species, *P. borneense*, *P. carusrubrum*, *P. pusillum* and *P. occultum* are having orange or reddish coenenchyme. However, the autozooids of *P. borneense* are distributed on all side of the branch (Bayer 1950). *Pleurocorallium carusrubrum* has smaller autozooids (about 0.4 mm in diameter), axis in crimson red, and almost no 8-radiate sclerite in its coenenchyme (Tu et al. 2012). And *P. occultum* is an Atlantic species. Therefore, the characters of these three species don't fit the present 11 specimens in this study.

In contrast, many characters of the present specimens fit the features of the original description of *P. pusillum* (Kishinouye 1903c, 1904, 1905), such as color of coenenchyme (“orange color, gradually changing to pale yellow at the terminal branches”) and axis (“white and striated”), distribution of autozoid clusters (“making small groups here and there”), diameter of autozooids (“about 1.5 mm in diameter”), presence of commensal polychaetes in burrows in the coenenchyme. Kishinouye (1905) reported “spicules of

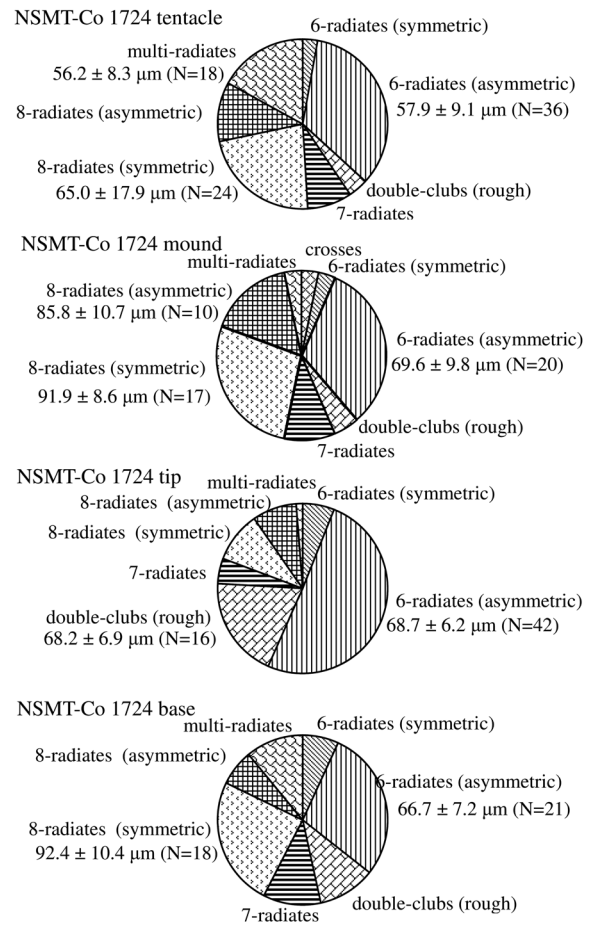


Fig. 11. *Pleurocorallium cf. pusillum*, NSMT-Co 1724. Composition of sclerites from each part sampled.

C. pusillum are the largest” in the Japanese Coralliidae he had ever studied at that time. Nonaka et al. (2012) measured the sizes of the sclerites of the Coralliidae specimens studied by Kishinouye preserved in the Smithsonian Institution, reporting that the largest sclerite was about 0.06–0.07 mm long [cross shape of *P. gotoense* (Nonaka, Muzik, and Iwasaki, 2012), or 6-radiate shape of *P. konojoi*]. In this study, large 8-radiate sclerites are about 0.07–0.09 mm long. *P. pusillum* was first described by Kishinouye (1903c), but the original specimen collected from around Izu-Ohshima Island (depth unknown) has been lost, and no further specimens have been found since then. Therefore, the identifications are tentative, and specimens of this study are reported as *P. cf. pusillum*.

The most abundant sclerites are symmetric 8-radiates and double-clubs in most of the specimens, such as NSMT-Co 1717 (Fig. 9). However, in 4 specimens (NSMT-Co 1722, NSMT-Co 1723, NSMT-Co 1724 and NSMT-Co 1726) asymmetric 6-radiates are most abundant (Fig. 11). However, the size of autozooids (Table 2) and sclerites (Table 3) are very uniform, and the other characters are also similar. Therefore, we conclude that the differences in % composition of sclerites can be attributed to intraspecific variation.

The photograph of a specimen of *Corallium secundum* in Tu et al. (2012: figure 4) showed very similar colony shape

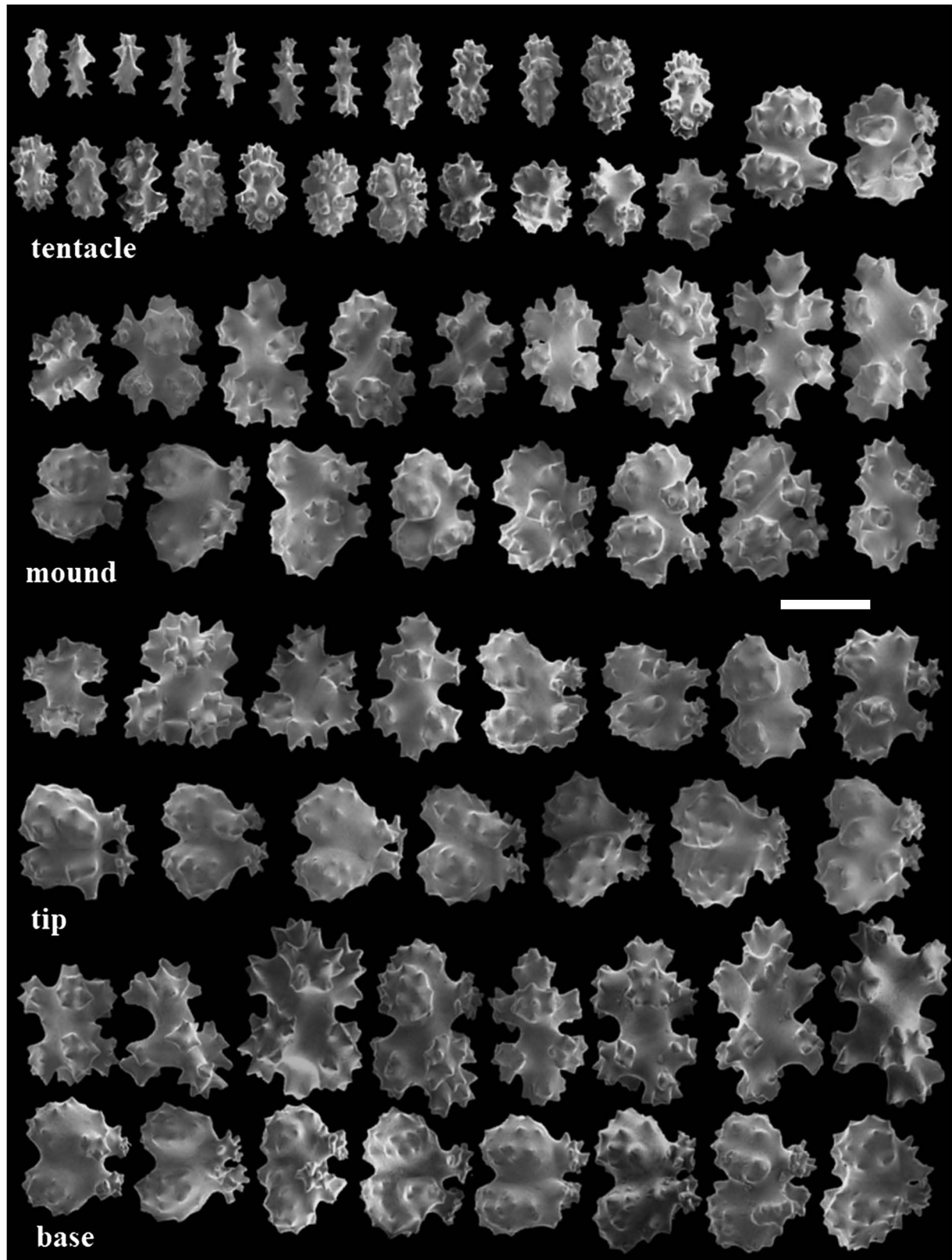


Fig. 12. *Pleurocorallium cf. pusillum*, NSMT-Co 1727. Sclerites: from tentacles, autozoid mounds, branch tips and colony base. Scale bar: 0.05 mm.

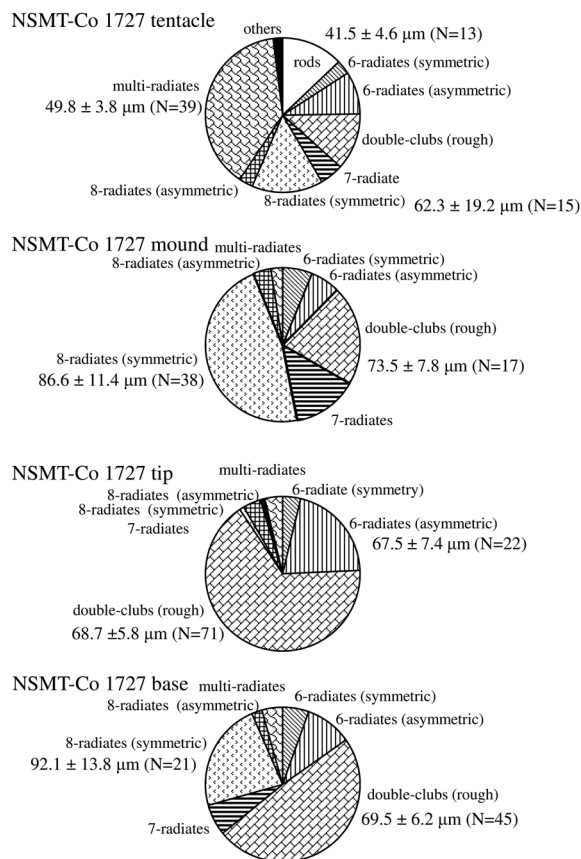


Fig. 13. *Pleurocorallium cf. pusillum*, NSMT-Co 1727. Composition of sclerites from each part sampled.

and color to the present specimens collected from the Emperor seamounts. However, Tu et al. (2012) only provided photos of a whole colony and sclerites, without any detailed descriptions (e.g., arrangement of autozooids, diameter of autozooids, size of sclerites etc.) of the specimen. The sizes of the sclerites can be inferred from the scale for the image with the length of the largest sclerite (8-radiate) being about 0.07 mm. The 8-radiate lengths of the specimens in our study average 0.08–0.09 mm (Table 3), suggesting that their specimen, USNM 1010758, is probably a different species from ours.

Bayer (1956) provided a detailed description and drawings of *P. secundum*. According to his description, some of the characters of this species are “the autozooids verrucae are evenly distributed and not clustered in groups except at the tips of the twigs where there may be two or three”, “well-formed 8-radiates are present but not common”, “the rind is salmon pink”, “the axis is pale pink, often almost white”. The diameter of the autozooids was approximately 1.0 mm, which could be inferred from the scales of his precise drawing (Bayer 1956: figs 5-d, 6-d). Because these characters of *P. secundum* do not fit our specimens, such as autozoid clusters (Figs 3B, 4B), 8-radiate sclerites (Table 3) and coenenchyme and axis color (Figs 3–7), they cannot be identified as *P. secundum*.

Since *P. pusillum* was described as “n. sp.” in Kishinouye (1904), we have reported that it was described as a new spe-

cies in 1904 (e.g. Nonaka and Muzik 2016). However, a one-page description in Japanese with this scientific name (Kishinouye 1903c) was found, and thus, the year of publication of the specific name *pusillum* is corrected in this paper.

Hemicorallium cf. abyssale (Bayer, 1956)

(Figs 14–20; Tables 2, 4)

Corallium abyssale Bayer, 1956: 76–77, figs 4, 5a, 7a–d; Nonaka and Muzik 2010: 100–101, figs 30–32; Tu et al. 2012: 5 (in key), fig. 10; Nonaka and Muzik 2012: 79 (in key), table 1.

Hemicorallium abyssale: Tu et al. 2015b: 181 (in list), table 1; Tu et al. 2016: 1035 (in key), table II; Nonaka and Muzik 2016: 16 (in list).

Material examined. NSMT-Co 1728, C-H Seamount, 1,121 m, 4 June 2010; NSMT-Co 1729, C-H Seamount, 861–942 m, 26 July 2012.

Diagnosis. Colony is zig-zag, with branching in one plane in an asymmetrically dichotomous manner. Angles of branching are acute and right. Contracted autozooids making cylindrical mounds, distributed biserially on the branches, very scarce, about 2–5 mm apart, about 1.5 mm in diameter. Siphonozooids are visible, forming small warts concentrated around the autozooids. Coenenchyme is thin, about 0.1 mm thick, pale pink in color. Axis is stout, surface with inconspicuous longitudinal grooves, reddish pink in color. Tentacles contain long (about 0.1 mm long) rods, coenenchyme contains mainly 6-radiates, 7-radiates and 8-radiates. Sclerites have rough surfaces. Inhabits depths of about 1000 m.

Description of specimen NSMT-Co 1728. Colony form. The specimen is in two parts, one the base of the colony and the other a small branch (Fig. 14A). The main stem is zig-zag, with branching in one plane in an asymmetrically dichotomous manner (Fig. 14A). Angles of branching are acute and right. The base of the colony is about 8 mm in diameter, and the sharp branchlet is about 2 mm in diameter. The cross section of the main branch is rounded.

Polyps. The contracted autozooids form cylindrical mounds in the coenenchyme (Fig. 14B). These mounds are distributed biserially on the branches, very scarcely, about 3–5 mm apart (Fig. 14B). They are 1.55 ± 0.19 mm in diameter and 1.76 ± 0.43 mm in height (Table 2). Siphonozooids are visible, forming small warts concentrated around the autozooids (Fig. 14B), 0.03 ± 0.01 mm in diameter (Table 2).

Axis. The surface of the axis is inconspicuously longitudinally grooved, the grooves visible through the thin coenenchyme (Fig. 14B), at about 0.33 mm in intervals (Table 2). There are no rounded pits on the surface of the axis at the position of each autozoid.

Coenenchyme. There are small and inconspicuous warts 0.29 ± 0.06 mm in diameter (Table 2) distributed on both sides (Fig. 14B). There is a brittle star tangled up in the branches.

Color. The dry coenenchyme is pale pink. The axis is red (Fig. 14).

Table 3. *Pleurocorallium* cf. *pusillum*. Summary of length and width of common (more than 11%) sclerites for each specimen examined. Measurements are reported the average \pm standard deviation in μm . Bold numbers indicate most abundant sclerite type. “+” means not common (less than 10%) sclerites. “–” means not found.

Specimen	Tentacles												8-radiates (asymmetrical)												Double-clubs												Multi-radiates																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
	Rods				6-radiates (symmetrical)				6-radiates (asymmetrical)				7-radiates				8-radiates (symmetrical)				Length				Width				N (%)				Length				Width				N (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
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NSMT-Co 1717	44.1±8.5	21.3±2.8	14	16																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											

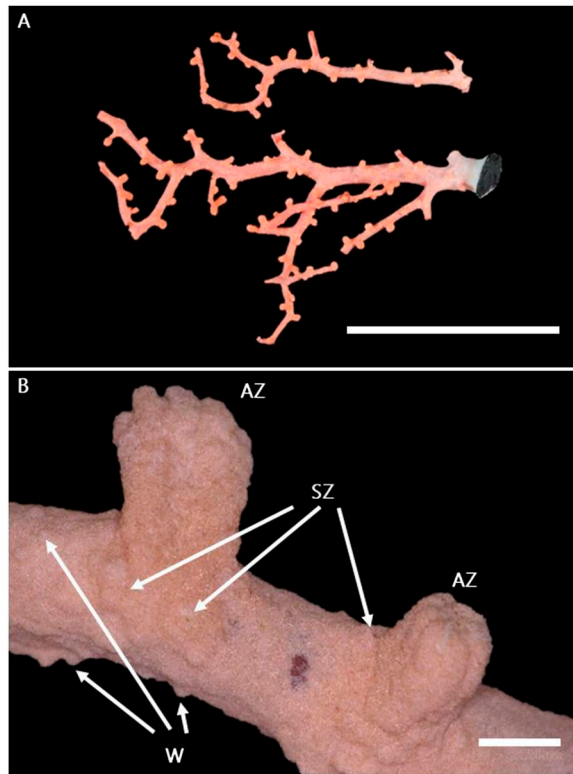


Fig. 14. *Hemicorallium* cf. *abyssale*, NSMT-Co 1728. A, Specimen branches; B, detail of coenenchymal surface. Abbreviations: AZ, autozooids; SZ, siphonozooid; W, wart. Scale bars: A, 50 mm; B, 1.0 mm.

Sclerites. The tentacles contain mainly rods (69%; 0.106 ± 0.019 mm long, 0.027 ± 0.006 mm wide), multi-radiates (15%; 0.079 ± 0.016 mm long, 0.036 ± 0.006 mm wide) and a few asymmetric 6-radiates, 7-radiates and asymmetric 8-radiates (Figs 15, 16; Table 4).

The autozooid mounds contain mainly asymmetric 6-radiates (37%; 0.063 ± 0.008 mm long, 0.039 ± 0.004 mm wide), 7-radiates (23%; 0.067 ± 0.007 mm long, 0.039 ± 0.003 mm wide), asymmetric 8-radiates (19%; 0.070 ± 0.005 mm long, 0.040 ± 0.003 mm wide). A few symmetric 6-radiates, 8-radiates and multi-radiates are present (Figs 15, 16; Table 4).

The branch tips contain mainly asymmetric 6-radiates (35%; 0.057 ± 0.004 mm long, 0.035 ± 0.002 mm wide), 7-radiates (18%; 0.063 ± 0.008 mm long, 0.038 ± 0.003 mm wide) and asymmetric 8-radiates (26%; 0.066 ± 0.008 mm long, 0.039 ± 0.003 mm wide), and a few double-clubs, symmetric 8-radiates and multi-radiates (Figs 15, 16; Table 4).

The coenenchyme on the base of the colony contains mainly asymmetric 8-radiates (48%; 0.058 ± 0.008 mm long, 0.034 ± 0.003 mm wide), with a few 6-radiates, double-clubs, 7-radiates, symmetric 8-radiates and multi-radiates (Figs 15, 16; Table 4).

Description of specimen NSMT-Co 1729. Colony form. The specimen consists of the base of the colony and four small branches without distal tips (Fig. 17A). The main stem zig-zag and branching is asymmetrically dichotomous (Fig. 17A). Angles of branching are right or acute. The base

of the colony is about 15 mm diameter, and the distal parts about 2–3 mm in diameter. The cross section of the main branch is rounded.

Polyps. The autozooids are not retracted, instead contracting to make cylindrical mounds with eight grooves on the tops (Fig. 17B). These mounds are distributed biserially on the branches, very scarce, about 2–5 mm apart (Fig. 17B). They are 1.66 ± 0.19 mm in diameter and 1.25 ± 0.32 mm in height (Table 2). Siphonozooids are visible, forming small warts tending to concentrate around the autozooids (Fig. 17B), 0.04 ± 0.01 mm in diameter.

Axis. The surface of the axis is inconspicuously longitudinally grooved, at about 0.28 mm in intervals (Table 2). There are no rounded pits on the surface of the axis at the position of each autozooid.

Coenenchyme. The coenenchyme is 0.10 ± 0.03 mm thick (Fig. 18; Table 2) and the longitudinal axial grooves are invisible through it (Fig. 17B). There are small and inconspicuous warts 0.51 ± 0.28 mm in diameter distributed on both sides (Fig. 17B). There are no commensal organisms.

Color. The dry coenenchyme is pale pink. The axis is reddish pink (Figs 17, 18).

Sclerites. The tentacles contain mainly rods (46%; 0.100 ± 0.016 mm long, 0.027 ± 0.004 mm wide), asymmetric 6-radiates (18%; 0.053 ± 0.007 mm long, 0.035 ± 0.001 mm wide) and a few symmetric 6-radiates, 7-radiates, 8-radiates and multi-radiates (Figs 19, 20; Table 4).

The autozooid mounds contain mainly asymmetric 6-radiates (33%; 0.060 ± 0.008 mm long, 0.039 ± 0.004 mm wide), 7-radiates (21%; 0.064 ± 0.007 mm long, 0.040 ± 0.002 mm wide), multi-radiates (24%; 0.074 ± 0.009 mm long, 0.038 ± 0.003 mm wide). A few symmetric 6-radiates and 8-radiates are present (Figs 19, 20; Table 4).

The branch tips contain mainly asymmetric 6-radiates (68%; 0.053 ± 0.004 mm long, 0.036 ± 0.003 mm wide), and some symmetric 6-radiates, 7-radiates and multi-radiates (Figs 19, 20; Table 4).

The coenenchyme on the base of the colony contains mainly symmetric 6-radiates (32%; 0.045 ± 0.004 mm long, 0.032 ± 0.002 mm wide), 7-radiates (31%; 0.048 ± 0.004 mm long, 0.032 ± 0.002 mm wide) with some asymmetric 6-radiates, 8-radiates and a few multi-radiates (Figs 19, 20; Table 4).

Remarks. *Hemicorallium abyssale* was described in 1956 based on a specimen collected from about 2000 m deep in Hawaii in 1902 (Bayer 1956). Tu et al. (2012) showed SEM images of sclerites from the holotype. According to these descriptions, the colony was slender, its branching alternate, producing a main stem with a zig-zag shape, with autozooids less dense than in other species, having 8-radiates and double-clubs with a smooth surface.

The present specimens (NSMT-Co 1728 and 1729) fit that of the original description, such as branching pattern autozooid arrangement, and the presence of long, blunt spindle sclerites in the tentacles, and relatively deep sampling depth (around 1000 m deep). However, the autozooids are smaller (1.5–1.7 mm in diameter, 1.2–1.8 mm in height) than those described for the holotype (about 2 mm in height). Further-

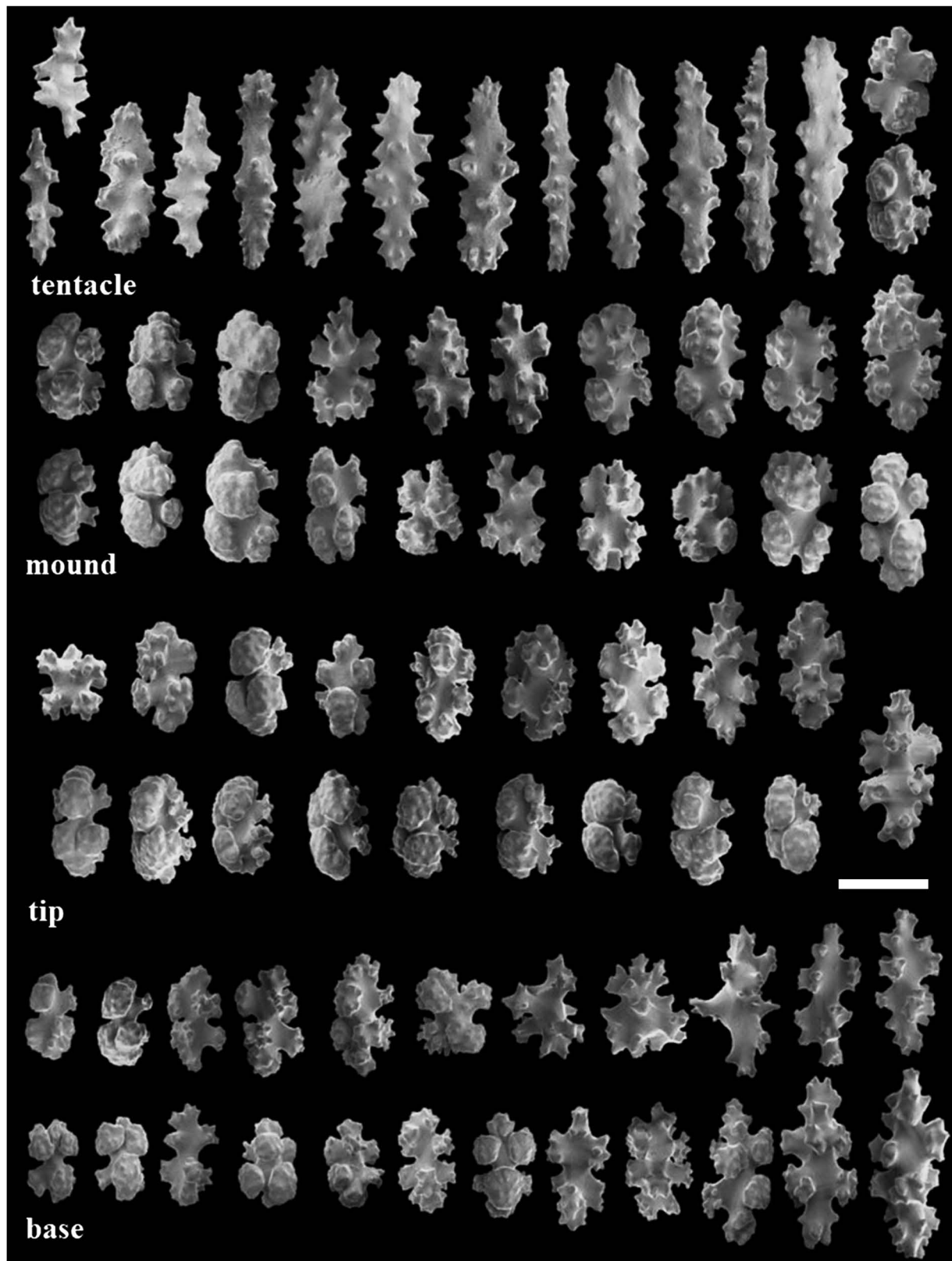


Fig. 15. *Hemicorallium cf. abyssale*, NSMT-Co 1728. Sclerites: from tentacles, autozooid mounds, branch tips and colony base. Scale bar: 0.05 mm.

diameter and 1.0 mm in height. Coenenchyme is thin, with fine granular protrusions on the surface, white in color. Axis is stout. Pale pink basally, white terminally in color. The burrows of commensal polychaetes are present on the surface of axis. Tentacles contain long (>0.1 mm long) rods, coenenchyme contains mainly 8-radiates, no double-clubs. Distributed in depths of about 350–800 m.

Description of the specimen: NSMT-Co 1730. Colony form. The specimen consists of one large base with little coenenchyme, and 7 small branches. The branching is almost in one plane, irregularly dichotomous in acute angles, without anastomoses (Fig. 21A). The base of the colony is about 20 mm wide, and the branchlets about 2 to 3 mm in diameter. The cross section of the main branch is rounded.

Polyps. The autozooids are not retracted into the coenenchyme, forming cylindrical mounds. They are distributed only on one side of the colony, about 1–3 mm apart from one other (Fig. 21B). They are 1.38 ± 0.11 mm in diameter and 1.14 ± 0.19 mm in height (Table 2). Siphonozooids are invisible to the naked eye, distributed on the side opposite the autozooids (Fig. 22), about 0.07 mm in diameter (Table 2).

Axis. The surface of the axis is very inconspicuously longitudinally grooved. There are no rounded pits on the surface of the axis at the position of each autozooid. The burrows of commensal polychaetes are present on the surface of the axis.

Coenenchyme. The thickness of the coenenchyme is about 0.15 mm (Table 2). There are small but rather conspicuous warts, 0.23 ± 0.05 mm in diameter (Table 2), distributed on both sides of the branches (Fig. 22).

Color. The dry coenenchyme is white to pale yellow. The axis is white (Figs 21, 22).

Sclerites. The tentacles contain mainly rods (44%; 0.122 ± 0.014 mm long, 0.032 ± 0.008 mm wide), symmetric 8-radiates (26%; 0.074 ± 0.005 mm long, 0.046 ± 0.003 mm wide), multi-radiates (16%; 0.085 ± 0.022 mm long, 0.043 ± 0.003 mm wide) and a few asymmetric 8-radiates, 7-radiates and others (Figs 23, 24; Table 5).

The autozooid mounds contain mainly symmetric 8-radiates (45%; 0.074 ± 0.007 mm long, 0.045 ± 0.004 mm wide), asymmetric 8-radiates (30%; 0.072 ± 0.006 mm long, 0.045 ± 0.003 mm wide), multi-radiates (13%; 0.078 ± 0.008 mm long, 0.042 ± 0.004 mm wide). A few asymmetric 6-radiate and 7-radiates are present (Figs 23, 24; Table 5).

The branch tips contain mainly asymmetric 8-radiates (56%; 0.067 ± 0.007 mm long, 0.043 ± 0.004 mm wide), symmetric 8-radiates (19%; 0.077 ± 0.014 mm long, 0.044 ± 0.004 mm wide), multi-radiates (15%; 0.092 ± 0.014 mm long, 0.050 ± 0.008 mm wide), and a few crosses, 5-radiates, 6-radiates and 7-radiates (Figs 23, 24; Table 5).

Basal sclerites are mainly asymmetric 8-radiates (55%; 0.062 ± 0.005 mm long, 0.041 ± 0.004 mm wide). Multi-radiates (18%; 0.077 ± 0.017 mm long, 0.044 ± 0.007 mm wide) and symmetric 8-radiates (13%; 0.067 ± 0.006 mm long, 0.042 ± 0.004 mm wide) are present, with a few crosses, 6-radiates, and 7-radiates (Figs 23, 24; Table 5).

Description of specimen NSMT-Co 1731. Colony

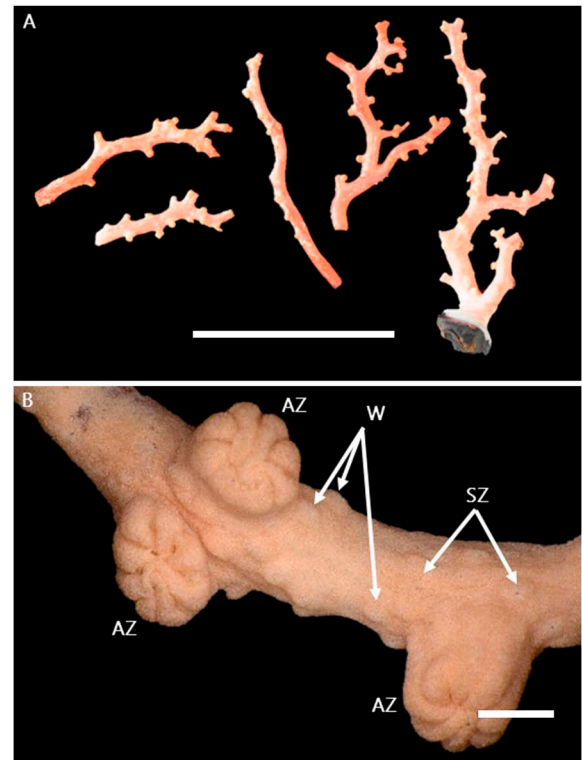


Fig. 17. *Hemicorallium* cf. *abyssale*, NSMT-Co 1729. A, Specimen branches; B, detail of coenenchymal surface. Abbreviations: AZ, autozooids; SZ, siphonozooid; W, wart. Scale bars: A, 50 mm; B, 1.0 mm.

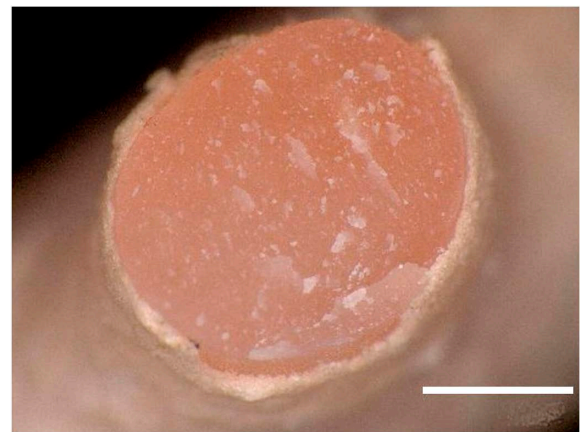


Fig. 18. A cross section of branch base of *H. cf. abyssale*, NSMT-Co 1729. Scale bar: 1.0 mm.

form. The specimen consists of two basal branches of the colony, tips missing (Fig. 25A). The branching is almost in one plane, irregularly dichotomous, with acute angles, without anastomoses (Fig. 25). The base of the colony is about 25 mm in diameter, the cross section of the main branch is rounded.

Polyps. The autozooids are not retracted into the coenenchyme, making cylindrical mounds. These mounds are distributed on only one side of the colony, about 1–3 mm apart (Fig. 25B, C). They are 1.36 ± 0.14 mm in diameter (Table 2). Siphonozooids are not evident because of the abraded con-

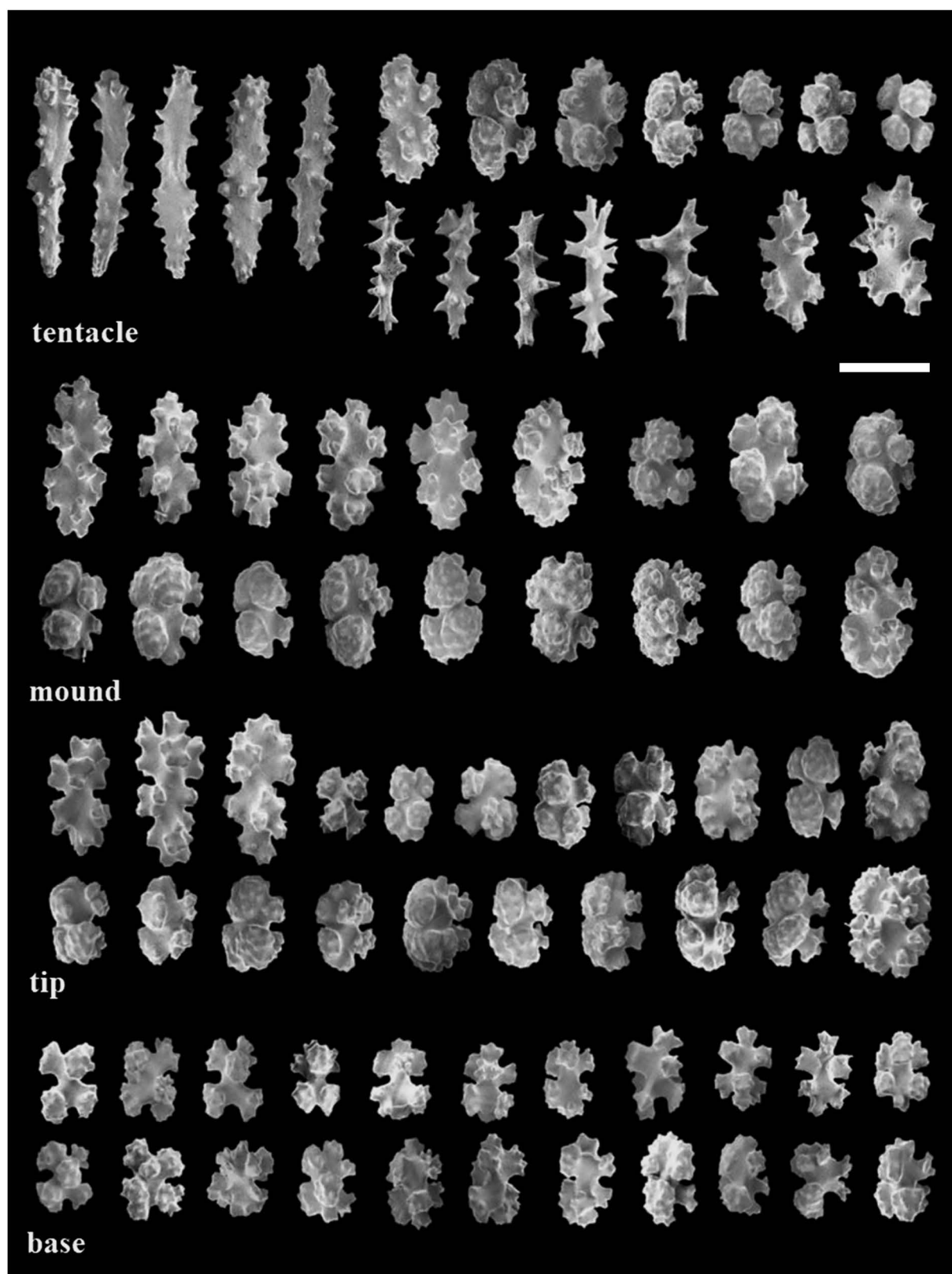


Fig. 19. *Hemicorallium cf. abyssale*, NSMT-Co 1729. Sclerites: from tentacles, autozooid mounds, branch tips and colony base. Scale bar: 0.05 mm.

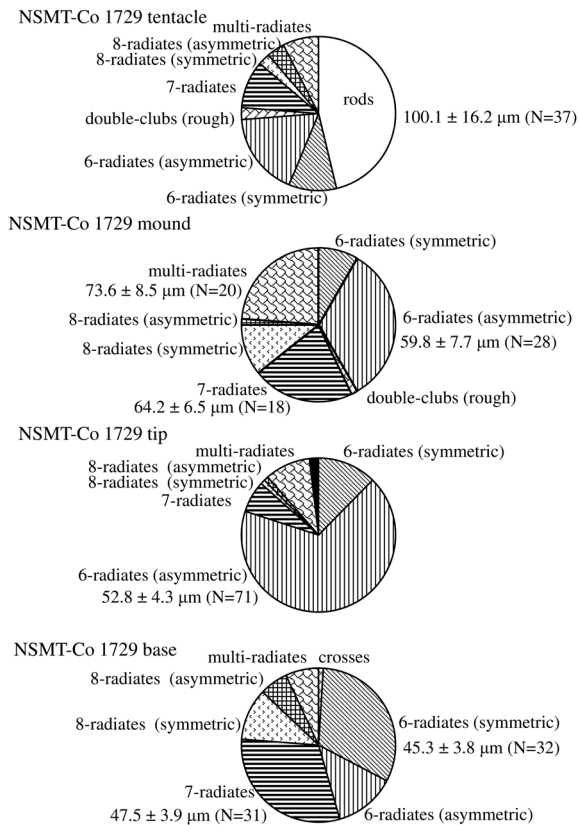


Fig. 20. *Hemicorallium* cf. *abyssale*, NSMT-Co 1729. Composition of sclerites from each part sampled.

dition of the side of the branch opposite the autozooids (Fig. 25C).

Axis. The surface of the axis is very inconspicuously longitudinally grooved. There are no rounded pits on the surface of the axis at the position of the autozooids. The burrows of commensal polychaetes are present on the surface of axis (Fig. 26).

Coenenchyme. There are small but rather conspicuous warts (Fig. 26), sized 0.21 ± 0.03 mm in diameter (Table 2) distributed on both sides of the branches. The coenenchyme above the polychaete burrows is swollen (Fig. 26).

Color. The dry specimen is white. The axis is pale pink basally, white terminally (Figs 25, 26).

Sclerites. The tentacles contain mainly rods (69%; 0.108 ± 0.015 mm long, 0.026 ± 0.005 mm wide), multi-radiates (18%; 0.083 ± 0.017 mm long, 0.037 ± 0.008 mm wide) and a few 7-radiates and 8-radiates (Figs 27, 28; Table 5).

The autozooid mounds contain mainly symmetric 8-radiates (46%; 0.075 ± 0.010 mm long, 0.043 ± 0.005 mm wide), asymmetric 8-radiates (23%; 0.074 ± 0.010 mm long, 0.043 ± 0.005 mm wide), multi-radiates (28%; 0.089 ± 0.015 mm long, 0.046 ± 0.007 mm wide). A few symmetric 6-radiate and 7-radiates are present (Figs 27, 28; Table 5).

The branch tips contain mainly asymmetric 8-radiates (36%; 0.061 ± 0.005 mm long, 0.040 ± 0.002 mm wide), symmetric 8-radiates (34%; 0.065 ± 0.010 mm long, 0.040 ± 0.004 mm wide), and a few crosses, 6-radiates, 7-radiates, multi-radiates and others (Figs 27, 28; Table 5).

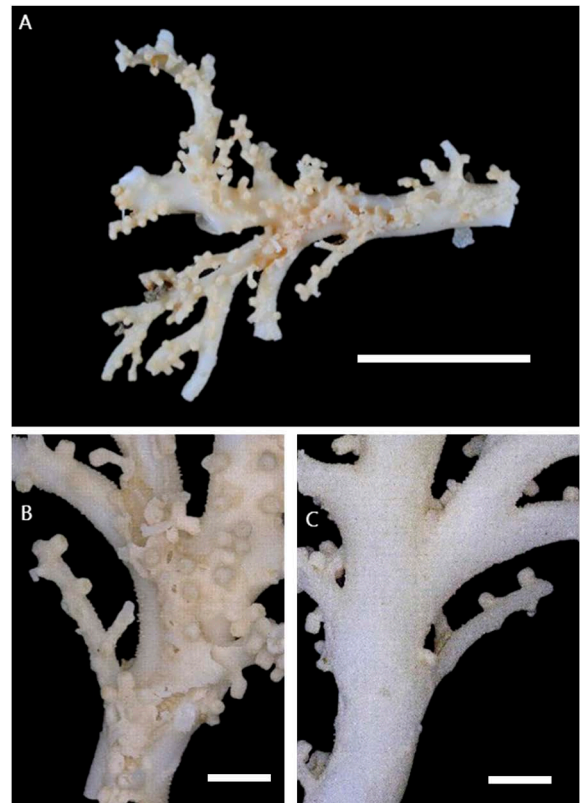


Fig. 21. *Hemicorallium laauense*, NSMT-Co 1730. A, Whole specimen; B, autozooid side surface; C, opposite side surface. Scale bars: A, 30 mm; B, C, 5.0 mm.

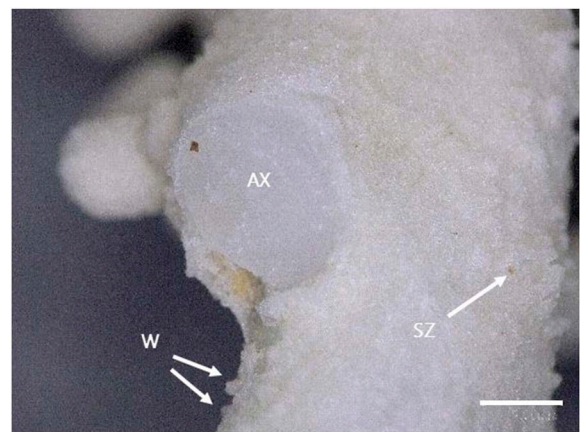


Fig. 22. Surface detail of *Hemicorallium laauense*, NSMT-Co 1730. Abbreviations: AX, axis; SZ, siphonozooid; W, wart. Scale bar: 1.0 mm.

The colony base contains mainly symmetric 8-radiates (53%; 0.058 ± 0.005 mm long, 0.036 ± 0.003 mm wide) and asymmetric 8-radiates (27%; 0.057 ± 0.005 mm long, 0.036 ± 0.003 mm wide), with a few 6-radiates, 7-radiates and multi-radiates (Figs 27, 28; Table 5).

Description of specimen NSMT-Co 1732. Colony form. The specimen consists of small branchlets of one colony (Fig. 29A), 20 to 30 mm wide. The branching is probably planar, but colony form is unknown. Branching is at acute

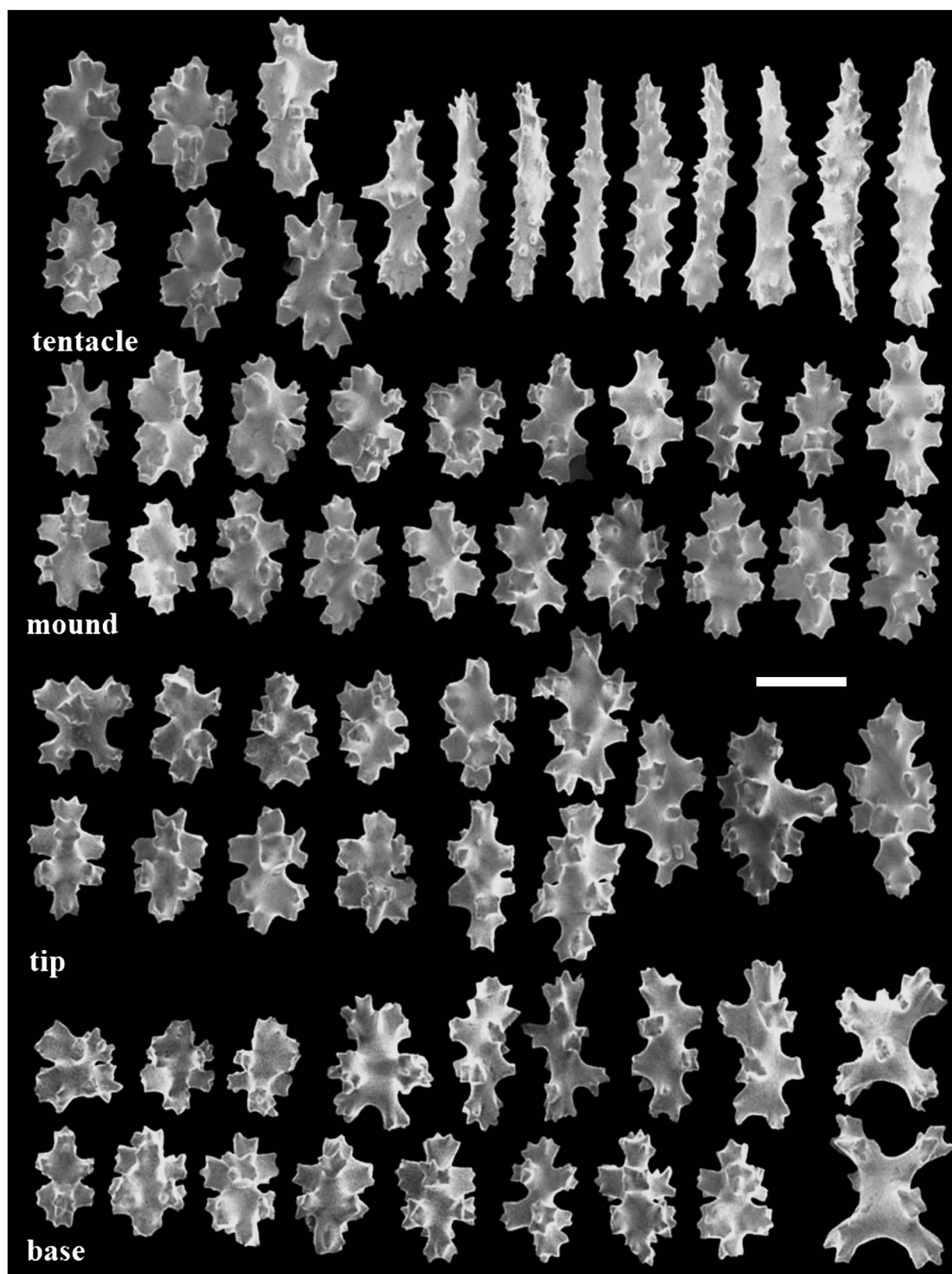


Fig. 23. *Hemicorallium laauense*, NSMT-Co 1730. Sclerites: from tentacles, autozooid mounds, branch tips and colony base. Scale bar: 0.05 mm.

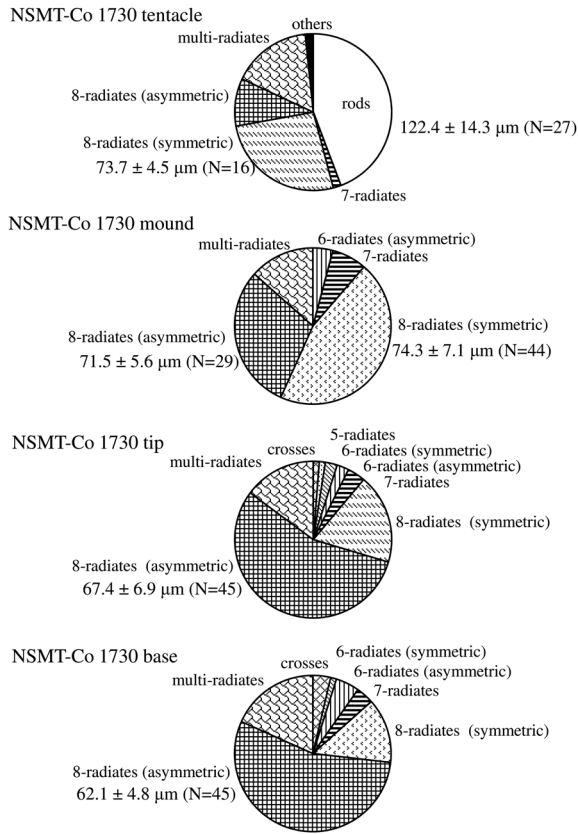


Fig. 24. *Hemicorallium laauense*, NSMT-Co 1730. Composition of sclerites from each part sampled.

angles without anastomoses (Fig. 29A). Bases of the branchlets are about 2 to 3 mm in diameter, the cross section of the main branch is rounded.

Polyps. The autozooids are not retracted into the coenenchyme, forming cylindrical mounds. These mounds are distributed biserially on branches, about 1–3 mm apart (Fig. 29A). They are 1.32 ± 0.17 mm in diameter and 1.04 ± 0.20 mm in height (Fig. 29B; Table 2). Siphonozooids are invisible to the naked eye, distributed around the autozooids (Fig. 29B), 0.06 ± 0.01 mm in diameter (Table 2).

Axis. There are no rounded pits on the surface of the axis at the position of each autozooid. No commensal organisms are found in the axis.

Coenenchyme. The surface is almost smooth, with some small warts, about 0.3 mm in diameter present (Table 2). There are some longitudinal wrinkles terminally (Fig. 29B).

Color. Dry coenenchyme is white. The axis is pale pink basally, white in the branchlets (Fig. 29A).

Sclerites. The tentacles contain mainly rods (51%; 0.100 ± 0.022 mm long, 0.029 ± 0.005 mm wide), multi-radiates (27%; 0.087 ± 0.014 mm long, 0.042 ± 0.005 mm wide), symmetric 8-radiates (13%; 0.074 ± 0.006 mm long, 0.042 ± 0.004 mm wide), and a few crosses and asymmetric 8-radiates (Figs 30, 31; Table 5).

The autozooid mounds contain mainly symmetric 8-radiates (55%; 0.075 ± 0.008 mm long, 0.046 ± 0.004 mm wide), asymmetric 8-radiates (27%; 0.075 ± 0.007 mm long, 0.047 ± 0.004 mm wide). A few crosses, 6-radiate, 7-radiates

Table 5. *Hemicorallium laauense*. Summary of length and width measurements of common (more than 11%) sclerites. Measurements are reported the average \pm standard deviation in μ m. Bold numbers indicate most abundant sclerite type. “+” means not common (less than 10%) sclerites. “–” means not found.

Specimen	Tentacles											
	Rods			6-radiates (symmetrical)			6-radiates (asymmetrical)			7-radiates		
	Length	Width	N (%)	Length	Width	N (%)	Length	Width	N (%)	Length	Width	N (%)
NSMT-Co 1730	122.4 ± 14.3	32.3 ± 7.7	27 44	–	–	–	–	–	–	–	–	–
NSMT-Co 1731	108.2 ± 14.8	26.0 ± 5.4	74 69	–	–	–	–	–	–	–	–	–
NSMT-Co 1732	100.3 ± 21.8	28.9 ± 4.5	48 51	–	–	–	–	–	–	–	–	–
Autozooid mounds												
NSMT-Co 1730	–	–	–	–	–	–	74.3 ± 7.1	44.6 ± 3.7	44 45	71.5 ± 5.6	44.6 ± 2.9	29 30
NSMT-Co 1731	–	–	–	–	–	–	75.3 ± 10.3	43.1 ± 4.8	28 46	73.5 ± 9.8	43.1 ± 4.6	14 23
NSMT-Co 1732	–	–	–	–	–	–	74.8 ± 8.1	45.7 ± 4.0	57 55	74.7 ± 7.2	46.8 ± 3.7	28 27
Branch tips												
NSMT-Co 1730	–	–	–	–	–	–	77.3 ± 13.6	43.5 ± 4.2	15 19	67.4 ± 6.9	43.2 ± 3.8	45 56
NSMT-Co 1731	–	–	–	–	–	–	65.2 ± 9.9	40.0 ± 3.5	30 34	60.5 ± 5.3	39.5 ± 2.3	32 36
NSMT-Co 1732	–	–	–	–	–	–	69.1 ± 9.7	42.9 ± 4.8	38 45	63.3 ± 4.8	42.3 ± 2.8	27 32
Colony bases												
NSMT-Co 1730	–	–	–	–	–	–	67.0 ± 6.3	41.5 ± 3.7	11 13	62.1 ± 4.8	41.0 ± 3.9	45 55
NSMT-Co 1731	–	–	–	–	–	–	58.1 ± 5.4	35.7 ± 2.7	55 53	56.5 ± 4.9	36.0 ± 3.3	28 27
NSMT-Co 1732	–	–	–	–	–	–	64.2 ± 7.3	40.3 ± 4.6	53 55	64.1 ± 6.2	40.8 ± 3.5	17 18

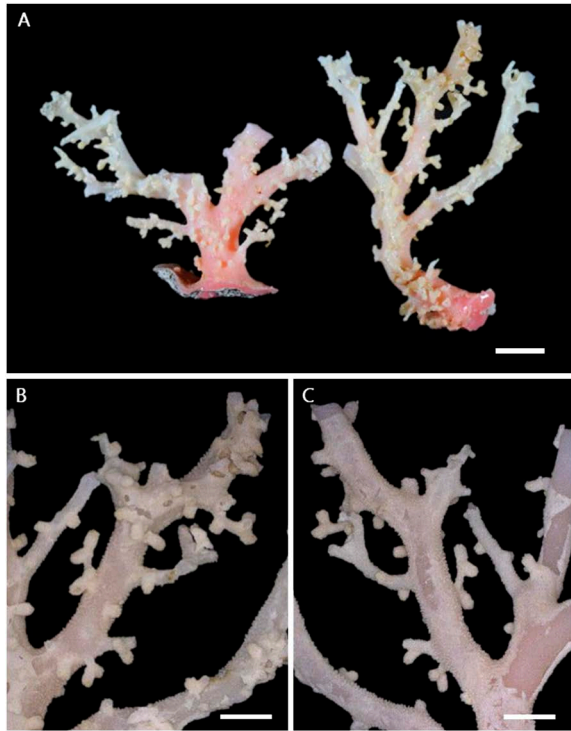


Fig. 25. *Hemicorallium laauense*, NSMT-Co 1731. A, Specimen branches; B, autozoid side surface; C, opposite side surface. Scale bars: A, 10 mm; B, C, 5.0 mm.

and multi-radiates are also present (Figs 30, 31; Table 5).

The branch tips contain mainly symmetric 8-radiates (45%; 0.069 ± 0.010 mm long, 0.043 ± 0.005 mm width), asymmetric 8-radiates (32%; 0.063 ± 0.005 mm long, 0.042 ± 0.003 mm width), and a few 6-radiates, 7-radiates, multi-radiates and others (Figs 30, 31; Table 5).

Coenenchyme of the basal branches contains mainly symmetric 8-radiates (55%; 0.064 ± 0.007 mm long, 0.040 ± 0.005 mm width) and asymmetric 8-radiates (18%; 0.064 ± 0.006 mm long, 0.041 ± 0.004 mm width). There are a few crosses, 6-radiates, 7-radiates, multi-radiates and others (Figs 30, 31; Table 5) in the coenenchyme.

Remarks. *Hemicorallium laauense* was described in 1956 based on a specimen collected in 1902 near Molokai Island, Hawaii, 365–584 m deep (Bayer 1956). The holotype consists only of terminal twigs. Colony shape was unknown. The three specimens of this study (NSMT-Co 1730–1732) are also only branch fragments, but they fit the following features of the original description:

- Branching almost in one plane, irregularly dichotomous in acute angles, without anastomoses.
- Coenenchyme is white and axis is white, basally pale pink.
- There are fine granular protrusions on the coenenchymal surface (although not discernible in NSMT-Co 1732).
- Cylindrical autozooids are about 1.0 mm (1.04–1.36 mm) high, and unevenly distributed on one side of the colony, or biserial on terminal branches.
- Coenenchymal sclerites are dominantly 8-radiates, crosses are also present. The rods in the tentacles are about

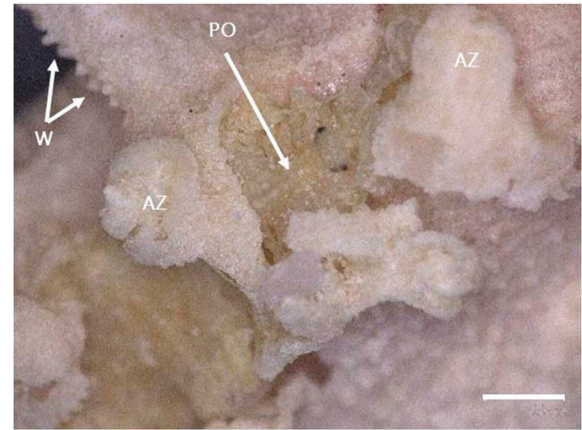


Fig. 26. Surface detail of *Hemicorallium laauense*, NSMT-Co 1731. Abbreviations: PO, commensal polychaete; AZ, autozoid; W, wart. Scale bar: 1.0 mm.

0.1 mm (0.10–0.12 mm) in length.

- The burrows of commensal polychaetes perforate the axes.
- The specimens are sampled from similar depths (350–800 m) and near (the Emperor Sea Mounts) the type locality (Hawaii).

The fine granular protrusions on the coenenchymal surface are not remarkable on branch-tips of the present specimens. Also, burrows of polychaete commensals have not been found in the axis. Although the color of the coenenchyme and axis, and the branching pattern resemble *Hemicorallium boshuense*, they can be distinguished by absence of double-club and irregularly-shape sclerites in the examined specimens.

Hemicorallium cf. regale (Bayer, 1956)

(Figs 32–35; Tables 2, 6)

Corallium regale Bayer 1956: 77–78, figs 5c, 7e–g; Nonaka and Muzik 2010: 106–107, figs 41–42; Tu et al. 2012: 5 (in key), fig. 13; Nonaka and Muzik 2012: 79 (in key), table 1. *Hemicorallium regale* Tu et al. 2015b: 181 (in list), table 1; Tu et al. 2016: 1035 (in key), table II; Nonaka and Muzik 2016: 16 (in list).

Material examined. NSMT-Co 1733, Colahan Seamount, 605–682 m, 24 June 2011.

Diagnosis. Colony is branching almost in one plane. Contracted autozooids form cylindrical mounds, distributed unevenly on only one side of the colony, about 1.2 mm in diameter. Siphonozooids are distributed around the autozooids. Coenenchyme is thin, with a smooth surface, pale pink in color. Axis is stout with a smooth surface, pale red to pink in color. The burrows of commensal polychaetes are present on the surface of the axis. Tentacles contain shorter (0.075 mm long) thorny rods. Coenenchyme contains spherical 6- radiates, and 8-radiates, no double-clubs. Distributed in depths of about 600 m.

Description of specimen NSMT-Co 1733. Colony form. The specimen consists of 4 branchlets, about

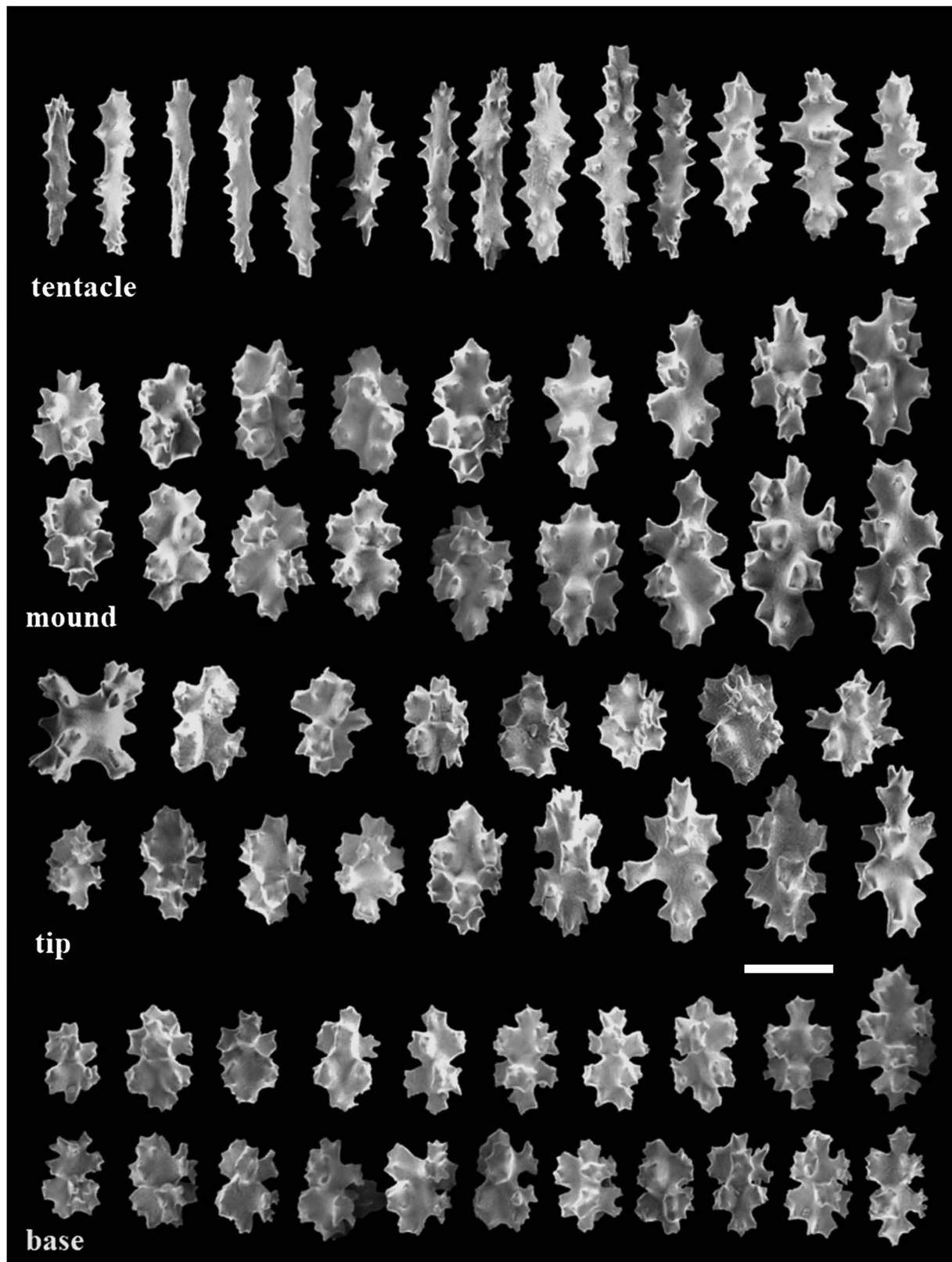


Fig. 27. *Hemicorallium laauense*, NSMT-Co 1731. Sclerites: from tentacles, autozoid mounds, branch tips and colony base. Scale bar: 0.05 mm.

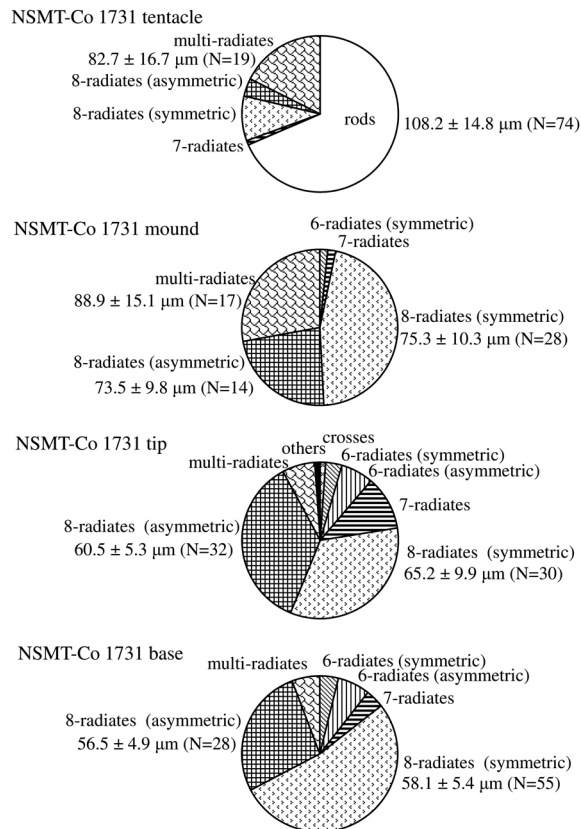


Fig. 28. *Hemicorallium laauense*, NSMT-Co 1731. Composition of sclerites from each part sampled.

30–60 mm long (Fig. 32A). The branching is almost in one plane, but whole colony form not determined (Fig. 32A). Branchlets are about 3 mm in diameter, with rounded cross sections.

Polyps. The autozooids are not retracted into the coenenchyme, making cylindrical mounds. They tend to be distributed on one side of the colony (Fig. 32B, C), rather crowded (Fig. 32B). They are 1.24 ± 0.13 mm in diameter and about 1.36 mm in height (Table 2). Siphonozooids are distributed around the autozooids (Fig. 33), about 0.06 mm in diameter.

Axis. The surface of the axis is smooth (Fig. 32C). There are no rounded pits on the surface of the axis at the position of each autozooids. The burrows of commensal organisms are found on the surface of the axis (Fig. 32B).

Coenenchyme. Coenenchyme is too thin to be measured. The surface is smooth and small warts are not remarkable (Fig. 33).

Color. The dry coenenchyme is pale pink. The axes are pink to pale red in color (Fig. 32).

Sclerites. The tentacles contain mainly rods (69%; 0.075 ± 0.014 mm long, 0.027 ± 0.005 mm wide), symmetric 8-radiates (15%; 0.061 ± 0.008 mm long, 0.038 ± 0.005 mm wide), and a few 6-radiates, 7-radiates, multi-radiates and others (Figs 34, 35; Table 6).

The autozoid mounds contain mainly symmetric 6-radiates (34%; 0.058 ± 0.005 mm long, 0.044 ± 0.004 mm wide), asymmetric 6-radiates (22%; 0.056 ± 0.005 mm long, 0.043 ± 0.004 mm wide), 7-radiates (20%; 0.062 ± 0.005 mm

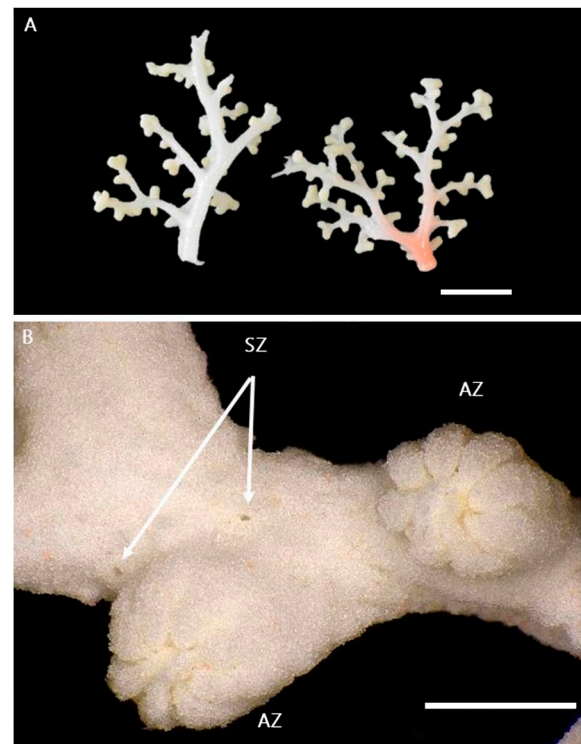


Fig. 29. *Hemicorallium laauense*, NSMT-Co 1732. A, Specimen branches; B, surface detail. Abbreviations: AZ, autozoid; SZ, siphonozooid. Scale bars: A, 10 mm; B, 1.0 mm.

long, 0.044 ± 0.002 mm wide). A few 8-radiates and multi-radiates are present (Figs 34, 35; Table 6).

The branch tips contain mainly asymmetric 8-radiates (31%; 0.056 ± 0.005 mm long, 0.038 ± 0.003 mm wide), symmetric 8-radiates (27%; 0.061 ± 0.013 mm long, 0.038 ± 0.006 mm wide), 7-radiates (15%; 0.056 ± 0.009 mm long, 0.039 ± 0.004 mm wide), and a few 6-radiates, and multi-radiates (Figs 34, 35; Table 6).

Basal coenenchyme contains mainly symmetric 8-radiates (32%; 0.065 ± 0.012 mm long, 0.040 ± 0.005 mm wide) and asymmetric 8-radiates (21%; 0.061 ± 0.012 mm long, 0.042 ± 0.006 mm wide). There are a few crosses, 6-radiates, 7-radiates and multi-radiates (Figs 34, 35; Table 6) in the coenenchyme.

Remarks. *Hemicorallium regale* was first described in 1956 based on a specimen collected around French Frigate Shoals (697–711 m deep) in Hawaii in 1902 (Bayer 1956). This species resembles *C. sulcatum* and *C. imperiale*, but can be distinguished by presence of the unique spherically shaped 6-radiates in the coenenchyme. Such sclerites have been found in *C. maderense* and *C. tricolor*, but these two species are distributed in the Atlantic, not the Pacific. This species is the reddest in color of the precious corals from Hawaii, but was not collected in quantities large enough to prove commercially valuable.

The following features of specimen NSMT-Co 1733 fit the original description.

- The coenenchyme is thin, without fine protrusions.

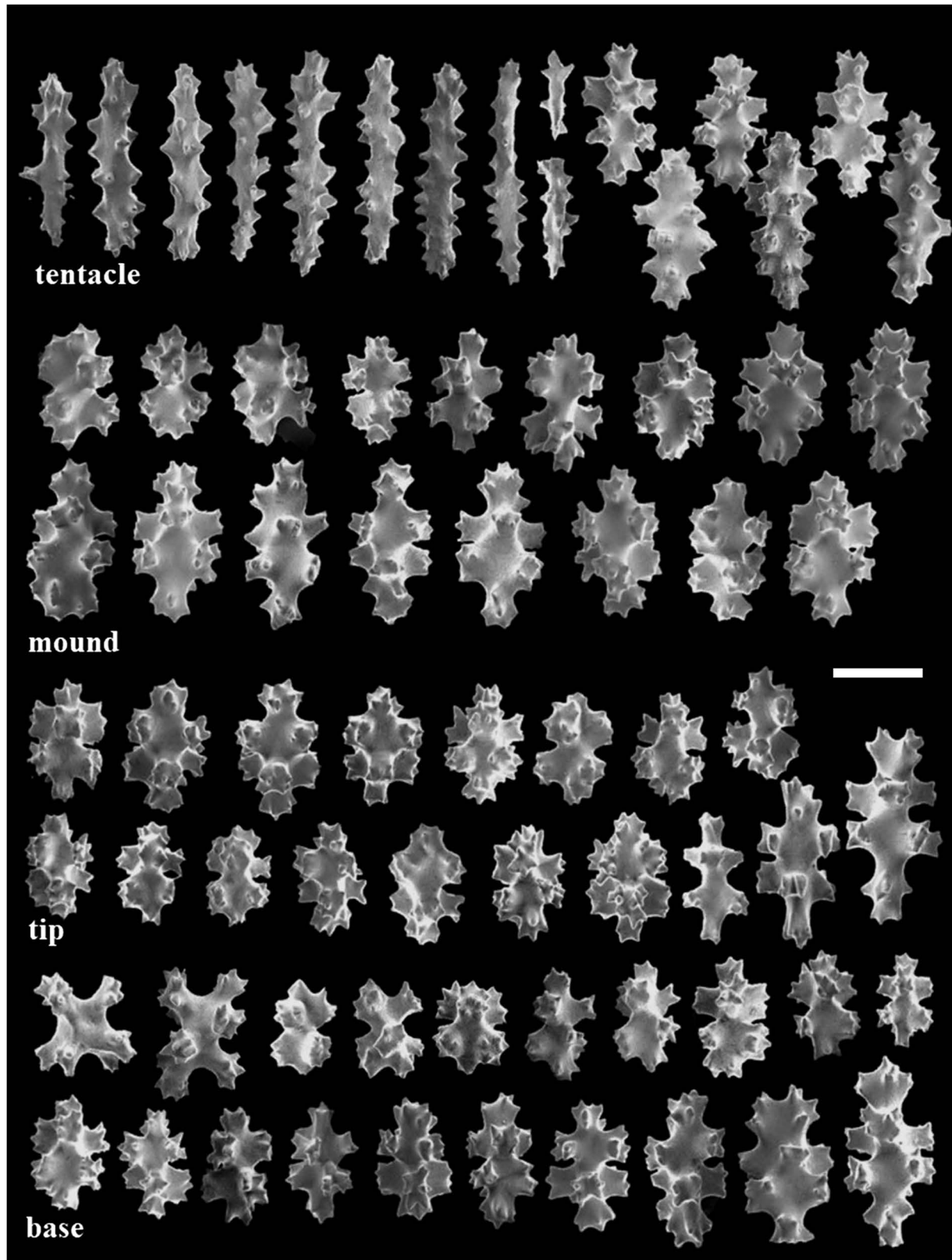


Fig. 30. *Hemicorallium laauense*, NSMT-Co 1732. Sclerites: from tentacles, autozooid mounds, branch tips and colony base. Scale bar: 0.05 mm.

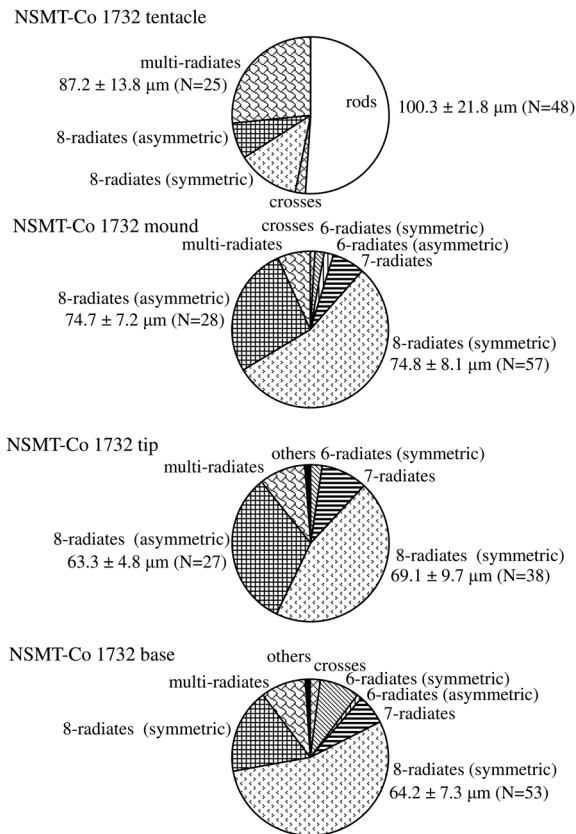


Fig. 31. *Hemicorallium laauense*, NSMT-Co 1732. Composition of sclerites from each part sampled.

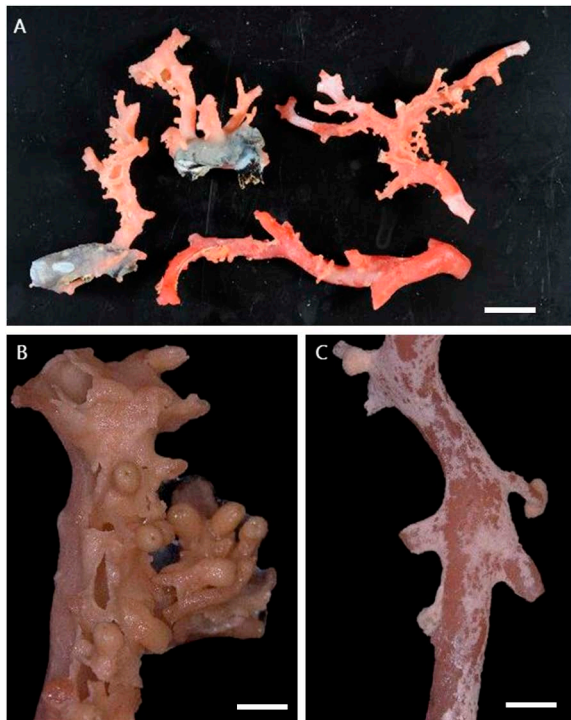


Fig. 32. *Hemicorallium cf. regale*, NSMT-Co 1733. A, Entire specimens; B, autozooid side; C, opposite side. Scale bars: A, 10 mm; B, C, 2.0 mm.

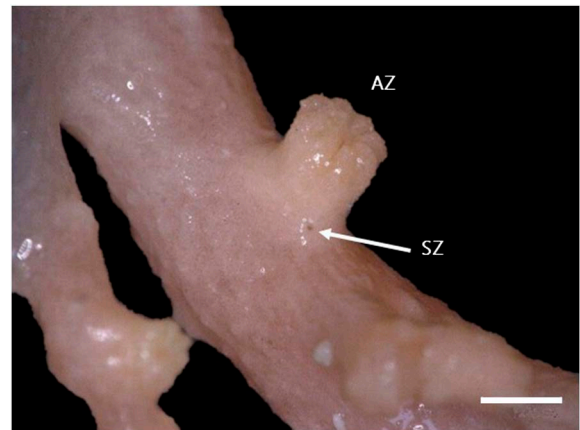


Fig. 33. Surface detail of *Hemicorallium cf. regale*, NSMT-Co 1733. Abbreviations: AZ, autozooid; SZ, siphonozooid. Scale bar: 1.0 mm.

- The axis is reddish or pink, with burrows of commensal organisms.
- The contracted autozooids are cylindrically shaped, 1.36 mm in height and 1.24 mm in diameter, and are unevenly distributed on one side of the colony.
- The dominant sclerites are 6-radiates and 8-radiates, and some 6-radiates have a spherical shape (Fig. 34). The rod-shaped sclerites in the tentacles are thorny and relative short (0.075 mm long).

However, the height of the autozooids, and the length of the rod sclerites are shorter than those described for *H. regale* in Bayer 1956. *H. regale* was probably pinnately branched, but branching pattern cannot be determined from the present specimen. Therefore, this specimen is only tentatively identified as *H. cf. regale* in this study. For accurate identification, comparison with the holotype specimen will be required.

Hemicorallium cf. sulcatum (Kishinouye, 1903a)
(Figs 36–42; Tables 2, 6)

Corallium sulcatum Kishinouye, 1903a: 104; Kishinouye 1903b: 624; Kishinouye 1904: 24–25, pl. 4, figs 1, 2, pl. 7, fig. 3 (in Japanese); Kishinouye 1905: 23–24, pl. 4, figs 1, 2, pl. 7, fig. 3; Kukenthal 1924: 52; Bayer 1956: 75 (in key); Imahara 1996: 28 (in list); Nonaka and Muzik 2010: 96–97, figs 20–22; Tu et al. 2012: 5 (in key); 14–16, fig. 14; Nonaka et al. 2012: 5 (in key); Nonaka and Muzik 2012: 80 (in key), table 1.

Hemicorallium sulcatum: Tu et al. 2015b: 181 (in list); Tu et al. 2016: 1035 (in key), table II; Nonaka and Muzik 2016: 16 (in list).

Hemicorallium cf. sulcatum: Nonaka and Muzik 2016: 17–24, figs 2–8, tables 1, 2.

Material examined. NSMT-Co 1734, Koko Seamount, 521–569 m, 20 August 2009. NSMT-Co 1735, Koko Seamount, 477–480 m, 9 August 2012.

Diagnosis. Colony is branching in almost one plane,

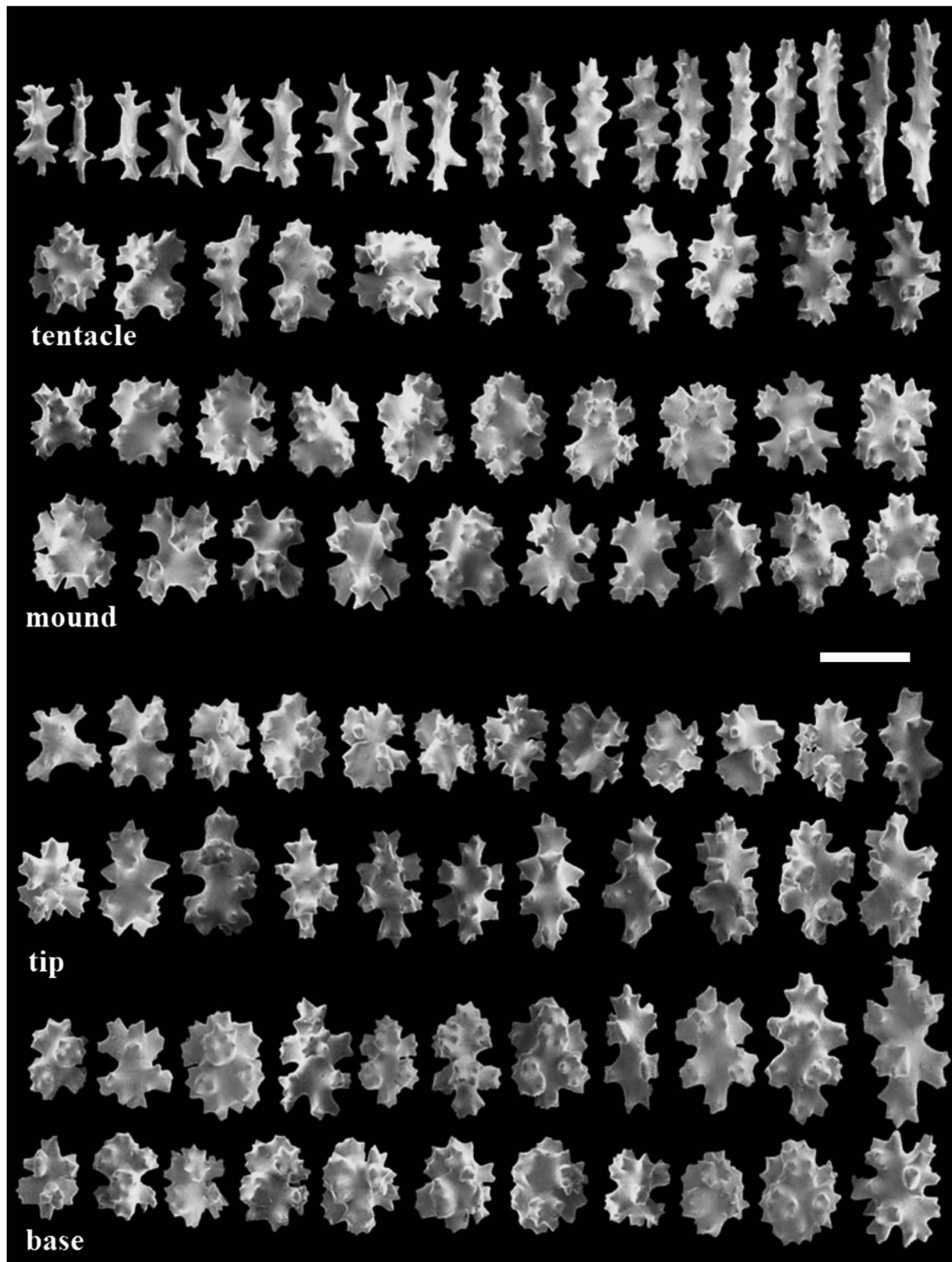


Fig. 34. *Hemicorallium cf. regale*, NSMT-Co 1733. Sclerites: from tentacles, autozooid mounds, branch tips and colony base. Scale bar: 0.05 mm.

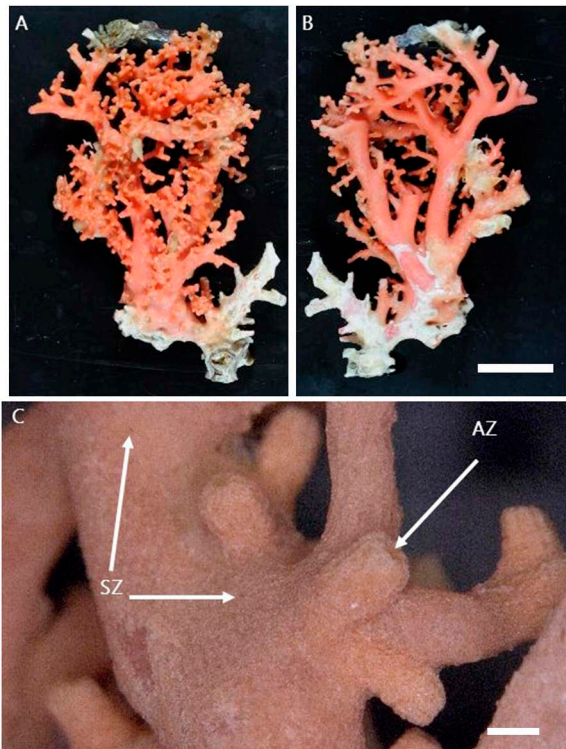


Fig. 36. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903a), NSMT-Co 1734. A, Autozoid side; B, opposite side; C, surface detail. Abbreviations: AZ, autozoid; SZ, siphonozoid. Scale bars: A, B, 20 mm; C, 1.0 mm.

dinally grooved in about 0.34 mm intervals (Table 2). There are no rounded pits on the surface of the axis at the position of each autozoid. There are burrows in the axis, some with commensal polychaetes (Fig. 37).

Coenenchyme. Coenenchyme is thin, its thickness not measurable. The surface is smooth, small warts inconspicuous on the stems, but somewhat prominent on the twigs (Fig. 37). At high magnifications, the gastrovascular system can be seen through the thin coenenchyme on the side of the colony without autozooids (Fig. 37).

Color. The dry coenenchyme and axis are both pale pink in color (Figs 36, 37).

Sclerites. The tentacles contain mainly rods (55%; 0.121 ± 0.018 mm long, 0.028 ± 0.005 mm wide), symmetric 8-radiates (18%; 0.072 ± 0.009 mm long, 0.045 ± 0.004 mm wide), multi-radiates (18%; 0.089 ± 0.014 mm long, 0.039 ± 0.004 mm wide) and a few 6-radiates, 7-radiates and asymmetric 8-radiates (Figs 38, 39; Table 6).

The autozoid mounds contain mainly symmetric 8-radiates (56%; 0.074 ± 0.011 mm long, 0.046 ± 0.004 mm wide), asymmetric 8-radiates (21%; 0.067 ± 0.007 mm long, 0.044 ± 0.005 mm wide), multi-radiates (17%; 0.089 ± 0.017 mm long, 0.051 ± 0.006 mm wide). A few 6-radiates and 7-radiates are present (Figs 38, 39; Table 6).

The branch tips contain mainly asymmetric 8-radiates (48%; 0.064 ± 0.005 mm long, 0.045 ± 0.004 mm wide), symmetric 8-radiates (29%; 0.070 ± 0.011 mm long, 0.045 ± 0.004 mm wide), and a few 6-radiates, 7-radiates,



Fig. 37. A commensal polychaete inside the coenenchyme of *Hemicorallium* cf. *sulcatum*, NSMT-Co 1734. Scale bar: 1.0 mm.

multi-radiates (Figs 38, 39; Table 6).

The coenenchyme at the base contains mainly symmetric 8-radiates (41%; 0.061 ± 0.006 mm long, 0.041 ± 0.004 mm wide), asymmetric 8-radiates (29%; 0.060 ± 0.004 mm long, 0.042 ± 0.003 mm wide) and asymmetric 6-radiates (12%; 0.054 ± 0.005 mm long, 0.042 ± 0.005 mm wide). There are a few 7-radiates, multi-radiates and others (Figs 38, 39; Table 6) in the coenenchyme.

Description of specimen NSMT-Co 1735. Colony form. Since the specimen is only a small branchlet about 2 cm long (Fig. 40A), colony shape is unknown.

Polyps. The autozooids are not retracted into the coenenchyme, making cylindrical mounds. 2–3 autozooids form clusters on branch terminals (Fig. 40B). Autozooids are 1.24 ± 0.15 mm in diameter and 1.09 ± 0.19 mm in height (Table 2). Siphonozoids are inconspicuous (Fig. 40B), about 0.06 mm in diameter.

Axis. There are no rounded pits on the surface of the axis at the position of each autozoid.

Coenenchyme. Coenenchyme is so thin its thickness is not measurable. Small warts are present but inconspicuous, about 0.19 mm in diameter (Fig. 40B; Table 2). At high magnifications, the gastrovascular system can be seen (Fig. 40B).

Color. The dry coenenchyme is pale pink, axis is reddish. (Figs 40).

Sclerites. The tentacles contain mainly rods (53%; 0.104 ± 0.020 mm long, 0.027 ± 0.005 mm wide), symmetric 8-radiates (14%; 0.065 ± 0.009 mm long, 0.037 ± 0.005 mm wide), multi-radiates (33%; 0.081 ± 0.015 mm long, 0.037 ± 0.006 mm wide) (Figs 41, 42; Table 6).

The autozoid mounds contain mainly symmetric 8-radiates (48%; 0.069 ± 0.010 mm long, 0.043 ± 0.006 mm wide), asymmetric 8-radiates (18%; 0.068 ± 0.006 mm long, 0.044 ± 0.003 mm wide), and multi-radiates (21%; 0.082 ± 0.014 mm long, 0.045 ± 0.005 mm wide). A few 6-radiates and 7-radiates are present (Figs 41, 42; Table 6).

The branch tip contains mainly symmetric 8-radiates (62%; 0.064 ± 0.009 mm long, 0.040 ± 0.005 mm wide), asymmetric 8-radiates (21%; 0.066 ± 0.009 mm long, 0.043 ± 0.004 mm wide), and a few 6-radiates, 7-radiates,

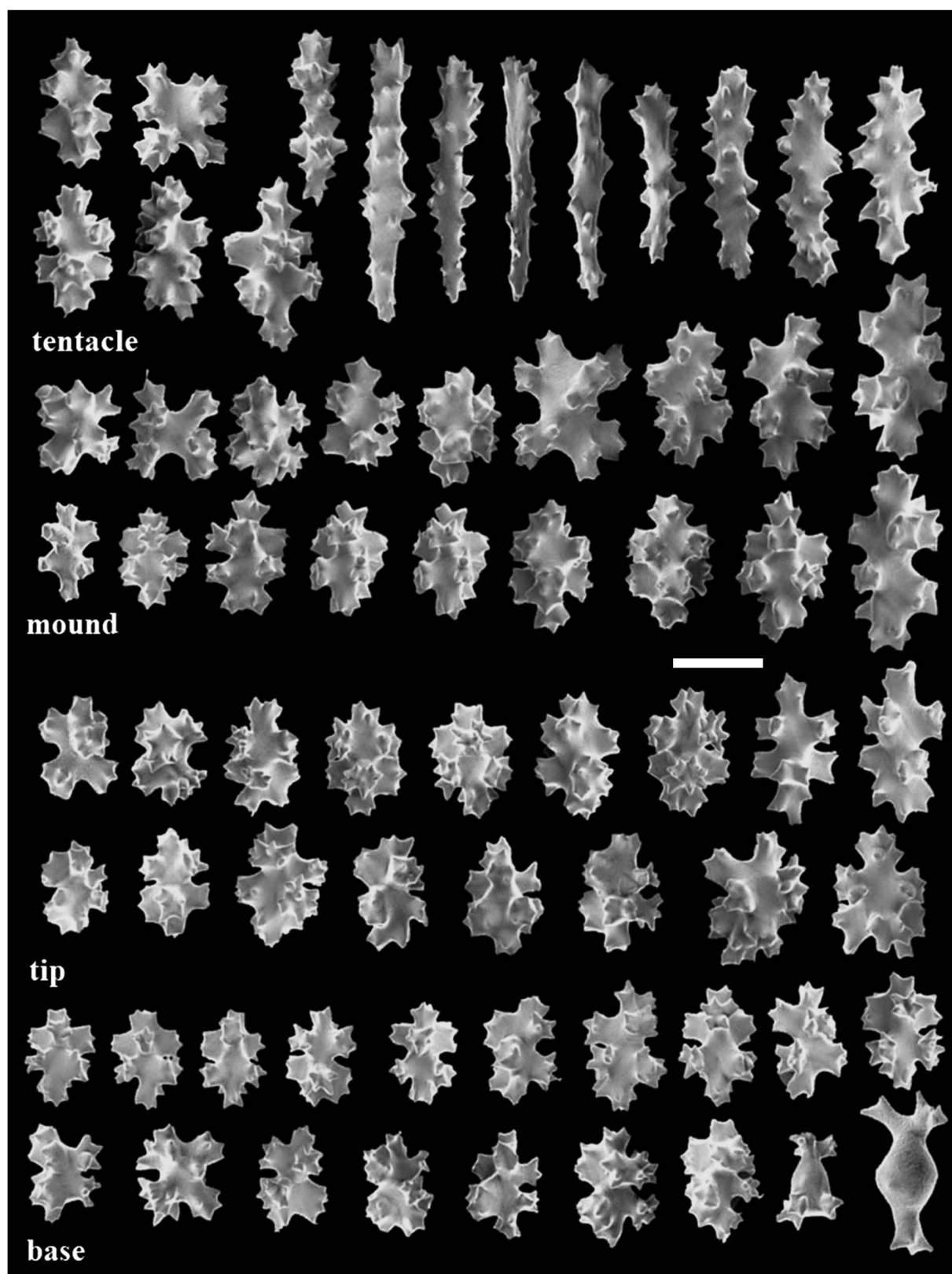


Fig. 38. *Hemicorallium cf. sulcatum*, NSMT-Co 1734. Sclerites: from tentacles, autozoid mounds, branch tips and colony base. Scale bar: 0.05 mm.

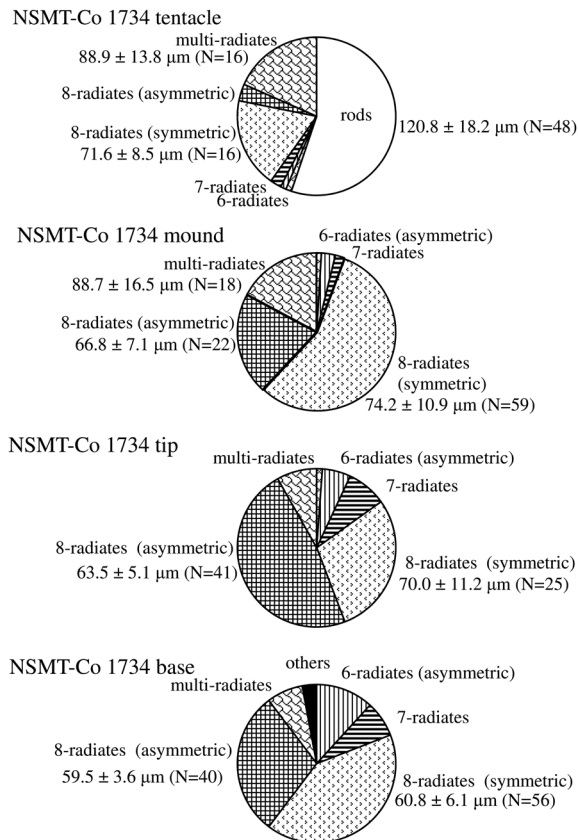


Fig. 39. *Hemicorallium* cf. *sulcatum*, NSMT-Co 1734. Composition of sclerites from each part sampled.

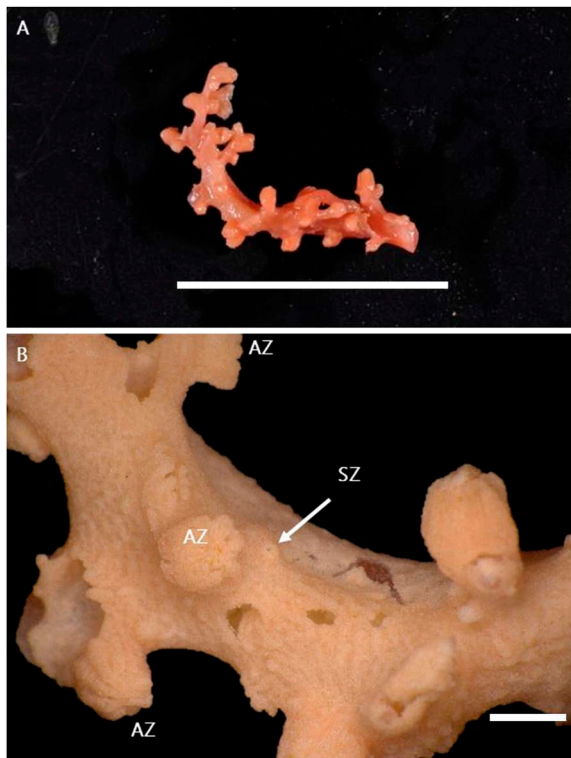


Fig. 40. *Hemicorallium* cf. *sulcatum*, NSMT-Co 1735. A, Whole specimen; B, surface detail. Abbreviations: AZ, autozooid; SZ, siphonozooid. Scale bars: A, 20 mm; B, 1.0 mm.

multi-radiates and others (Figs 41, 42; Table 6).

Coenenchyme on the base of the colony contains mainly symmetric 8-radiates (57%; 0.060 ± 0.006 mm long, 0.039 ± 0.004 mm wide) and asymmetric 8-radiates (23%; 0.058 ± 0.005 mm long, 0.040 ± 0.004 mm wide). There are a few 6-radiates, 7-radiates, multi-radiates and others (Figs 41, 42; Table 6) in the coenenchyme.

Remarks. *Hemicorallium sulcatum* was first described by Kishinouye (1903a), and the type locality is in Chiba Prefecture, Japan (Kishinouye 1903a, b). The specimen described by Kishinouye (1903a, b) was 30 cm in height, 21 cm in width, about 2.1 cm in diameter at the colony base, and taken from around 180 to 550 m deep off Chiba Prefecture off the coast, although the accurate depth was not recorded (Kishinouye 1904). Kishinouye received only two specimens, one of which had already been halfway polished, so he reported he could not study it for taxonomic research (Kishinouye 1904). Both specimens are currently lost. Several specimens were subsequently identified as belonging to this species (Tu et al. 2012; Nonaka et al. 2016), but identifications cannot be confirmed without comparison with the still-missing type-specimen.

In specimen NSMT-Co 1734 the features recorded below fit the original description of this species:

- The colony is branched in one plane, and has some anastomoses.
- The autozooids are unevenly distributed on one side of the colony.
- Some perforated grooves can be found on the axis. The axis is pale pink in color.
- The sclerites are predominantly 8 radiates, and some irregular shaped can also be found.

In specimen NSMT-Co 1735, consisting of only a branch tip, sclerite features mostly fit the original description.

Regarding autozooid size, there was no record in the original description (Kishinouye 1903a, b). The papers published subsequently by Kishinouye in 1904 had more detailed descriptions of this species, but the length units he used to report autozooid size differed in the Japanese and the English versions. In the Japanese version (Kishinouye 1904), the height was 3–6 “rin” (0.9–1.8 mm) and the diameter was 3 “rin” (0.9 mm), whereas in the English version (Kishinouye 1905), height was about 2 mm and diameter 1.5 mm. The specimens examined here have autozooids which are slightly shorter (1.0–1.1 mm) than in the original description, but almost the same diameter (1.25 mm).

Although these specimens best resemble *H. sulcatum*, some morphological characters do not fit, therefore, they are only tentatively identified as *H. cf. sulcatum* in this study. For precise identification, it will be necessary to designate a neotype in the future.

***Hemicorallium kaiyo* sp. nov.**
(Figs 43–48; Tables 2, 7)

Material examined. Holotype, NSMT-Co 1737, Koko Seamount, 409–942 m, 14 June 2011.

Diagnosis. Colony may branch almost in one plane,

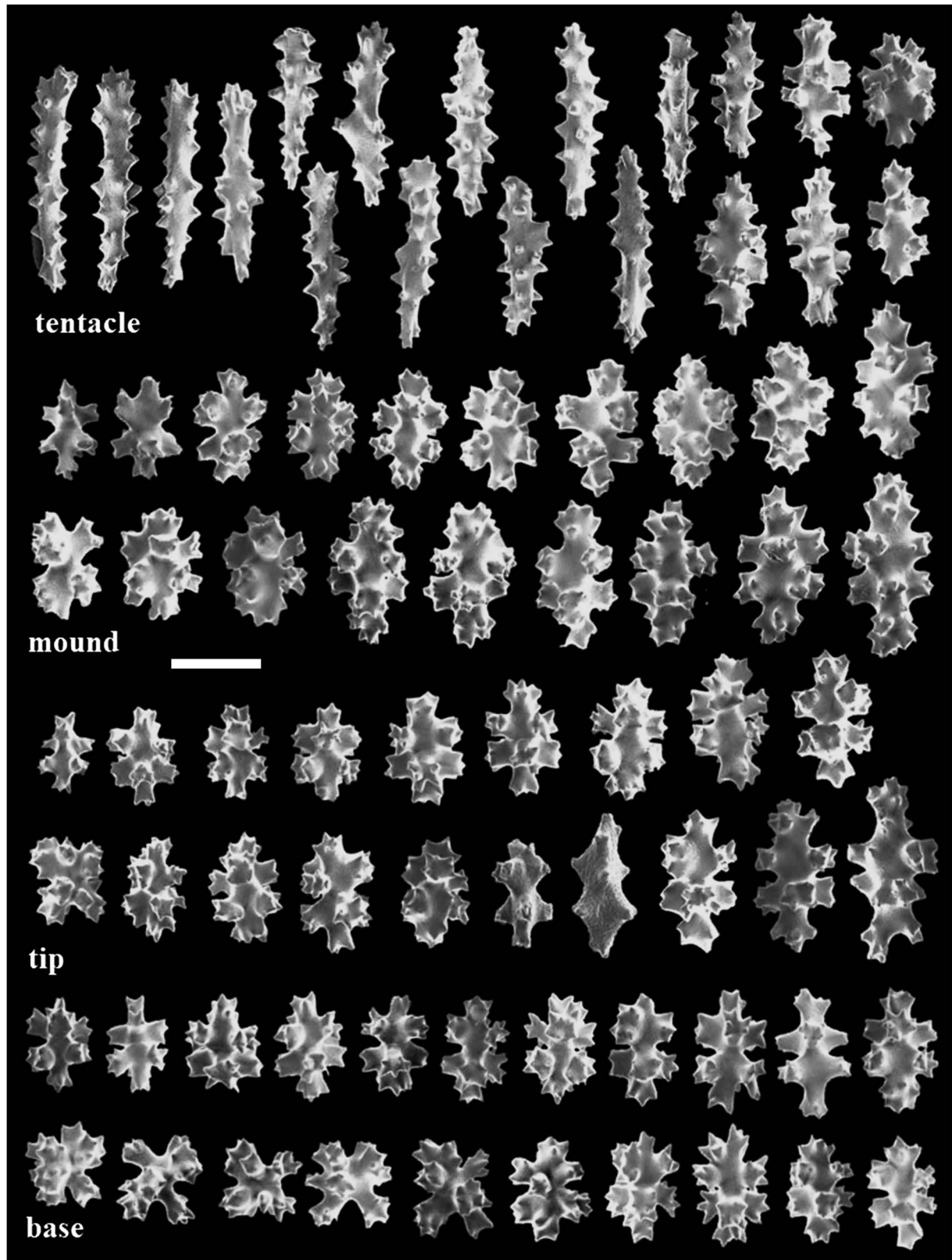


Fig. 41. *Hemicorallium cf. sulcatum*, NSMT-Co 1735. Sclerites: from tentacles, autozooid mounds, branch tips and colony base. Scale bar: 0.05 mm.

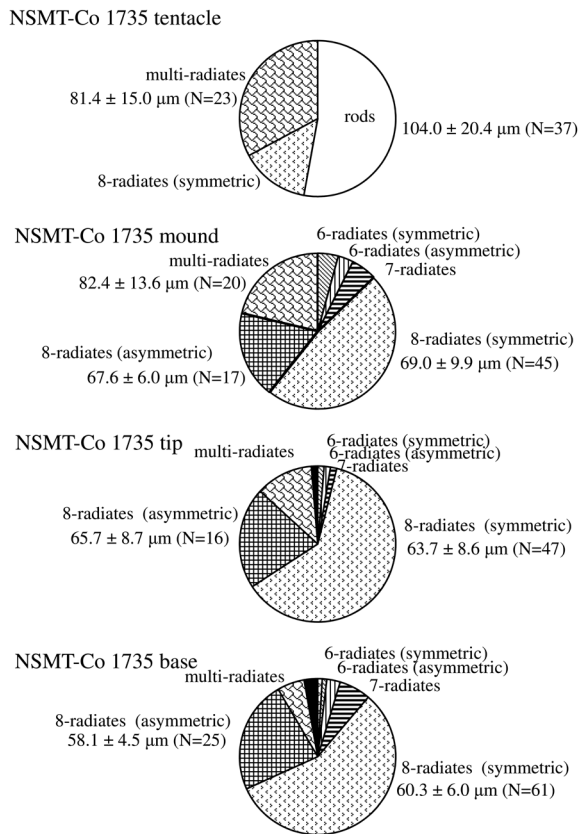


Fig. 42. *Hemicorallium* cf. *sulcatum*, NSMT-Co 1735. Composition of sclerites from each part sampled.

without anastomoses, but colony form is unknown. Branching is irregular, at acute angles. Contracted autozooids are concentrated on the terminal twigs, interpolypar distance 1–3 mm, diameter 0.8–1.5 mm (average 1.06 mm) and height 0.7–1.3 mm (average 1.0 mm). Coenenchyme is 0.05–0.12 mm (average 0.08 mm) thick in the dry condition, without small warts, pale red in color. Axis stout, having many commensal burrows, no depressions underneath autozooids, smooth surface, red. Tentacles contain rods (about 0.1 mm long), coenenchyme contains 6-, 7-, and 8-radiates. Multi-radiates are rare, and double-clubs are absent.

Description of the holotype. Colony form. The specimen is a branch tip with some twigs (Fig. 43). It is about 50 mm long and 20 mm wide. Branch diameter is 4–5 mm, terminals 1–2 mm. It is presumed that branching is almost in one plane, without anastomoses, but the colony form is unknown. The angle of branching is acute (Fig. 43). Two commensal brittle stars were found on the branch.

Polyps. The autozooids are not retracted into the coenenchyme, making cylindrical mounds with 8 inconspicuous longitudinal striations. They tend to concentrate on the terminal twigs, but not in clusters (Fig. 43). Autozooids are 1.06 ± 0.13 mm in diameter and 1.00 ± 0.19 mm in height (Table 2), distributed at 1–3 mm intervals on the twigs (Fig. 44). Siphonozooids cannot be found in this specimen.

Axis. The surface of the stem of the axis is smooth and the twigs of the axis have shallow longitudinal grooves (Figs 45, 46). The grooves are distributed at about 0.34 mm intervals

(Table 2). There are no rounded pits on the surface of the axis at the position of each autozooid. Many polychaete burrows are found in the axis, with some polychaetes visible by microscope (Fig. 45).

Coenenchyme. The coenenchyme is very thin, 0.08 ± 0.03 mm and smooth, covering the axis (Figs 45, 46; Table 2). There are no warts on its surface (Figs 45, 46). At high magnification, the gastrovascular system is visible through it (Fig. 45).

Color. The dry coenenchyme is pale red, the axis a deeper red color (Figs 43–46).

Sclerites. The tentacles contain mainly rods (60%; 0.102 ± 0.014 mm long, 0.028 ± 0.004 mm wide), multi-radiates (27%; 0.084 ± 0.014 mm long, 0.036 ± 0.006 mm wide) and a few 7-radiates, 8-radiates and others (Figs 47, 48; Table 7).

The autozooid mounds contain mainly symmetric 6-radiates (25%; 0.058 ± 0.008 mm long, 0.039 ± 0.005 mm wide), symmetric 8-radiates (20%; 0.068 ± 0.011 mm long, 0.041 ± 0.004 mm wide), 7-radiates (18%; 0.062 ± 0.009 mm long, 0.039 ± 0.005 mm width), and some asymmetric 6-radiates, asymmetric 8-radiates, multi-radiates are present (Figs 47, 48; Table 7).

The branch tips contain mainly symmetric 8-radiates (29%; 0.061 ± 0.006 mm long, 0.039 ± 0.004 mm width), 7-radiates (26%; 0.057 ± 0.008 mm long, 0.039 ± 0.004 mm width), asymmetric 8-radiates (18%; 0.061 ± 0.006 mm long, 0.040 ± 0.003 mm width), symmetric 6-radiates (15%; 0.058 ± 0.006 mm long, 0.039 ± 0.004 mm width), and a few asymmetric 6-radiates and multi-radiates (Figs 47, 48; Table 7).

The coenenchyme at the base of the colony contains mainly symmetric 8-radiates (39%; 0.059 ± 0.006 mm long, 0.038 ± 0.003 mm wide), 7-radiates (22%; 0.053 ± 0.006 mm long, 0.035 ± 0.004 mm wide), asymmetric 8-radiates (16%; 0.056 ± 0.006 mm long, 0.036 ± 0.003 mm width) and symmetric 6-radiates (13%; 0.053 ± 0.006 mm long, 0.037 ± 0.004 mm width). There are a few asymmetric 6-radiates and multi-radiates (Figs 47, 48; Table 7).

Etymology. The survey at the Emperor Seamounts was conducted by the Fisheries Agency research vessel “*Kaiyo-maru*”. This species is named “*kaiyo*” from the name of the vessel, to give thanks to the *Kaiyo-maru* crew who collected the specimens studied here.

Remarks. Specimen NSMT-Co 1737 has non-retracted, cylindrical autozooids (Figs 45, 46), slender rod-shaped sclerites in the tentacles (Fig. 47), and lacks rounded pits on the surface of the axis at the position of each autozooid, thus belonging in the genus *Hemicorallium*.

There are only two species in the Pacific *Hemicorallium* previously described as having small contracted autozooids about 1.0 mm in both height and diameter: *H. laauense* and *H. taiwanicum* (Tu, Dai, and Jeng, 2012). However, *H. laauense* has both axis and coenenchyme whitish in color, and *H. taiwanicum* has an orange axis and dark-pink coenenchyme. Both species have no (or rare) 6-radiates in their coenenchyme, but NSMT-Co 1737 has about 25% 6-radiates (Figs 47, 48; Table 7). The color of the axis of this specimen

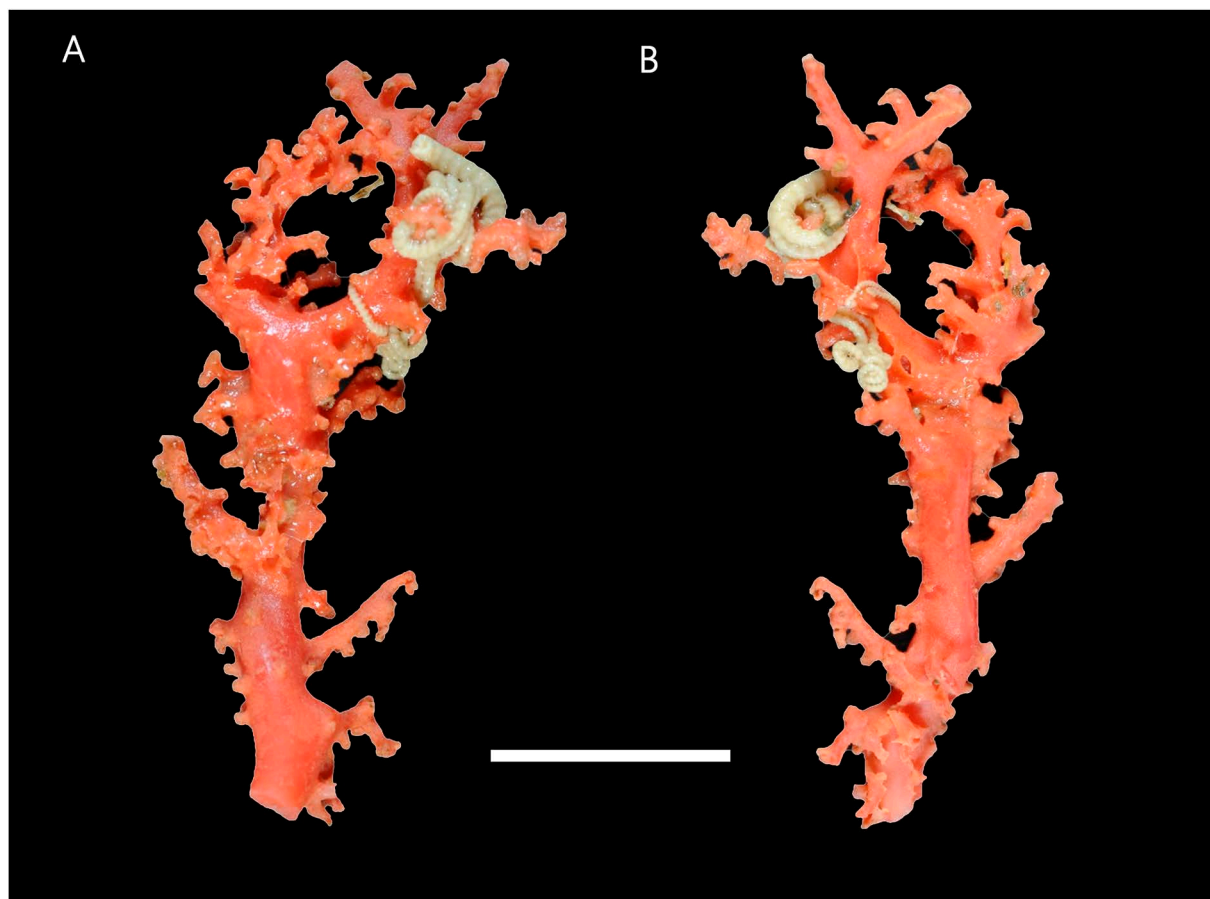


Fig. 43. *Hemicorallium kaiyo* sp. nov., holotype, NSMT-Co 1737. A, Autozooid side; B, opposite side. Scale bar: 20 mm.

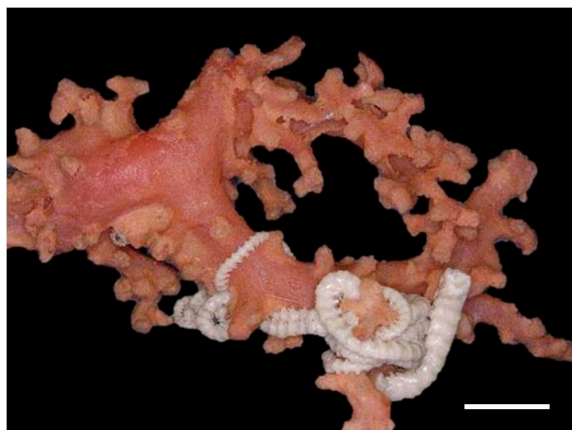


Fig. 44. The distribution of autozooids of *Hemicorallium kaiyo* sp. nov., NSMT-Co 1737. Scale bar: 5.0 mm.

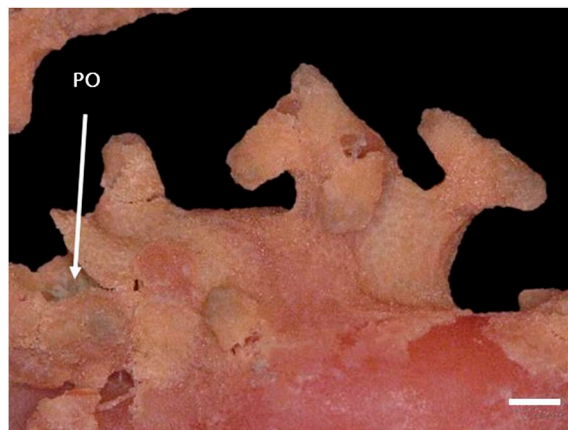


Fig. 45. Surface detail of *Hemicorallium kaiyo* sp. nov., NSMT-Co 1737. Abbreviation: PO, commensal polychaete. Scale bar: 1.0 mm.

is the reddest encountered in this collection, comparable to that of *C. japonicum*. However, it seems unsuitable for ornamental use because of the numerous burrows in the axis (Fig. 45).

***Hemicorallium muzikae* sp. nov.**
(Figs 49–56; Tables 2, 7)

Material examined. Holotype, NSMT-Co 1738, Cola-

han Seamount, 682–712 m, 2 August 2012.

Diagnosis. Colony may branch almost in one plane, with some anastomoses, but the whole colony form is unknown. Branching irregular, almost acute angles. Contracted autozooids are concentrated on one side of the colony, interpolypary distance 1.1–3.7 mm, diameter 0.9–1.3 mm (average 1.08 mm) and height 0.7–1.3 mm (average 0.99 mm). Coenenchyme is 0.09–0.18 mm (average 0.13 mm) thick in the dry condition, with small warts, pale pink in color. Axis

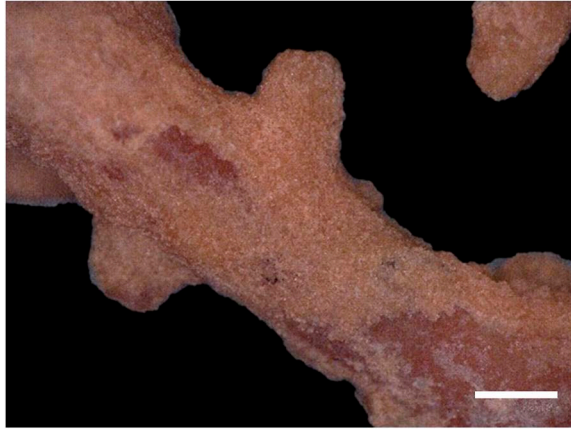


Fig. 46. Surface detail of *Hemicorallium kaiyo* sp. nov., NSMT-Co 1737. Scale bar: 1.0 mm.

pink, stout, with longitudinal grooves, many commensal burrows, no depressions underneath autozooids. Tentacles contain rods about 0.1 mm long, coenenchyme contains mainly 8-radiates, 6-, 7-, multi-radiates are present, double-clubs are absent.

Description of the holotype. Colony form. The specimen consists of two twigs (Fig. 49). One is 80 mm long and 60 mm wide, the other about 60 mm long and 60 mm wide. Diameter is 5–10 mm at the branch base, 1–2 mm terminally (Fig. 49). Branching may be almost planar, with some anastomoses, but colony form is unknown. The angle of branching is irregular, almost acute (Fig. 49).

Polyps. The autozooids are not retracted into the coenenchyme, making cylindrical mounds with 8 conspicuous longitudinal striations (Fig. 52). They are present on only one side of the colony, absent on the opposite side (Fig. 50), tending to concentrate on the terminal twigs, but not making clusters (Fig. 51). They measure 1.08 ± 0.09 mm in diameter and 0.99 ± 0.20 mm in height (Fig. 52; Table 2). Interpolypary distance is 1–3.5 mm on the twigs (Fig. 52). Siphonozooids (0.08 ± 0.03 mm in diameter) are sparsely distributed on the basal parts of the autozooids (Fig. 52; Table 2).

Axis. The surface of the axis is almost smooth, having shallow longitudinal grooves about 0.32 mm apart (Fig. 53; Table 2). There are no rounded pits on the surface of the axis at the positions of autozooids. Many polychaete burrows are present in the axis (Fig. 51).

Coenenchyme. Coenenchyme is very thin, 0.13 ± 0.02 mm thick, covering the axis (Fig. 54; Table 2). Warts (about 0.23 mm in diameter) are visible on the surface (Figs 51, 52), tending to line up longitudinally. On the twigs they become raised ridges (Fig. 52), especially on the side without autozooids. At high magnifications, the gastrovascular system is visible through the thin coenenchyme (Fig. 54). This thin coenenchymal “curtain” covers the burrows of commensal worms (Fig. 51).

Color. The dry coenenchyme is pale pink, the axis is a deeper pink color (Figs 49–54).

Sclerites. The tentacles contain mainly rods (37%; 0.092 ± 0.017 mm long, 0.024 ± 0.005 mm wide), multi-radi-

ates (29%; 0.079 ± 0.013 mm long, 0.033 ± 0.005 mm wide) and a few 6-radiates, 7-radiates and 8-radiates (Figs 55, 56; Table 7).

The autozooid mounds contain mainly symmetric 8-radiates (45%; 0.068 ± 0.008 mm long, 0.041 ± 0.004 mm wide), asymmetric 8-radiates (19%; 0.071 ± 0.006 mm long, 0.044 ± 0.003 mm wide), 7-radiates (19%; 0.065 ± 0.003 mm long, 0.042 ± 0.003 mm wide), and a few 6-radiates and multi-radiates (Figs 55, 56; Table 7).

The branch tips contain mainly symmetric 8-radiates (37%; 0.059 ± 0.009 mm long, 0.037 ± 0.005 mm width), asymmetric 8-radiates (32%; 0.056 ± 0.004 mm long, 0.038 ± 0.003 mm width), and a few 6-radiates, 7-radiates, multi-radiates, others (Figs 55, 56; Table 7).

Basal coenenchyme contains mainly symmetric 8-radiates (46%; 0.058 ± 0.005 mm long, 0.037 ± 0.003 mm wide) and asymmetric 8-radiates (35%; 0.056 ± 0.005 mm long, 0.037 ± 0.003 mm width), 7-radiates (13%; 0.056 ± 0.006 mm long, 0.036 ± 0.003 mm width), with a few crosses, 6-radiates and multi-radiates (Figs 55, 56; Table 7).

Etymology. This species is named in honor of Dr. Katherine Muzik, scientist and octocoral researcher for over 50 years (since 1970). She studied taxonomy, including of the Coralliidae, with Dr. Frederick Bayer, and conducted field research on octocorals worldwide, especially in the Caribbean, Fiji, the Hawaiian Islands, Okinawa and Japan. Her excellent studies have greatly supported our research on octocorals.

Remarks. Because specimen NSMT-Co 1738, has non-retracted, cylindrical autozooids (Fig. 52), slender rod-shaped sclerites in the tentacles (Fig. 55), and lacks rounded pits on the axis at the position of each autozooid, this specimen is placed in the genus *Hemicorallium*.

There are only two species of *Hemicorallium* previously described from the Pacific having small (about 1.0 mm in both height and diameter) contracted autozooids: *H. laauense* and *H. taiwanicum*. The two other new species described in this study, *H. kaiyo* sp. nov. and *H. tokiyasui* sp. nov., have similarly sized autozooids, but differ in sclerite composition (both 6-radiates and 8-radiates present) from *H. muzikae* sp. nov. (8-radiates dominant). *Hemicorallium taiwanicum* differs in color (dark-pink coenenchyme and orange axis) and contains predominantly double-club sclerites in its coenenchyme (Tu et al. 2012). *Hemicorallium laauense* and *H. muzikae* sp. nov. have similar sclerite composition, but differ in color of axis and coenenchyme. Additionally, the rod-shaped sclerites of *H. laauense* are reportedly much larger (0.145 mm) (Bayer 1956) than those of *H. muzikae* (0.092 mm).

***Hemicorallium tokiyasui* sp. nov.**

(Figs 57–63; Tables 2, 7)

Material examined. Holotype, NSMT-Co 1736, Koko Seamount, 414 m, 4 September 2009.

Diagnosis. Colony is branched almost in one plane with a few anastomoses. Branching irregular, at acute angles near the base and almost right angles in the twigs. Contract-

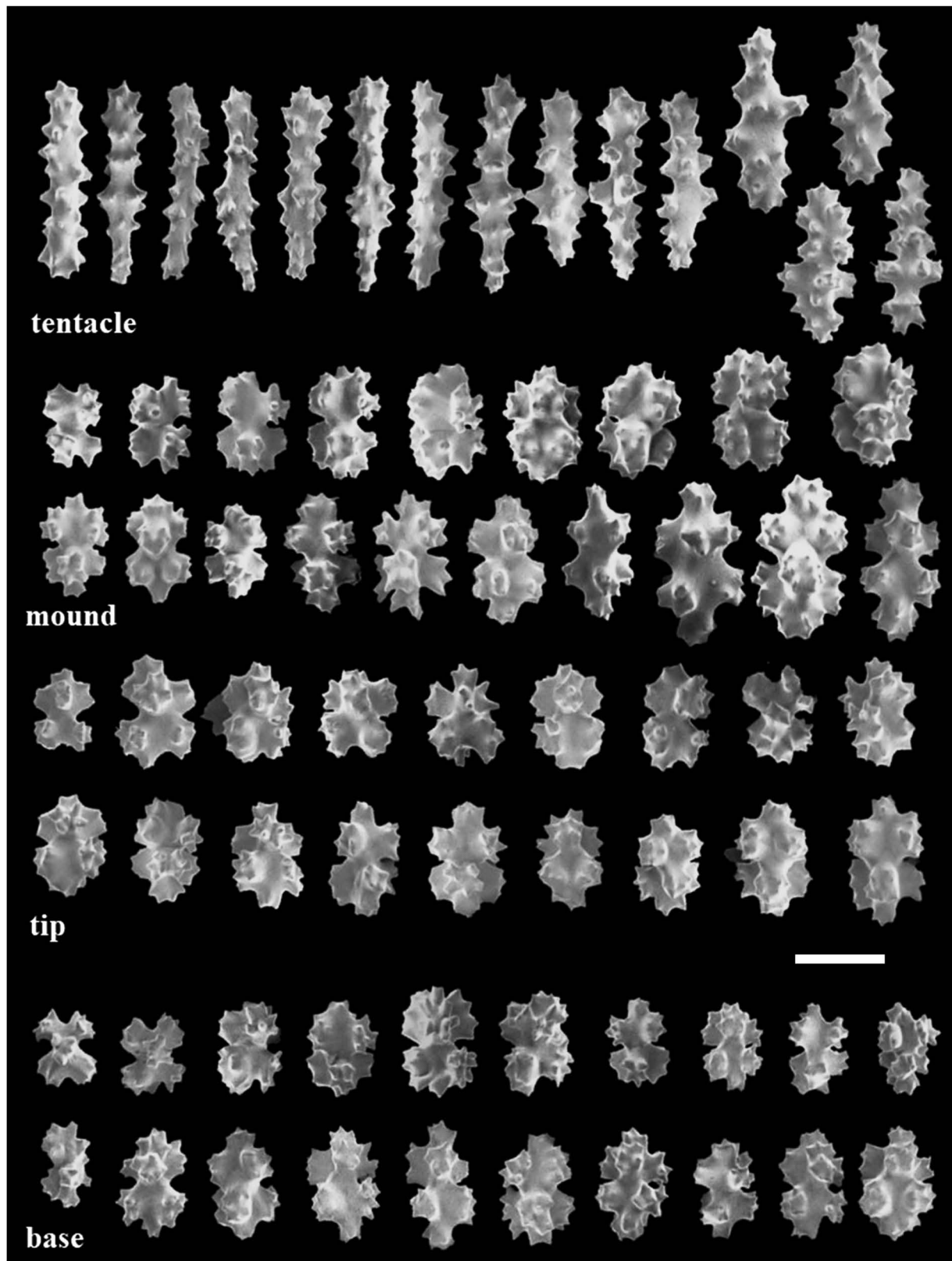
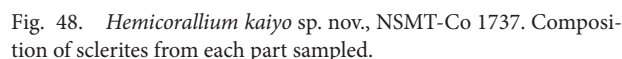


Fig. 47. *Hemicorallium kaiyo* sp. nov., NSMT-Co 1737. Sclerites: from tentacles, autozooid mounds, branch tips and colony base. Scale bar: 0.05 mm.



Description of the holotype. Colony form. The specimen is part of a colony with a thick stem and sharp twigs (Fig. 57). The colony is about 80 mm tall and 60 mm wide, and is branched in almost one plane. Very thin twigs branch off directly from the thick stems, and the twigs have a few anastomoses (Fig. 58). They tend to occur on one side of the colony, with almost no twigs on the remaining sides. Their angle of branching is acute in the stem, but at almost right angles in the twigs. Stem diameter is about 12 mm and thinnest branch tip is about 1–2 mm. Branch cross sections are rounded (Fig. 61).

Polyps. The autozooids are not retracted into the coenenchyme, making cylindrical mounds with 8 longitudinal striations (Fig. 60). Most of them are distributed on all sides of the twigs, with a few of them tending to one side of the stem (Fig. 58). They are 1.00 ± 0.12 mm in diameter and 1.10 ± 0.26 mm in height (Table 2), distributed at 1–2 mm intervals on the twigs (Fig. 59). Siphonozooids are incon-

Table 7. Summary of length and width measurements of common (more than 11%) sclerites for each specimen examined of *Hemicorallium kaiyo* sp. nov., *H. muzikae* sp. nov. and *H. tokiyasui* sp. nov. Measurements are reported the average \pm standard deviation in μ m. Bold numbers indicate most abundant sclerite type. "+" means not common (less than 10%) sclerites. "-" means not found.

Specimen	Species	Tentacles																								
		Rods			6-radiates (symmetrical)			6-radiates (asymmetrical)			7-radiates			8-radiates (symmetrical)			8-radiates (asymmetrical)			Multi-radiates						
		Length	Width	N (%)	Length	Width	N (%)	Length	Width	N (%)	Length	Width	N (%)	Length	Width	N (%)	Length	Width	N (%)	Length	Width	N (%)				
NSMST-Co 1737	<i>H. kaiyo</i> sp. nov.	102.3±14.2	28.0±4.4	49	60	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	84.4±14.3	36.1±6.4	22	27
NSMST-Co 1738	<i>H. muzikae</i> sp. nov.	92.4±17.1	23.7±4.6	26	37	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	79.3±13.3	33.1±5.1	20	29
NSMST-Co 1736	<i>H. tokiyasui</i> sp. nov.	76.7±10.6	23.3±3.6	51	46	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	60.0±9.2	35.8±4.5	31	28
Autozoid mounds																										
NSMST-Co 1737	<i>H. kaiyo</i> sp. nov.	—	57.8±8.3	39.0±4.7	32	25	58.3±5.7	41.5±3.9	16	13	62.0±9.1	39.4±5.1	23	18	67.9±10.6	40.6±4.2	25	20	66.2±6.8	42.2±3.6	19	15	—	—	—	—
NSMST-Co 1738	<i>H. muzikae</i> sp. nov.	—	—	+	—	—	—	—	—	—	65.3±2.5	41.5±3.1	16	19	67.8±7.6	41.4±4.0	38	45	70.5±5.5	43.8±3.0	16	19	—	—	—	—
NSMST-Co 1736	<i>H. tokiyasui</i> sp. nov.	—	—	+	—	—	46.7±4.4	37.0±3.9	16	12	52.5±7.7	36.7±4.0	16	12	—	+	—	—	60.1±8.9	40.6±3.8	22	17	59.1±9.1	42.1±4.3	49	38
Branch tips																										
NSMST-Co 1737	<i>H. kaiyo</i> sp. nov.	—	57.8±5.5	38.7±3.9	11	15	—	—	—	—	57.4±7.9	38.9±3.5	19	26	60.7±5.7	39.2±3.6	21	29	60.5±6.0	40.1±2.9	13	18	—	—	—	—
NSMST-Co 1738	<i>H. muzikae</i> sp. nov.	—	—	+	—	—	—	—	—	—	54.1±5.8	36.3±4.1	8	11	58.6±9.3	36.6±5.0	26	37	55.8±3.8	37.8±3.0	23	32	—	—	—	—
NSMST-Co 1736	<i>H. tokiyasui</i> sp. nov.	—	—	+	—	—	43.6±3.5	34.4±2.7	23	23	46.5±4.2	35.0±2.8	23	23	—	+	—	—	47.2±5.3	34.4±3.7	20	20	49.9±10.9	37.1±4.2	19	19
Colony bases																										
NSMST-Co 1737	<i>H. kaiyo</i> sp. nov.	—	52.8±6.4	36.6±3.8	16	13	—	—	—	—	52.6±5.5	34.9±4.3	27	22	59.0±6.1	37.9±3.3	47	39	56.4±5.7	36.0±3.0	19	16	—	—	—	—
NSMST-Co 1738	<i>H. muzikae</i> sp. nov.	—	—	+	—	—	—	—	—	—	55.8±5.7	36.4±2.6	13	13	57.9±4.9	37.0±2.8	46	46	56.1±5.3	36.6±3.0	35	35	—	—	—	—
NSMST-Co 1736	<i>H. tokiyasui</i> sp. nov.	—	—	+	—	—	44.3±4.1	34.1±2.0	18	14	45.5±5.4	34.5±3.7	21	16	46.9±5.4	33.4±3.8	22	17	47.6±3.4	34.2±2.9	33	26	45.1±3.3	35.5±3.2	19	15

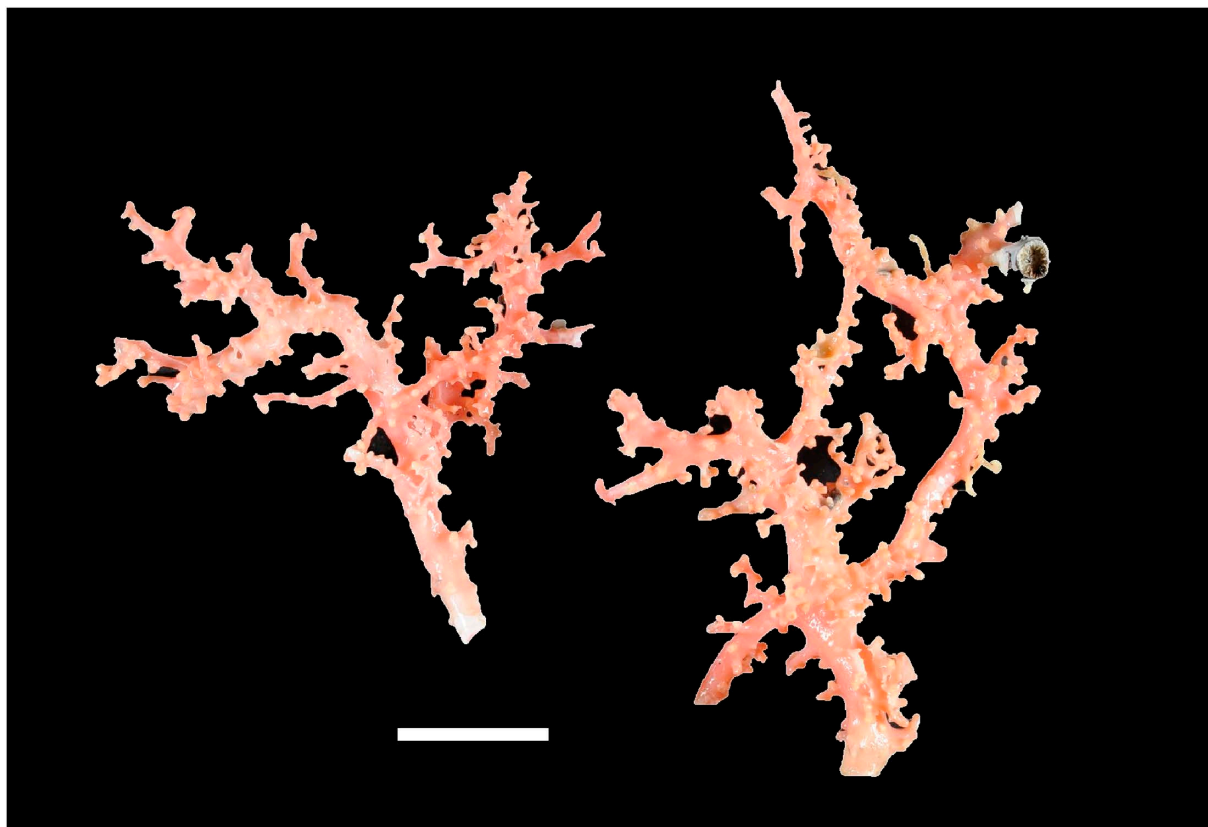


Fig. 49. *Hemicorallium muzikae* sp. nov., holotype, NSMT-Co 1738. Scale bar: 20 mm.

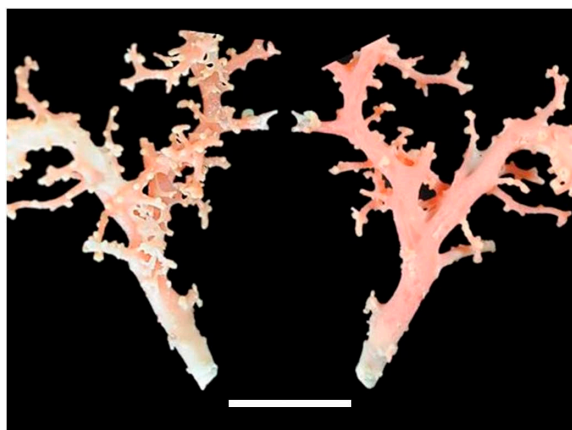


Fig. 50. *Hemicorallium muzikae* sp. nov., NSMT-Co 1738. A, Autozoid side; B, opposite side. Scale bar: 20 mm.

spicuous, distributed on the twigs, and about 0.06 mm in diameter (Fig. 59; Table 2).

Axis. The surface of the axis is smooth, not striated (Fig. 58). There are no rounded pits on the surface of the axis at the position of each autozoid. A few commensal burrows are present in the axis, with one polychaete visible by microscope (Fig. 60).

Coenenchyme. Coenenchyme is very thin, 0.06 ± 0.02 mm thick (Fig. 61; Table 2). Small but distinct warts 0.20 ± 0.02 mm in diameter, are distributed in longitudinal rows on the surface of the colony (Fig. 59).

Color. The dry coenenchyme is pale pink, some twigs are

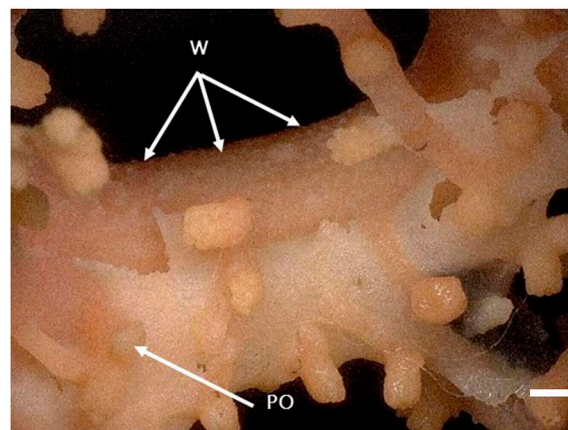


Fig. 51. Surface detail of *Hemicorallium muzikae* sp. nov., NSMT-Co 1738. Abbreviations: PO, commensal polychaete; W, wart. Scale bars: 1.0 mm.

whitish to white (Figs 57, 58). Axis is pale purple to pink in the stem, whitish in the twigs (Figs 57, 58).

Sclerites. The tentacles contain mainly rods (46%; 0.077 ± 0.011 mm long, 0.023 ± 0.004 mm wide), multi-radiates (28%; 0.060 ± 0.009 mm long, 0.036 ± 0.005 mm wide) and a few 6-radiates, 7-radiates, 8-radiates and others (Figs 62, 63; Table 7).

The autozoid mounds contain mainly multi-radiates (38%; 0.059 ± 0.009 mm long, 0.042 ± 0.004 mm wide), asymmetric 8-radiates (17%; 0.060 ± 0.009 mm long, 0.041 ± 0.004 mm wide), and some 6-radiates, 7-radiates,

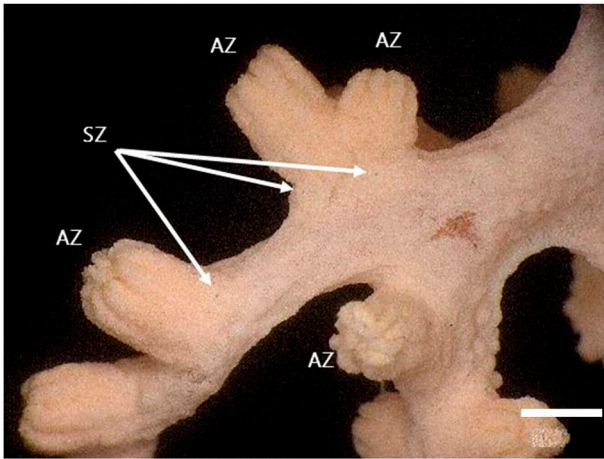


Fig. 52. Detail of twig of *Hemicorallium muzikae* sp. nov., NSMT-Co 1738. Abbreviations: AZ, autozooid; SZ, siphonozooid. Scale bar: 1.0 mm.

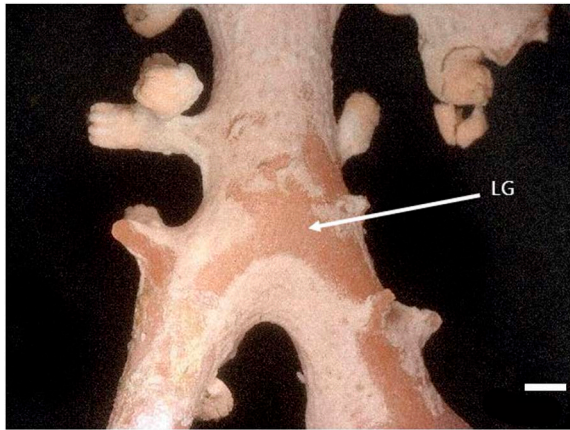


Fig. 53. Detail of twig of *Hemicorallium muzikae* sp. nov., NSMT-Co 1738. Abbreviation: LG, longitudinal groove. Scale bar: 1.0 mm.

symmetric 8-radiates, a few 5-radiates and others are present (Figs 62, 63; Table 7).

The branch tips contain mainly asymmetric 6-radiates (23%; 0.044 ± 0.004 mm long, 0.034 ± 0.003 mm wide), 7-radiates (23%; 0.047 ± 0.004 mm long, 0.035 ± 0.003 mm wide), asymmetric 8-radiates (20%; 0.047 ± 0.005 mm long, 0.034 ± 0.004 mm wide), multi-radiates (19%; 0.050 ± 0.011 mm long, 0.037 ± 0.004 mm wide), and a few crosses, symmetric 6-radiates, and symmetric 8-radiates (Figs 62, 63; Table 7).

Coenenchyme on the base of the colony contains mainly asymmetric 8-radiates (26%; 0.048 ± 0.003 mm long, 0.034 ± 0.003 mm wide), symmetric 8-radiates (17%; 0.047 ± 0.005 mm long, 0.033 ± 0.004 mm wide), 7-radiates (16%; 0.046 ± 0.005 mm long, 0.035 ± 0.004 mm wide), multi-radiates (15%; 0.045 ± 0.003 mm long, 0.036 ± 0.003 mm wide) and asymmetric 6-radiates (14%; 0.044 ± 0.004 mm long, 0.034 ± 0.002 mm wide). There are a few crosses 5-radiates and symmetric 6-radiates (Figs 62, 63; Table 7).

Etymology. Named for the location where the specimen collected, Koko Seamount, one of the Emperor Sea-

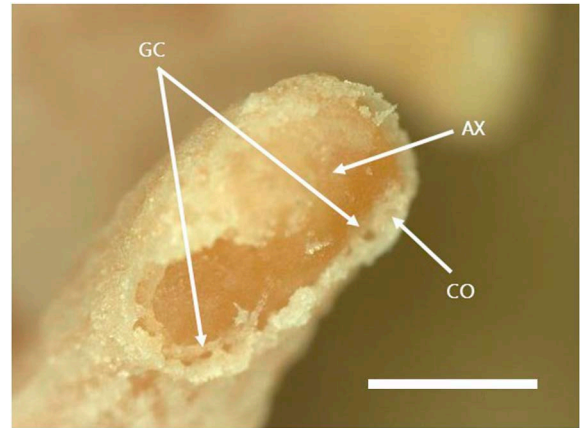


Fig. 54. Section of a twig of *Hemicorallium muzikae* sp. nov., NSMT-Co 1738. Abbreviations: GC, gastrovascular cavity; AX, axis; CO, coenenchyme. Scale bar: 1.0 mm.

mounts. In 1954, Robert S. Dietz, a United States oceanographer, named the seamounts in the chain after Japanese emperors (mainly ancient) (Sugiyama 2005). Koko Seamount was named for the 58th Japanese Emperor, Koko (830–887). The scientific name of this new species honors Emperor Koko and is derived from his “Imina” or personal name, Tokiyasu.

Remarks. Tu et al. (2015b) described the morphological characters of the genus *Hemicorallium* as follows: Contracted autozooids are not retracted in the coenenchyme, cylindrical in shape, usually distributed on one side of the colony. The tentacles contain slender rod-shaped sclerites. These characters are all found in NSMT-Co 1736.

In the species of the genus *Hemicorallium* described from the Pacific, only *H. laauense* and *H. taiwanicum* have contracted autozooids similar in size to NSMT-Co 1736 (about 1.0 mm in both height and diameter). However, *H. laauense* has a whitish axis and coenenchyme, and *H. taiwanicum* has an orange axis and dark-pink coenenchyme. The morphological features of this specimen most resemble *H. kaiyo* sp. nov. as described above (in autozooid size and sclerite composition) but axis color and sclerite size are remarkably different (those of *H. kaiyo* are much larger). A unique character of NSMT-Co 1736 is having a pale purple to pink axis. Moreover, except for the tentacle rods, the sclerites of NSMT-Co 1736 are smaller, <0.05 mm, than those of *H. laauense* (>0.08 mm) and *H. taiwanicum*: 0.054–0.096 mm).

Molecular analysis of the three new species

Forty-one sequences were obtained with the IGR1 primers. The sequences were trimmed to 426–581 base pairs length. The results of IGR1 analyses performed on the mitochondrial datasets are presented in Fig. 64 [by the Neighbor-joining (NJ) method], Fig. 65 [by the Maximum Likelihood (ML) method], and Fig. 66 [by the Bayesian Inference (BI)]. The genus *Hemicorallium* was recovered as a monophyly with strong support in NJ and ML (Figs 64, 65; 100%

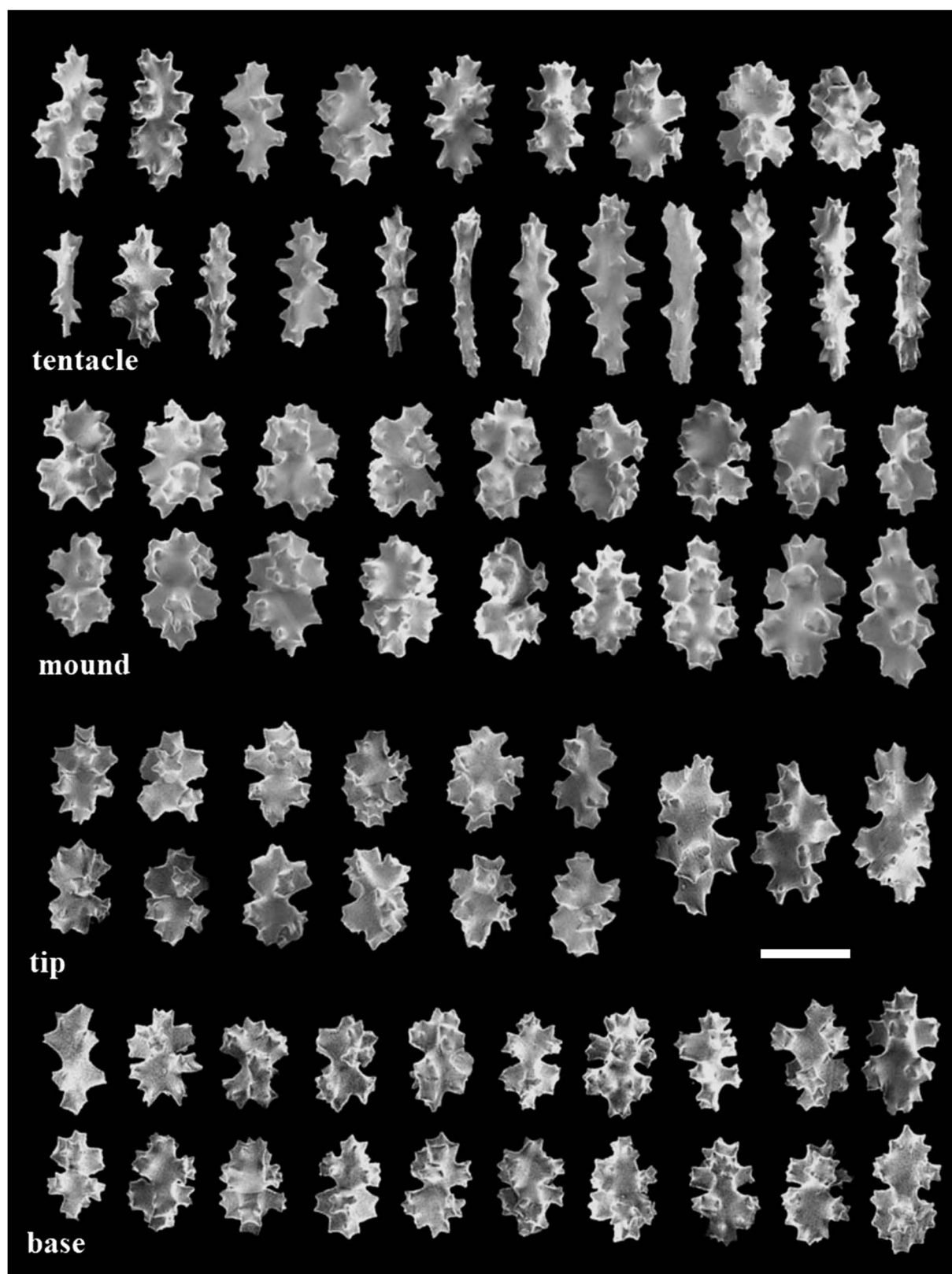


Fig. 55. *Hemicorallium muzikae* sp. nov.: NSMT-Co 1738. Sclerites: from tentacles, autozoid mounds, branch tips and colony base. Scale bar: 0.05 mm.

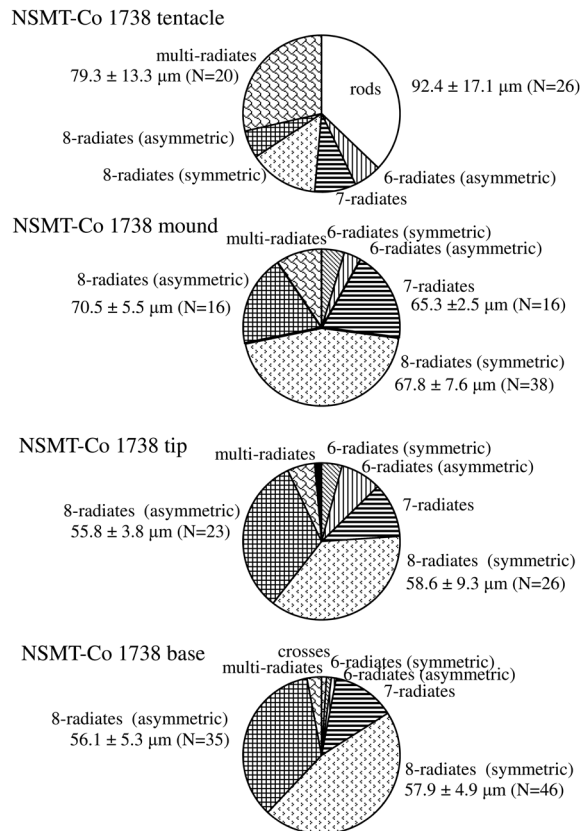


Fig. 56. *Hemicorallium muzikae* sp. nov., NSMT-Co 1738. Composition of sclerites from each part sampled.

bootstrap value), but not supported in BI (Fig. 66).

Hemicorallium bayeri (Simpson and Watling, 2011) (KF854964) and *H. niobe* (Bayer, 1964) (KF854965) formed a clade with strong support (NJ=100%, ML=100% and BI=0.99, respectively) (Figs 64–66). Other species of *Hemicorallium* formed a clade with strongly supported branches (NJ=99%, ML=96% and BI=0.99, respectively) (Figs 64–66). In any of the three phylogenetic trees, “*H. tokiyasui* sp. nov. NSMT-Co 1736”, “*H. muzikae* sp. nov. NSMT-Co 1738” and “*H. kaiyo* sp. nov. NSMT-Co 1737” appeared to be polyphyletic (Figs 64–66). The K2P genetic distance from the nearest species were; 0.004 in NSMT-Co 1737 (*H. kaiyo* sp. nov.), 0.015 in NSMT-Co 1738 (*H. muzikae* sp. nov.) and 0.011 in NSMT-Co 1736 (*H. tokiyasui* sp. nov.).

Discussion

Pleurocorallium secundum has been identified as the main fishery species reported from Hawaii (e.g., Grigg 1974). It was also considered to be the most dominant species harvested in the Emperor Seamounts Chain, where it was called “Mid” until now. “Mid” was identified as *P. secundum* (e.g. Grigg 1984), but there were no taxonomic descriptions of any corals collected. Dana (1846) relied only on colony shape and color in describing his *P. secundum* specimen, without making any reference to taxonomically important microscopic features such as polyp size and arrangement, and sclerite size, shape, color and arrangement. Moreover, even its locality (the Sandwich Islands, or Hawaii) is still in question. Because of the poor condition of the holotype specimen of *P. secundum* “long known only from the unique

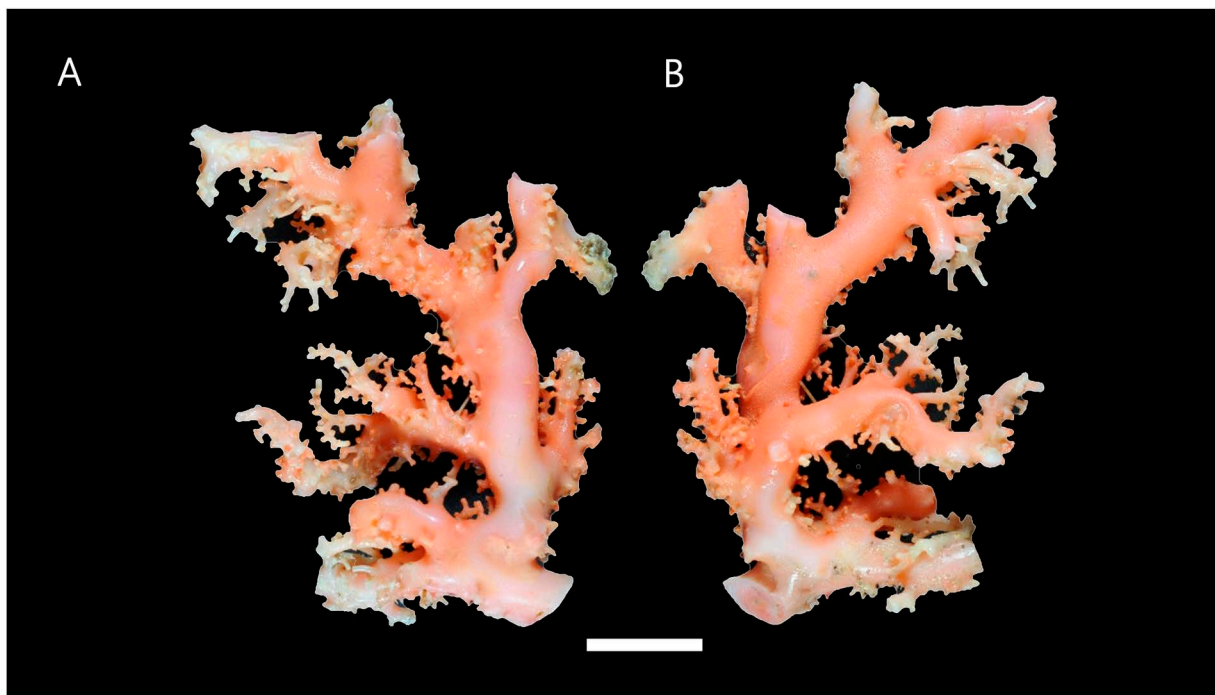


Fig. 57. *Hemicorallium tokiyasui* sp. nov., holotype, NSMT-Co 1736. A, Autozooid side, B, opposite side. Scale bar: 20 mm.

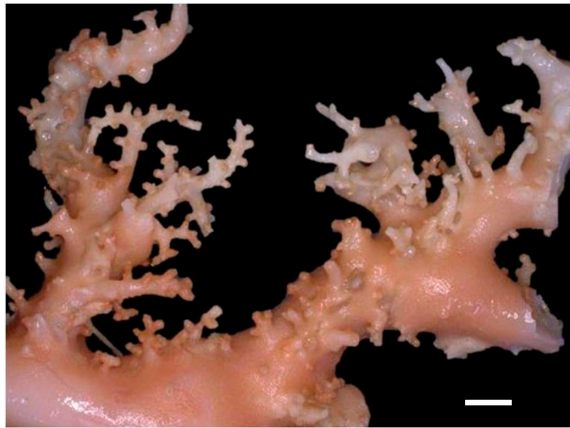


Fig. 58. The distribution of autozooids of *Hemicorallium tokiyasui* sp. nov., NSMT-Co 1736. Scale bar: 5.0 mm.

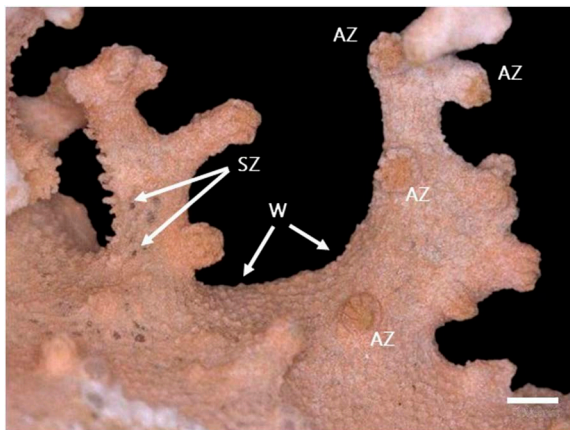


Fig. 59. Surface detail of *Hemicorallium tokiyasui* sp. nov., NSMT-Co 1736. Abbreviations: AZ, autozooid; SZ, siphonozooid; W, wart. Scale bar: 1.0 mm.

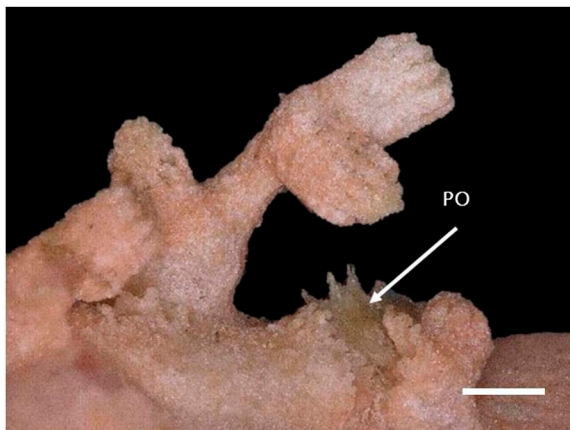


Fig. 60. Surface detail and polychaete of *Hemicorallium tokiyasui* sp. nov., NSMT-Co 1736. Abbreviation: PO, commensal polychaete. Scale bar: 1.0 mm.



Fig. 61. Cross section of basal branch of *Hemicorallium tokiyasui* sp. nov., NSMT-Co 1736. Scale bar: 1.0 mm.

type, which is now decorticated" (Bayer 1956), Bayer re-described the species, illustrating characters of polyps and sclerites with detailed drawings (Bayer 1956). However, he did not report any features of the damaged Dana holotype but instead, only of two specimens collected at two "Albatross" Expedition stations in Hawaii in 1902. Therefore, it remains uncertain if any of the "Albatross" specimens he described were indeed *P. secundum* (Nonaka et al. 2015). None of the 22 specimens studied here fit the description of "*P. secundum* sensu Bayer 1956." The eleven specimens identified as *P. cf. pusillum* are somewhat similar to the drawing of *P. secundum* (Dana 1846), but are substantially different in some characters, e.g., number of autozooids in a cluster (Figs 3B, 4B) and the maximum size (nearly 0.09 mm) of the sclerites (Table 3). Therefore, it is quite possible that the specimens called "Mid" from the Emperor Seamounts were misidentified, being not *P. secundum*, but instead, *P. pusillum*. However, since the holotype of *P. pusillum* is lost and no other specimens were ever identified by Kishinouye as belonging to this species, we cannot yet definitively conclude that any of our specimens are indeed *P. pusillum* in this study.

We report three new species that are morphologically distinguishable from all previously described species. Tu et al. (2015b) conducted molecular analyses of various specimens of Coralliidae and reported the gene region of IGR1 to be the best marker for identifying species. With reference to that report, samples in this study were also analyzed using IGR1 sequences. Results confirmed that the three morphologically distinguished specimens, described here as new species, are polyphyletic in the three phylogenetic trees (Figs 64–66). Tu et al. (2015a) found that the genetic distance of interspecific variation was 0.005 to 0.006, and those of intraspecific was 0.001 in the species of the family Coralliidae. The pairwise distance of the three specimens of the new species is from 0.004 to 0.015 apart from the closest species, which is larger than the intraspecific variation. In conjunction with the morphological differences between the three new species, they are considered independent species in this study.

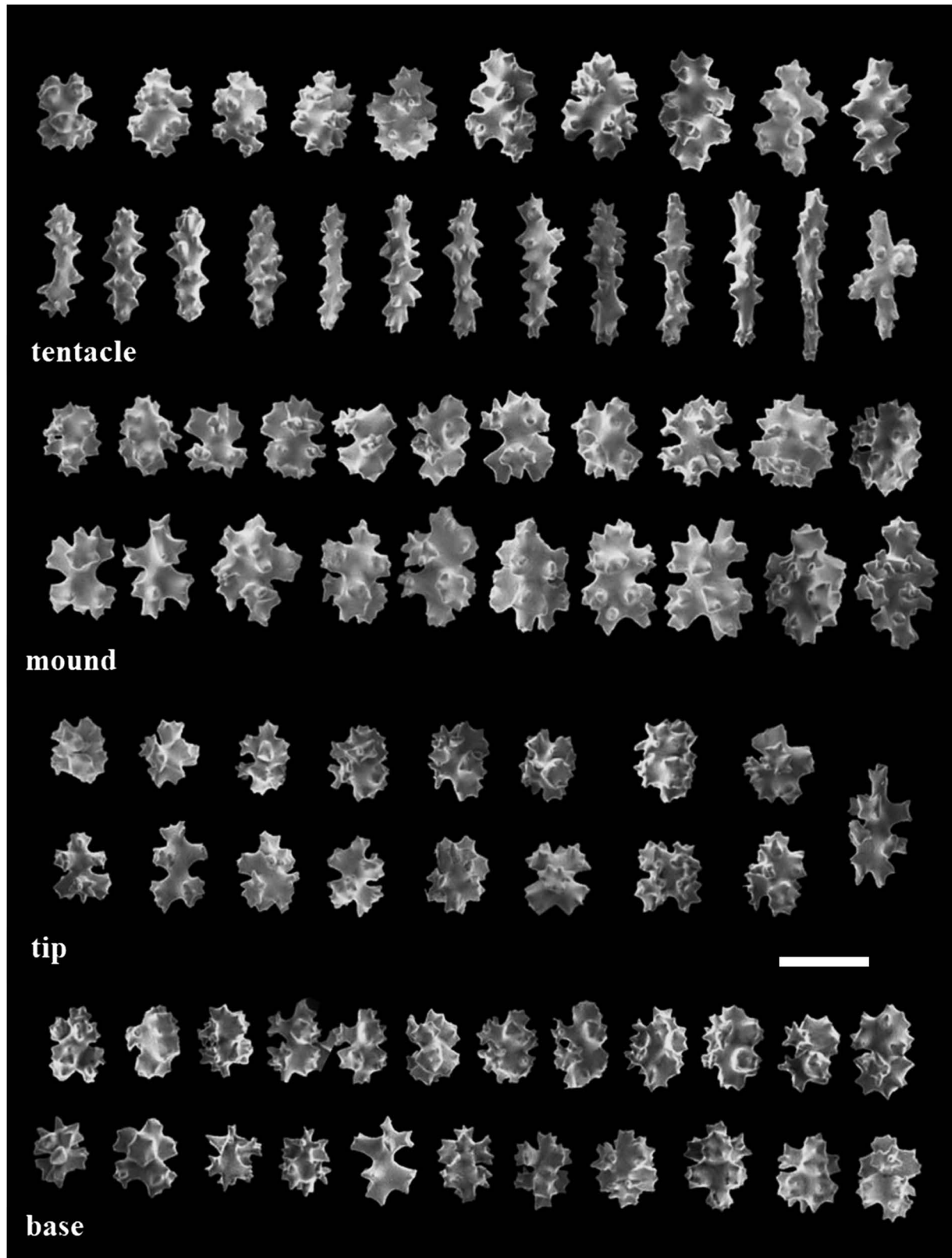


Fig. 62. *Hemicorallium tokiyasui* sp. nov., NSMT-Co 1736. Sclerites: from tentacles, autozoid mounds, branch tips and colony base. Scale bar: 0.05 mm.

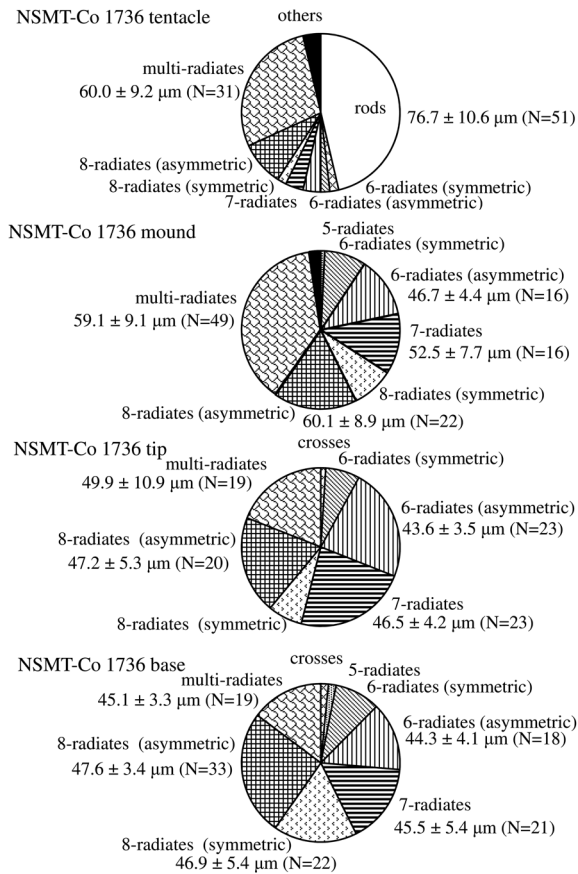


Fig. 63. *Hemicorallium tokiyasui* sp. nov., NSMT-Co 1736. Composition of sclerites from each part sampled.

At Midway and the Emperor Seamounts, corals in the undescribed species called “Midway deep-sea coral” were harvested from more than 1000–1500 m deep (Grigg 1984). It is possible that one of the three new species described in this research is the “Midway deep-sea coral”. However, they were all collected from shallower depths, 414 m (*H. tokiyasui* sp. nov.), 409–942 m (*H. kaiyo* sp. nov.), and 682 m (*H. muzikae* sp. nov.) respectively, so none can yet be definitively considered to be the “Midway deep-sea coral”. In order to reveal the taxonomic diversity of the Coralliidae in this area, further investigations and collections in deeper waters will be necessary.

Key to the species of *Hemicorallium* from Hawaii and the Western Pacific

1. Coenenchyme (except tip or autozooid mounds) color whitish or yellowish 2
 - Coenenchyme color reddish or orangeish 4
2. Autozooid mounds large (1.4–1.6 mm in diameter) and tall (1.7–2.2 mm), pale red in color 3
 - Autozooid mounds small and short (approx. 1.0 mm), whitish in color 3
3. Branching rather bushy; double-clubs present

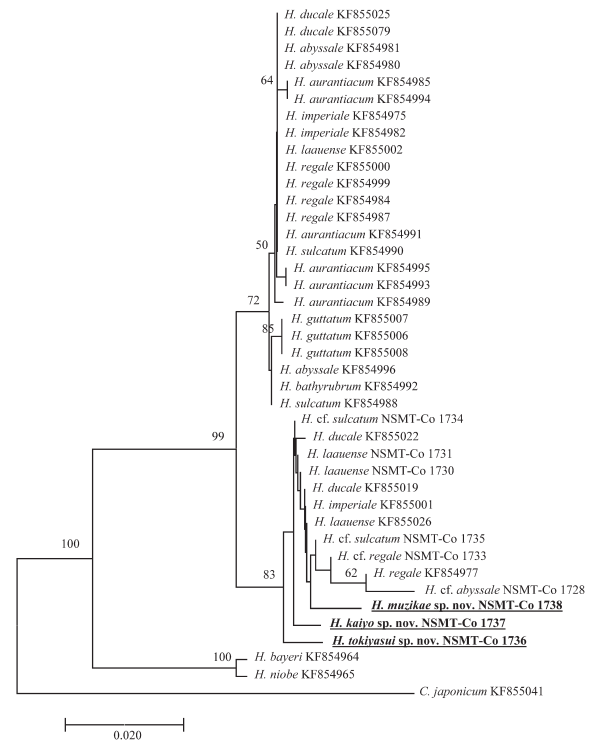


Fig. 64. Phylogenetic trees reconstructed from the concatenated mitochondrial dataset (IGR1). The evolutionary history is inferred by using the Neighbor-joining (NJ) method based on the T92+G model. Numbers on nodes represent bootstrap values (only >50% values are shown respectively). The three undescribed species are shown in bold and underlined.

Hemicorallium boshuense (Kishinouye, 1903)

- Branching lateral; double-clubs absent

Hemicorallium laauense (Bayer, 1956)

4. Autozooid mounds scarce, distributed biserially, large (app. 2.0 mm in both diameter and height)

Hemicorallium abyssale (Bayer, 1956)

- Autozooid mounds crowded, predominant on one side 5

5. Double-clubs abundant 6

- Double-clubs absent or rare 7

6. Autozooid mounds tall (0.9–2.0 mm in height); axis pinkish 6

- Autozooid mounds short (app. 1.0 mm in height); axis orange 7

Hemicorallium taiwanicum (Tu, Dai and Jeng, 2012)

7. 8-radiates abundant (>60%) 8

- 8-radiates present but not abundant (<50%) 12

8. Autozooid mounds tall (2.0–3.0 mm) 8

Hemicorallium halmahirens (Hickson, 1907)

- Autozooid mounds not tall (less than 1.5 mm) 9

9. Spherical sclerites absent

Hemicorallium muzikae sp. nov.

- Spherical sclerites present 10

10. Spherical 8-radiates present

Hemicorallium aurantiacum Tu, Dai and Jeng, 2016

- Spherical 8-radiates absent 11

11. Large irregular sclerites present; coenenchyme and axis orangeish *Hemicorallium reginae* (Hickson, 1905)
- Large irregular sclerites absent; coenenchyme and axis red *Hemicorallium regale* (Bayer, 1956)
12. Most coenenchymal sclerites small (<0.05 mm in length); coenenchyme pinkish and axis pale purple *Hemicorallium tokiyasui* sp. nov.
- Most coenenchymal sclerites large (>0.05 mm in length); coenenchyme and axis red *Hemicorallium kaiyo* sp. nov.

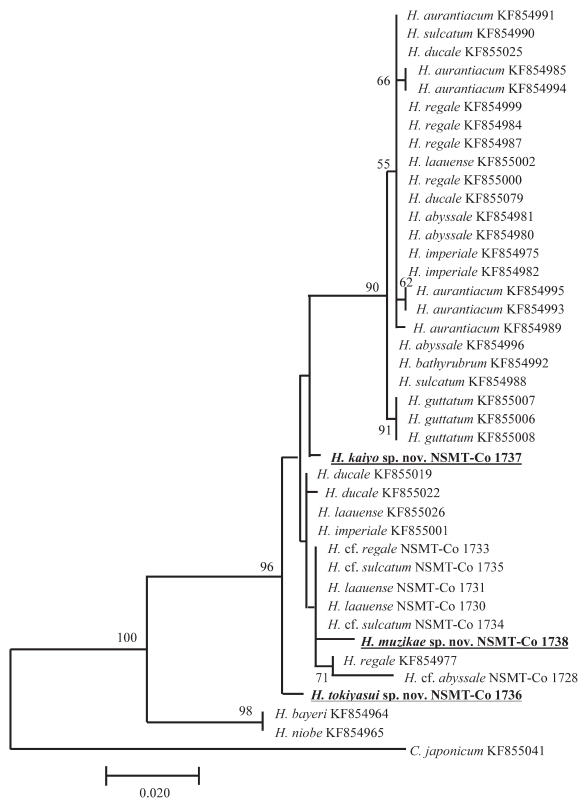


Fig. 65. Phylogenetic trees reconstructed from the concatenated mitochondrial dataset (IGR1). The evolutionary history was inferred by using the Maximum Likelihood (ML) method based on the T92+G model. Numbers on nodes represent bootstrap values (only >50% values are shown respectively). The three undescribed species are shown in bold and underlined.

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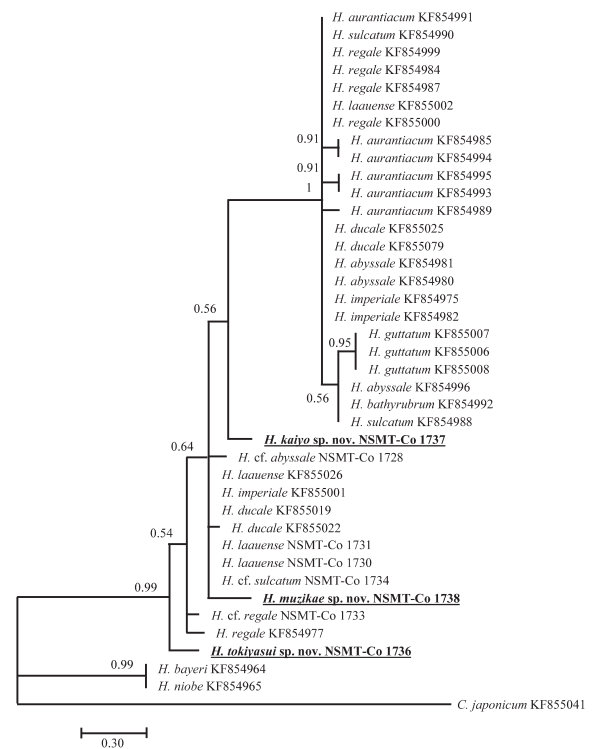


Fig. 66. Phylogenetic trees reconstructed from the concatenated mitochondrial dataset (IGR1). The evolutionary history was inferred by using the Bayesian inference (BI). Numbers on nodes represent bootstrap values (only >0.5 values are shown respectively). The three undescribed species are shown in bold and underlined.

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References

- Ardila, N. E., Giribet, G., and Sanchez, J. A. 2012. A time-calibrated molecular phylogeny of the precious corals: reconciling discrepancies in the taxonomic classification and insights into their evolutionary history. *BMC Evolutionary Biology* 12: 246.
- Baco, A. R., Roark, E. B., and Morgan, N. B. 2019. Amid fields of rubble, scars, and lost gear, signs of recovery observed on seamounts on 30- to 40-year time scales. *Science Advances Research Article* 5: 1–7.
- Bayer, F. M. 1950. A new precious coral from North Borneo. *Journal of the Washington Academy of Science* 40: 59–61.
- Bayer, F. M. 1956. Descriptions and redescrptions of the Hawaiian octocorals collected by the U.S. Fish Commission steamer “Albatross” (2. Gorgonacea: Scleraxonia). *Pacific Science* 10: 67–95.
- Bayer, F. M. and Cairns, S. D. 2003. A new genus of the scleraxonian family Coralliidae (Octocorallia: Gorgonacea). *Proceedings of the Biological Society of Washington* 116: 222–228.

- Bayer, F. M., Grasshoff, M., and Verseveldt, J. 1983. *Illustrated Trilingual Glossary of Morphological and Anatomical Terms Applied to Octocorallia*. E.J.Brill / Dr. W.Backhuys, Leiden, 75 pp.
- Bayer, F. M. 1996. Three new species of precious coral (Anthozoa: Gorgonacea, genus *Corallium*) from Pacific waters. *Proceedings of the Biological Society of Washington* 109: 205–228.
- Dana, J. D. 1846. *Zoophytes. United States Exploring Expedition Vol. 7*. C. Sherman, Philadelphia, 740 pp., 45 figs, atlas of 61 col. pls.
- Figueroa, D. F. and Baco, A. R. 2014. Complete mitochondrial genomes elucidate phylogenetic relationships of the deep-sea octocoral families Coralliidae and Paragorgiidae. *Deep Sea Research Part II: Topical Studies in Oceanography* 99: 83–91.
- Grigg, R. W. 1974. Distribution and abundance of Precious Corals in Hawaii. *Proceedings of the 2nd International Coral Reef Symposium* 2: 235–240.
- Grigg, R. W. 1984. Resource management of precious corals; A review and application to shallow water reef building corals. *Marine Ecology* 5: 57–74.
- Grigg, R. W. 2002. Precious corals in Hawaii: discovery of a new bed and revised management measures for existing beds. *Marine Fisheries Review* 64: 13–20.
- Imahara, Y. 1996. Previously recorded octocorals from Japan and adjacent seas. *Precious Corals & Octocoral Research* 4–5: 17–44.
- Kishinouye, K. 1902. [A new species of coral collected from Japan]. *Dobutsugaku Zasshi* 14: 419–420. [In Japanese]
- Kishinouye, K. 1903a. [The corals collected from Japan]. *Dobutsugaku Zasshi* 15: 103–106. [In Japanese]
- Kishinouye, K. 1903b. Preliminary note on the Coralliidae of Japan. *Zoologischer Anzeiger* 26: 623–626.
- Kishinouye, K. 1903c. [Kosango]. *Dobutsugaku Zasshi* 15: 372. [In Japanese]
- Kishinouye, K. 1904. [The study of the corals]. *Suisan Chosa Hokoku* 14: 1–31. [In Japanese]
- Kishinouye, K. 1905. Notes on the natural history of corals. *Journal of Imperial Fishery Bureau* 14: 1–32.
- Kosuge, S. 1993. History of the Precious Coral Fisheries in Japan (1). *Precious Corals & Octocoral Research* 1: 30–38.
- Kukenthal, W. 1924. *Gorgonaria*. *Das Tierreich* 47: 1–478.
- Miyamoto, M., Kiyota, M., Hayashibara, T., Nonaka, M., Imahara, Y., and Tachikawa, H. 2017. Megafaunal composition of cold-water corals and other deep-sea benthos in the southern Emperor Seamounts area, North Pacific Ocean. *Galaxea, Journal of Coral Reef Studies* 19: 19–30.
- Nonaka, M. and Muzik, K. 2010. Jewels of the deep sea: precious corals. Pp. 84–127. In: Uchida, S. (Ed.) *Into the Unknown, Researching Mysterious Deep-sea Animals. Proceedings of an International Symposium, 23–24 Feb 2007*. Okinawa Churaumi Aquarium, Okinawa.
- Nonaka, M. and K. Muzik, 2012. Systematic studies of the Indo-Pacific Coralliidae. Pp. 70–84. In: *Proceedings of an International Precious Coral Forum 2012 in Kochi*. The Precious Coral Protection and Development Association, Kochi.
- Nonaka, M. and Muzik, K. 2016. The first records of two species of precious coral (Octocorallia: Coralliidae) from the Ryukyu Archipelago. *Fauna Ryukyuana* 29: 15–36.
- Nonaka, M., Muzik, K., and Iwasaki, N. 2012. Descriptions of two new species and designation of three neotypes of Japanese Coralliidae from recently discovered specimens that were collected by Kishinouye, and the introduction of a statistical approach to sclerite abundance and size. *Zootaxa* 3428: 1–67.
- Nonaka, M., Takaoka, H., and Muzik, K. 2015. The taxonomic problem of the Hawaiian pink coral, *Corallium secundum*. Pp. 247–256. In: Jeng, M-S. (Ed.) *International Symposium on Pacific Precious Corals Final Report 2014*. Taiwan Jewelry Industry Association, Taipei.
- Pasternak, F. A. 1981. Alcyonacea and Gorgonacea. Pp. 40–55. In: Kuznetsov, A. P. and Mironov, A. N. (Eds) *Benthos of the Submarine Mountains Marcus-Necker and Adjacent Pacific Regions*. Akademiya Nauk, Moscow.
- Ridley, S. O. 1882. On the arrangement of the Coralliidae, with descriptions of new or rare species. *Proceedings of the Zoological Society of London* 50: 221–233.
- Sugiyama, A. 2005. [Emperor Seamount Chain.—Discovery, naming and enigma of its formation—*Earth Science*]. *Chikyuu Kagaku* 59: 72–79. [In Japanese]
- Tu, T. H., Dai, C. F. and Jeng, M. S. 2012. Precious corals (Octocorallia: Coralliidae) from the northern West Pacific region with descriptions of two New Species. *Zootaxa* 3395: 1–17.
- Tu, T. H., Altuna, A., and Jeng, M. S. 2015a. Coralliidae (Anthozoa: Octocorallia) from the INDEMARES 2010 expedition to north and northwest Spain (northeast Atlantic), with delimitation of a new species using both morphological and molecular approaches. *Zootaxa* 3926: 301–328.
- Tu, T. H., Dai, C. F., and Jeng, M. S. 2015b. Phylogeny and systematics of deep-sea precious corals (Anthozoa: Octocorallia: Coralliidae). *Molecular Phylogenetics and Evolution* 84: 173–184.
- Tu, T. H., Dai, C. F., and Jeng, M. S. 2016. Taxonomic revision of Coralliidae with descriptions of new species from New Caledonia and the Hawaiian Archipelago. *Marine Biology Research* 12: 1003–1038.