Species Diversity **28**: 231–243
Published online 9 November 2023
DOI: 10.12782/specdiv.28.231

A New Species of Coralliidae (Cnidaria: Octocorallia) Collected from Eastern Japan

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(Received 15 March 2023; Accepted 31 August 2023)

https://zoobank.org/01B87E02-9319-40F1-B2E7-D36F4F1FC2FC

A new species of *Hemicorallium* Gray, 1867 (Coralliidae), *Hemicorallium meraboshi* sp. nov., is described here. The specimen was found at a depth of 1744–1755 m, approximately 340 km east of the Honshu (mainland Japan) coast. The colony was identified by visual and microscopic observation of standard morphological characteristics (colony size, diameters of colony base and branches, diameter and height of autozooid mound, thickness of coenenchyme, sclerite sizes, etc.) along with support from molecular evidence. The unique features of this specimen are the large (more than 2 mm in diameter) autozooid mounds and the sizable sclerites in the coenenchyme (over 0.1 mm long) that are 8-radiates and multi-radiates predominantly. This new species is the northernmost record of Pacific precious corals.

Key Words: bathyal, coral, deep sea, Iwaki Seamount, phylogeny, precious coral.

Introduction

In Coralliidae comprising 14 genera (McFadden et al. 2022), species in the genera *Corallium* Cuvier, 1798, *Hemicorallium* Gray, 1867, and *Pleurocorallium* Gray, 1867 are known as precious corals, because their hard, colorful axial skeletons have been valuable for use as jewelry, medicine, and other products for nearly 5000 years (Grigg 1984).

The first taxonomic papers on the Japanese precious corals were those by Ridley (1882) and Kishinouye (1902, 1903a–c, 1904, 1905) over 100 years ago. Kishinouye's description of *Pleurocorallium inutile* Kishinouye, 1902 as a new species (Kishinouye 1902) was the first octocoral study ever published by a Japanese scientist (Imahara 2007). Pasternak (1981) recorded *C. boshuensis* Kishinouye, 1903 (currently *H. boshuense*) in the Marcus-Necker Sea Mounts near Hawaii. Imahara (1996) listed all octocorals reported in Japanese waters, with eight species of *Corallium*, and two species of *Pleurocoralloides* Moroff, 1902 in the family Coralliidae. Bayer and Cairns (2003) suggested that the genus *Pleurocoralloides* was a synonym of *Acabaria* Gray, 1859, and in the same publication, they established the new genus, *Paracorallium* Bayer and Cairns, 2003 in the family Coralliidae. Nonaka et al. (2012) also described two new species from Japan.

Using molecular analyses, Ardila et al. (2012) recognized *Paracorallium* as a junior synonym of *Corallium* and proposed the use of the genus *Hemicorallium* for species having tentacles with long rod sclerites, cylindrical autozooid mounds, and smooth axes. Figueroa and Baco (2014) concluded that *Paracorallium* should be subsumed into *Corallium* and resurrected the genus *Pleurocorallium*. Tu et al. (2015) revised the three genera of Coralliidae as *Corallium* (strong longitudinally grooved axes with pits usually raindrop-shaped, especially near branch tips), *Hemicorallium* (tentacles with long rod sclerites, cylindrical autozooid mounds, and smooth axes), and *Pleurocorallium* (hemispherical autozooid mounds and axes without raindrop-shaped pits). Currently, there are nine species of the three genera from Japan, one of the genus *Corallium* (*C. japonicum* Kishinouye, 1903), two of *Hemicorallium* [*H. boshuense* and *H. sulcatum* (Kishinouye, 1903)], and six of *Pleurocorallium* [*P. elatius* (Ridley, 1882), *P. gotoense* (Nonaka, Muzik, and Iwasaki, 2012), *P. inutile*, *P. konojoi* (Kishinouye, 1903), *P. pusillum* (Kishinouye, 1903) and *P. uchidai* (Nonaka, Muzik, and Iwasaki, 2012)].

The specimen examined in this study was sampled in 2009 using the research vessel, "Soyo-maru" during investigations for the conservation of deep-water benthic ecosystems in the Iwaki Seamount (Fig. 1).

Materials and Methods

The coral colony was collected using a beam trawl (benthos net) from a depth of 1744–1755 m, approximately 340 km off the eastern coast of the Japanese mainland (Fig. 1). The sample was photographed on a millimeter scale, preserved in 99.5% ethanol, and deposited in the National Museum of Nature and Science, Tokyo (NSMT).

The specimen (NSMT-Co 1801) was observed using both

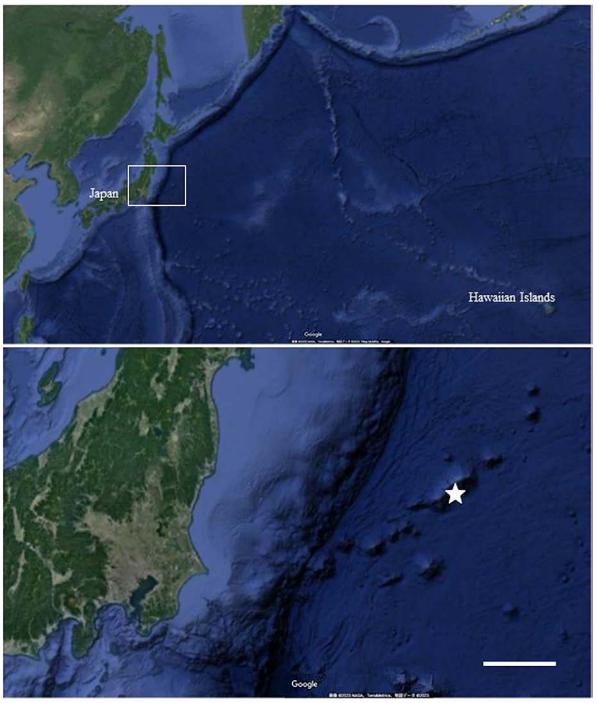

Fig. 1. Maps of northwestern Pacific. The square in the top map indicates the area in the bottom map. The star is the location of the sampling station in this study. Maps were produced using Google Maps. Scale bar: 100 km.

the naked eye and a digital microscope (Keyence VHX). Measurements, including those of colony size, diameter of colony base and branches, diameter and height of autozooid mounds (not soft tissues but fully contracted autozooid covered with coenenchyme), and thickness of coenenchyme were taken using measurement software, as well as Keyence VHX and Image J software. Small pieces of coenenchyme were removed by hand using a dissecting needle from the four colony parts (tentacles, autozooid mounds, branch tips, and colony base) for sclerite examination. For scanning electron microscopy (SEM) examination, sclerites were separated and cleaned using a 5% sodium hypochlorite solution (household bleach), and details of sclerites were observed with the Keyence VE-8800.

The sclerites were classified according to standard taxonomic convention (Bayer 1956; Bayer et al. 1983) and 6- and 8-radiates were separated as "symmetric" and "asymmetric" (Nonaka and Hayashibara 2021). In addition, for this study, multi-radiates were subdivided into "elongate," "spherical," and "cross" shapes (Fig. 2). All observed sclerites are presented in a pie chart (Fig. 17) and in Table 1. These sclerites were photographed using SEM, and the length and width were measured with SEM accessory software. Important taxonomic characteristics such as the dimensions of contracted autozooids, coenenchyme thickness, and sclerite sizes were measured several times, but only ranges (average ± standard deviation) are reported in the descriptions. Morphological identification followed taxonomic keys by Bayer (1956), Nonaka et al. (2012), Tu et al. (2016), and Nonaka and Hayashibara (2021).

For genetic analysis, total DNA was extracted from tissue samples of the holotype (NSMT-Co 1801) using the "HotSHOT" method (Truett et al. 2000). Segments of six mitochondrial regions [16S rRNA (16S), ND1 (NADH dehydrogenase subunit 1), 16S–ND2, ND3–ND6, ND6–COI (cytochrome *c* oxidase subunit I), and MSH (MutS-like protein] and one nuclear region, elongation factor 1 (EF1), were amplified using the primer pairs described by Tu et al. (2015). A polymerase chain reaction (PCR) was performed using the KOD FX Neo DNA polymerase kit (Toyobo, Osaka, Japan) under the following cycling conditions: 94°C for 2 min, 15 cycles of denaturation at 98°C for 10 s, annealing at 50°C (MSH and ND6–COI, 53°C) for 15 s, extension at 68°C for 20 s, 30 cycles of denaturation at 98°C for 10 s, annealing at 47°C (MSH and ND6–COI, 50°C) for 15 s, extension at 68°C for 20 s, and a final extension at 68°C for 2 min. Sequence reactions were performed using the BigDye™ Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems, Massachusetts, USA), followed by sequencing on an ABI 3730xl sequencer (Applied Biosystems). Sequences of six regions (16S, ND1, 16S–ND2, ND3–ND6, ND6–COI, and MSH) were successfully determined and deposited into the International Nucleotide Sequence Databases (INSD) under accession numbers LC716760–LC716764 and LC770918. Sequences of the six mitochondrial regions of 38 specimens of the three genera (*Corallium*, *Hemicorallium*, and *Pleurocorallium*) from Tu et al. (2015) and two specimens of the outgroup *Paragorgia* sp. were retrieved from the INSD (Table 2). All sequences were reconstructed into eight datasets and aligned using the ClustalW algorithm (Thompson et al. 1994) [16S (764 bp), ND1 (692 bp), ND2 (303 bp), ND3 (112 bp), ND6 (341 bp), intergenic spacer (IGR1; 533 bp), COI (80 bp), and MSH (497 bp)]. A Bayesian inference tree was constructed using MrBayes 3.2.7 (Ronquist et al. 2012). The optimal models of nucleotide substitutions for each dataset were the same as those used by Tu et al. (2015), and the Markov chain Monte Carlo (MCMC) process was run with four chains for 1,000,000 generations, with trees sampled every 100 generations. The first 2500 trees were discarded as burn-in.

Systematic Descriptions

Hemicorallium meraboshi sp. nov.
[Japanese common name: Meraboshi-sango]
(Figs 3–18; Tables 1, 2)

Material examined. Holotype, NSMT-Co 1801; 36°51.8′N 144°48.8′E to 36°51.5′N 144°48.7′E, Stn. Kago-7, Iwaki Seamount, Northwestern Pacific, 1744–1755 m depth, 9 August 2009, coll. by Keiichi Kakui.

Diagnosis. Branched colony in almost one plane without anastomoses. Branching irregular, at close to right angles near the base and acute angles in twigs. Contracted autozooids sparsely distributed on stem of one side of the colony, at approximately 5–10 mm intervals on twigs. Two

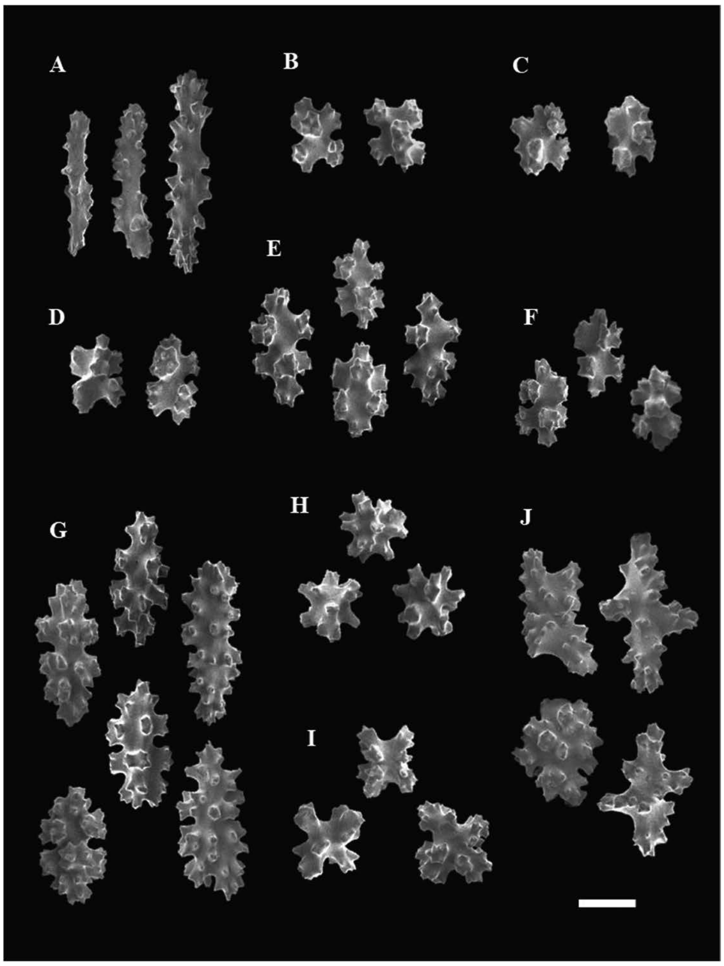

Fig. 2. Morphological terms used in this study for sclerites. A, Rods; B, 6-radiates (symmetric); C, 6-radiates (asymmetric); D, 7-radiates; E, 8-radiates (symmetric); F, 8-radiates (asymmetric); G, multi-radiates (elongate); H, multi-radiates (spherical); I, multi-radiates (cross); J, others. Scale bar: 0.05 mm.

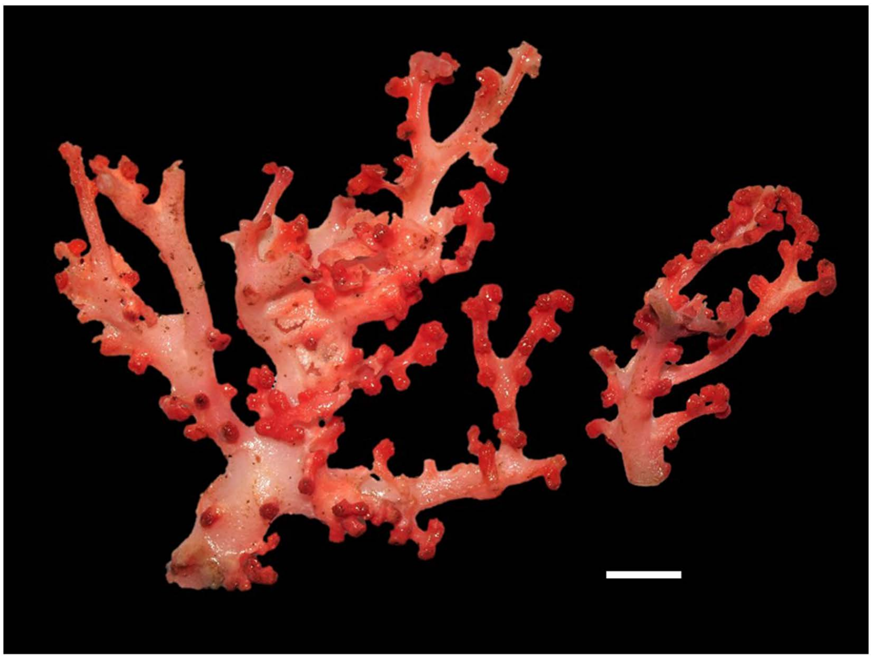

Fig. 3. *Hemicorallium meraboshi* sp. nov., holotype, NSMT-Co 1801. Larger two branches of the specimen in natural color (before preserved in ethanol). Scale bar: 10 mm.

Table 1. Summary of length and width measurements of sclerites of *Hemicorallium meraboshi* sp. nov. Measurements are reported as the average ± standard deviation (more than 10%), or only the average (less than 9%), in μm. Shaded bold numbers indicate most abundant sclerite type. A "—" means not found.

Sclerite type	Tentacle				Autozooid mound				Branch tip				Colony base			
	Length	Width	N	(%)	Length	Width	N	(%)	Length	Width	N	(%)	Length	Width	N	(%)
Rods	141.8 ± 19.1	41.1 ± 8.0	55	**37**	157.4	33.7	1	1		—				—		
6-radiates (symmetrical)		—				—			79.5	47.4	1	1	67.0	52.4	2	1
6-radiates (asymmetrical)		—				—				—			63.4	49.4	3	2
7-radiates		—			76.4	51.1	1	1	76.2	48.5	4	2	73.6	47.5	13	8
8-radiates (symmetrical)	80.3	47.7	6	4	93.9 ± 8.3	51.2 ± 4.9	22	12	81.4 ± 7.8	49.1 ± 4.2	96	**55**	76.9 ± 4.0	46.1 ± 3.1	63	**38**
8-radiates (asymmetrical)	95.2	55.8	2	1	88.1	51.2	7	4	78.6 ± 5.9	48.2 ± 4.1	36	21	75.8 ± 4.6	45.6 ± 3.1	54	33
Multi-radiates (elongate)	116.7 ± 19.1	53.9 ± 4.7	50	34	104.2 ± 7.6	56.0 ± 4.1	92	**50**	92.2 ± 14.7	50.7 ± 5.6	28	16	78.4	48.8	11	7
Multi-radiates (spherical)	93.3 ± 8.2	57.3 ± 6.3	30	20	93.2 ± 8.3	56.5 ± 4.9	45	25	70.7	54.8	3	2	65.5 ± 5.2	57.8 ± 4.3	16	10
Multi-radiates (cross)		—			88.6	67.5	9	5	66.4	62.9	4	2	64.9	57.5	4	2
Others	112.6	70.9	4	3	98.1	69.1	6	3	103.1	66.5	1	1		—		

Table 2. INSD accession numbers of the materials used in this study.

Specimen ID	16S	ND1	16S–ND2	ND3–ND6	ND6–COI	MSH	Reference
Hemicorallium meraboshi sp. nov.	LC716760	LC716762	LC716763	LC716764	LC770918	LC716761	Present study
Corallium japonicum	KF850198	KF854776	KF850283	KF850341	KF855041	KF854882	Tu et al. (2015)
Corallium nix	KF417750	KF854833	KF417751	KF417752	KF855010	KF854939	Tu et al. (2015)
Corallium rubrum	KF286554	KF854765	KF286555	KF286556	KF855039	KF854871	Tu et al. (2015)
Corallium tortuosum	KF850173	KF854814	KF850291	KF850358	KF855011	KF854920	Tu et al. (2015)
Corallium sp. 1	N.A.*	KF854820	N.A.	N.A.	KF854998	KF854926	Tu et al. (2015)
Corallium sp. 3 (1)	N.A.	KF854731	N.A.	N.A.	KF855004	KF854837	Tu et al. (2015)
Corallium sp. 3 (2)	N.A.	KF854831	N.A.	N.A.	KF854976	KF854937	Tu et al. (2015)
Corallium sp. 5	KF850220	KF854743	KF850272	KF850319	KF855021	KF854849	Tu et al. (2015)
Corallium sp. 7	KF850212	KF854755	KF850275	KF850311	KF855005	KF854861	Tu et al. (2015)
Corallium sp. 14	KF850207	KF854766	KF850281	KF850337	KF854986	KF854872	Tu et al. (2015)
Corallium sp. 15	KF850166	KF854834	KF850298	KF850313	KF855009	KF854940	Tu et al. (2015)
Hemicorallium abyssale (1)	N.A.	KF854815	N.A.	N.A.	KF854996	KF854921	Tu et al. (2015)
Hemicorallium abyssale (2)	KF850208	KF854763	KF850279	KF850335	KF854981	KF854869	Tu et al. (2015)
Hemicorallium aurantiacum	KF850175	KF854812	KF850295	KF850357	KF854995	KF854918	Tu et al. (2015)
Hemicorallium bathyrubrum	KF850178	KF854808	KF850292	KF850308	KF854992	KF854914	Tu et al. (2015)
Hemicorallium bayeri	N.A.	KF854780	N.A.	N.A.	KF854964	KF854886	Tu et al. (2015)
Hemicorallium ducale (1)	KF850232	KF854764	KF850280	KF850336	KF855025	KF854870	Tu et al. (2015)
Hemicorallium ducale (2)	KF850213	KF854754	KF850274	KF850330	KF854978	KF854860	Tu et al. (2015)
Hemicorallium guttatum (1)	KF850211	KF854756	KF850276	KF850312	KF855006	KF854862	Tu et al. (2015)
Hemicorallium guttatum (2)	N.A.	KF854773	N.A.	N.A.	KF855007	KF854879	Tu et al. (2015)
Hemicorallium imperiale (1)	N.A.	KF854737	N.A.	N.A.	KF855020	KF854843	Tu et al. (2015)
Hemicorallium imperiale (2)	KF850169	KF854825	KF850297	KF850361	KF854975	KF854931	Tu et al. (2015)
Hemicorallium laauense	KF850210	KF854760	KF850277	KF850332	KF855024	KF854866	Tu et al. (2015)
Hemicorallium niobe	N.A.	KF854799	N.A.	N.A.	KF854965	KF854905	Tu et al. (2015)
Hemicorallium regale	N.A.	KF854826	N.A.	N.A.	KF855000	KF854932	Tu et al. (2015)
Hemicorallium sulcatum	KF850191	KF854795	KF850269	KF850349	KF854988	KF854901	Tu et al. (2015)
Pleurocorallium bonsaiarborum	KF850181	KF854805	KF850267	KF850353	KF854957	KF854911	Tu et al. (2015)
Pleurocorallium borneense	KF850218	KF854750	KF850236	KF850326	KF854973	KF854856	Tu et al. (2015)
Pleurocorallium carusrubrum	KF483567	KF854802	KF483568	KF483569	KF855038	KF854908	Tu et al. (2015)
Pleurocorallium clavatum	KF850183	KF854803	KF850240	KF850351	KF855003	KF854909	Tu et al. (2015)
Pleurocorallium elatius	KF850201	KF854772	KF850258	KF850301	KF855028	KF854878	Tu et al. (2015)
Pleurocorallium inutile	KF286557	KF854792	KF286558	KF286559	KF854943	KF854898	Tu et al. (2015)
Pleurocorallium konojoi	KF850184	KF854800	KF850266	KF850307	KF855032	KF854906	Tu et al. (2015)
Pleurocorallium niveum	KF850192	KF854786	KF850239	KF850346	KF854952	KF854893	Tu et al. (2015)
Pleurocorallium norfolkicum	KF850222	KF854747	KF850250	KF850323	KF854949	KF854853	Tu et al. (2015)
Pleurocorallium porcellanum	KF850174	KF854813	KF850242	KF850309	KF855017	KF854919	Tu et al. (2015)
Pleurocorallium secundum	KF850194	KF854784	KF850238	KF850310	KF854951	KF854890	Tu et al. (2015)
Pleurocorallium thrinax	KF850227	KF854739	KF850246	KF850315	KF854959	KF854845	Tu et al. (2015)
Paragorgia sp.	KC782349	KC782349	N.A.	KC782349	KC782349	N.A.	Figueroa and Baco (2014)
Paragorgia sp.	KC782350	KC782350	N.A.	KC782350	KC782350	N.A.	Figueroa and Baco (2014)

* N.A.: not applicable

to three autozooids form clusters on branch tips. Autozooid diameter 1.7–2.8 mm (average 2.24 mm) and height 1.0–2.3 mm (average 1.66 mm): bright red in color. Coenenchyme 0.10–0.19 mm (average 0.14 mm) thick, pale pink in color, with inconspicuous longitudinal grooves. Axis stout, no pits underneath autozooids, surface smooth, white in color. Tentacles contain blunt warty rods, elongate multiradiate mainly, coenenchyme contains 8-radiates and multiradiates. Double clubs absent.

Description of the holotype. *Colony form*. The specimen comprised nine parts of a colony. The largest two parts are shown in Fig. 3, larger one is approximately 85 mm tall and 70 mm wide, and is branched almost in one plane without anastomoses (Fig. 3). Their angle of branching is almost right in the stem but acute in twigs. At some bifurcation of the acute-angled twigs, there is a part where the crotch of the two twigs adheres to form a thin membrane (Figs 3, 5, 10). Thick stem diameter greater than 10 mm, and thinnest branch tip is approximately 2–3 mm. Branch cross-sections are almost rounded to oval (Fig. 14).

Polyps. Autozooids are not retracted into coenenchyme, forming cylindrical mounds with 8 longitudinal striations (Figs 4–7) distributed mainly on one side of colony (Figs 3, 5, 10). They are sparsely distributed on the stem at approximately 5–10 mm intervals (Fig. 3), with 2–3 autozooids clustered on branch tips (Figs 4–6). Diameter of autozooid mound is 2.24±0.28 mm (N=43); height 1.66±0.35 mm (N=10). Inconspicuous siphonozooids are distributed around autozooids, 0.10±0.018 mm in diameter (N=10) (Figs 7–9).

Axis. Axis surface is smooth, weakly striated (Figs 12, 13). No rounded pits are observed on axis surface at each autozooid position. A few commensal burrows are present along axis (Fig. 11).

Coenenchyme. Coenenchyme is thin, 0.14±0.034 mm (N=10) (Fig. 14), smooth, with weak longitudinal grooves (in approximately 0.39 mm intervals) on colony surface

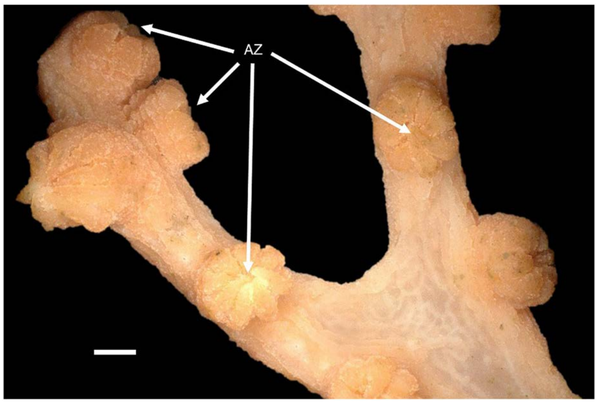

Fig. 5. Surface detail of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Autozooid side. Abbreviation: AZ, autozooid. Scale bar: 1.0 mm.

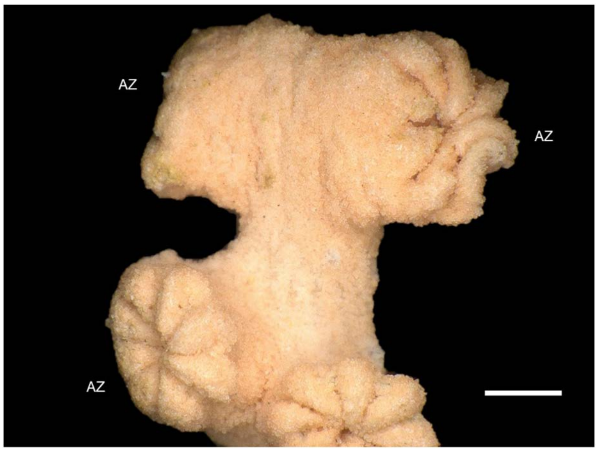

Fig. 6. Detail of twig of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Abbreviation: AZ, autozooid. Scale bar: 1.0 mm.

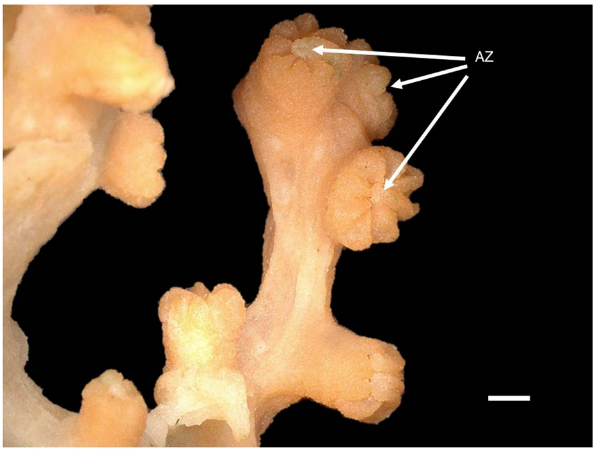

Fig. 4. The distribution of autozooids of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Abbreviation: AZ, autozooid. Scale bar: 1.0 mm.

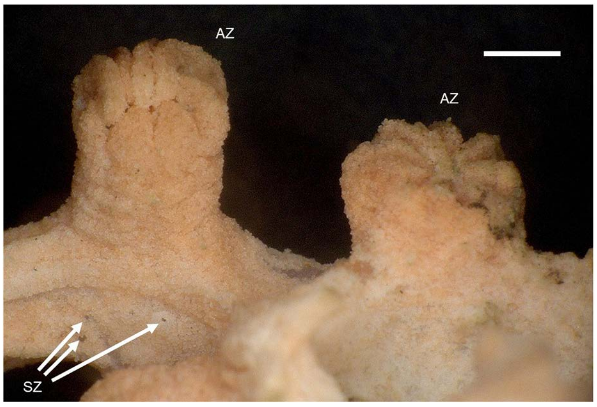

Fig. 7. Surface detail of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Autozooid side. Abbreviations: AZ, autozooid; SZ, siphonozooid. Scale bar: 1.0 mm.

(Figs 9, 10).

Color. Fresh coenenchyme is pale pink on branch: bright red on autozooid mounds (Fig. 3). Preserved specimen is faded and discolored whitish. Axis is white in color (Figs 12–14).

Sclerites. Tentacles have mainly rods (37%; 0.142±0.019 mm long, 0.041±0.008 mm wide), elongated multi-radiates (34%; 0.117±0.019 mm long, 0.054±0.005 mm wide), spherical multi-radiates (20%; 0.093±0.008 mm long, 0.057±0.006 mm wide), a few 8-radiates, and others (Figs 15, 17; Table 1).

Autozooid mounds contain mainly elongated multi-radiates (50%; 0.104±0.008 mm long, 0.056±0.004 mm wide), spherical multi-radiates (25%; 0.093±0.008 mm long, 0.057±0.005 mm wide), symmetrical 8-radiates (12%; 0.094±0.008 mm long, 0.051±0.005 mm wide), and some 7-radiates, asymmetrical 8-radiates, crossed multi-radiates,

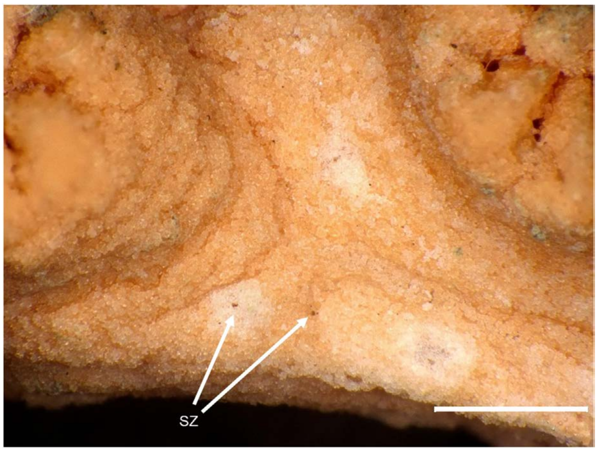

Fig. 8. Surface detail of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Autozooid side. Abbreviation: SZ, siphonozooid. Scale bar: 1.0 mm.

Fig. 9. Surface detail of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Autozooid side. Abbreviation: SZ, siphonozooid. Scale bar: 1.0 mm.

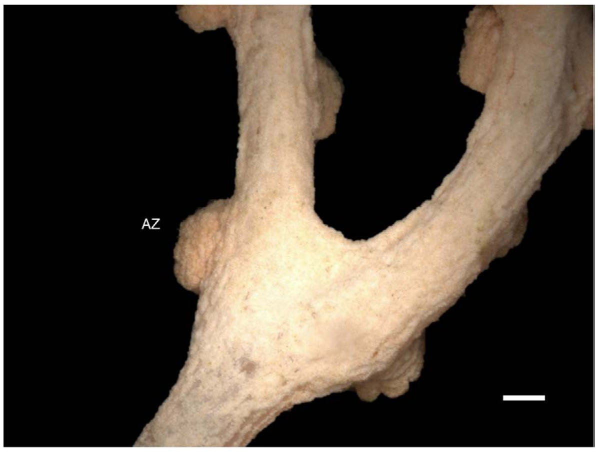

Fig. 10. Surface detail of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Opposite side. Abbreviation: AZ, autozooid. Scale bar: 1.0 mm.

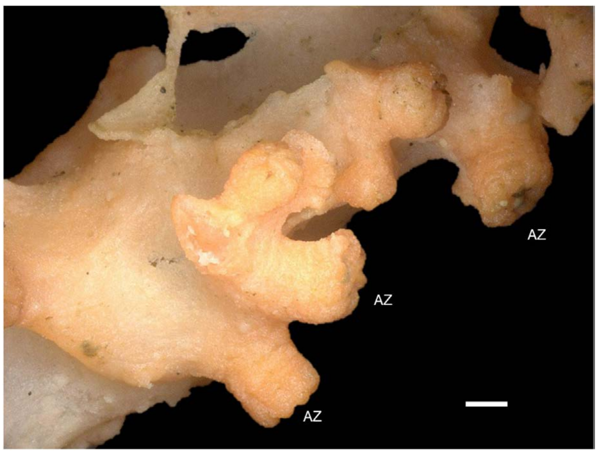

Fig. 11. Surface detail of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Opposite side. Abbreviation: AZ, autozooid. Scale bar: 1.0 mm.

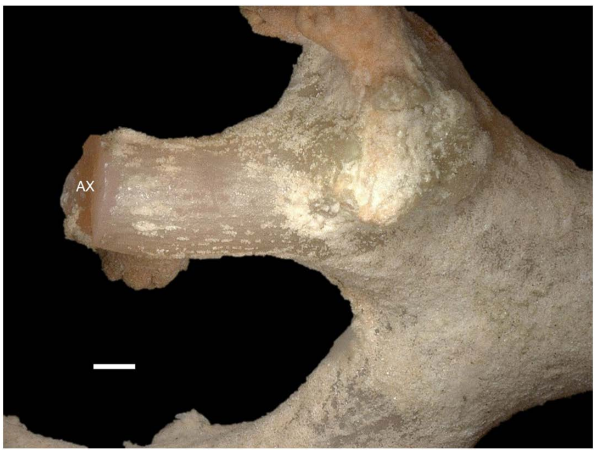

Fig. 12. Surface detail of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Opposite side. Abbreviation: AX, axis. Scale bar: 1.0 mm.

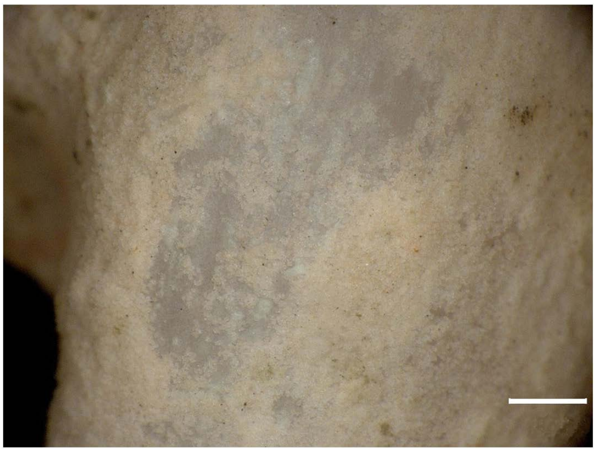

Fig. 13. Surface detail of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Opposite side. Scale bar: 1.0 mm.

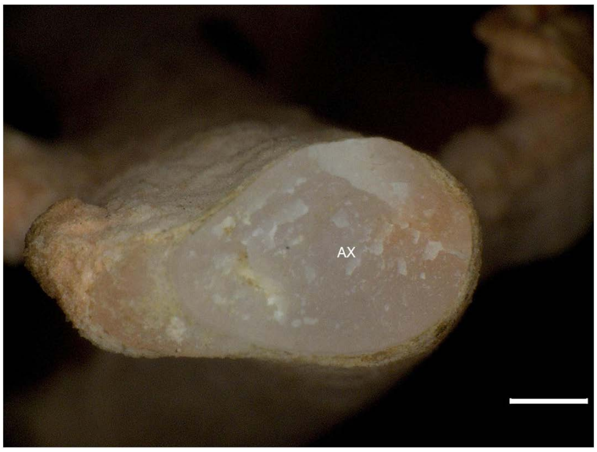

Fig. 14. Cross section of a twig of *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Abbreviation: AX, axis. Scale bar: 1.0 mm.

and others (Figs 15, 17; Table 1).

Branch tips contain mainly symmetrical 8-radiates (55%; 0.081 ± 0.008 mm long, 0.049 ± 0.004 mm wide), asymmetrical 8-radiates (21%; 0.079 ± 0.006 mm long, 0.048 ± 0.004 mm wide), elongated multi-radiates (16%; 0.092 ± 0.015 mm long, 0.051 ± 0.006 mm wide), a few 6-radiates, 7-radiates, multi-radiates (spherical and cross), and others (Figs 16, 17; Table 1).

Coenenchyme on colony base contains mainly asymmetric 8-radiates (38%; 0.077 ± 0.004 mm long, 0.046 ± 0.003 mm wide), symmetric 8-radiates (33%; 0.076 ± 0.005 mm long, 0.046 ± 0.003 mm wide), and spherical multi-radiates (10%; 0.066 ± 0.005 mm long, 0.058 ± 0.004 mm wide). A few 6-radiates, 7-radiates, and multi-radiates (elongated and crossed) are present (Figs 16, 17; Table 1).

Etymology. The specific name "meraboshi" is a Japanese noun that has been passed down from ancient times on the Pacific coast of Japan and refers to the Canopus of the Argo constellation. In this region, the Canopus is a rare star that can only be observed under certain seasonal and weather conditions. This red star has been revered as the god who controls maritime conditions, and if seen near the eastern horizon, it is said that the sea will be rough (Nojiri 1957: 257–264). The described coral inhabits the eastern offshore region of this area, and has bright red autozooids, hence the specific name given of "meraboshi."

Remarks. Tu et al. (2015) described the morphological characteristics of the genus *Hemicorallium* as follows: contracted autozooids that are not retracted in the coenenchyme, cylindrical in shape, and usually distributed on one side of the colony. The tentacles contain rod-shaped sclerites. All of these characteristics were found in the holotype of the new species.

Among the species of the genus *Hemicorallium* described from Hawaii and the western Pacific, *H. meraboshi* sp. nov. has the largest autozooid mounds (2.24 ± 0.28 mm in diameter) (Table 3). Those of *H. abyssale* (Bayer, 1956), *H. guttatum* Tu, Dai, and Jeng, 2016, *H. laauense* (Bayer, 1956), *H. regale* (Bayer, 1956) and *H. sulcatum* are also large, i.e., larger that are more than 1.5 mm in diameter. However, they differ from the new species in the following morphological characters.

Hemicorallium abyssale has a pale pink axis and pink coenenchyme, no cluster of autozooid, and has double-club sclerites in the coenenchyme dominantly. *Hemicorallium guttatum* has yellowish white coenenchyme, very tall autozooid mounds (diameter < height), and spherical 8-radiates in the coenenchyme. Both coenenchyme and autozooid mounds of *H. laauense* are white in color. Those of *H. regale* and *H. sulcatum* are all pale pink.

The unique characteristics of *H. meraboshi* sp. nov. are that it has thin membranes between two twigs (Figs 2, 4, 9), and large (over 0.1 mm long) multi-radiate sclerites (Figs 14, 16) in the tentacles and autozooid mounds.

Molecular analysis. The phylogenetic tree retrieved with Bayesian inference (Fig. 18) recovered well-supported topologies concordant with the clades (*Corallium* clade, *Hemicorallium* clade, *Pleurocorallium* clade) hypothesized by Tu et al. (2015) and indicated that the new species was included in the *Hemicorallium* clade.

Discussion

The family Coralliidae was established by Gray in 1857 (see Ridley 1882), and subsequently divided into three genera (Gray 1867). The genus *Hemicorallium* was defined as follows: "the polyps prominent, ovate-cylindrical, often clustered, all distributed on one side of the branches" (Gray 1867). However, Ridley (1882) and Kishinouye (1903a–c) did not accept Gray's opinion. Since then, this family has only included the genus *Corallium*. Using molecular analyses, Ardila et al. (2012) proposed the genus *Hemicorallium* for species with long rod sclerites, cylindrical autozooid mounds, and smooth axes, and Figueroa and Baco (2014)

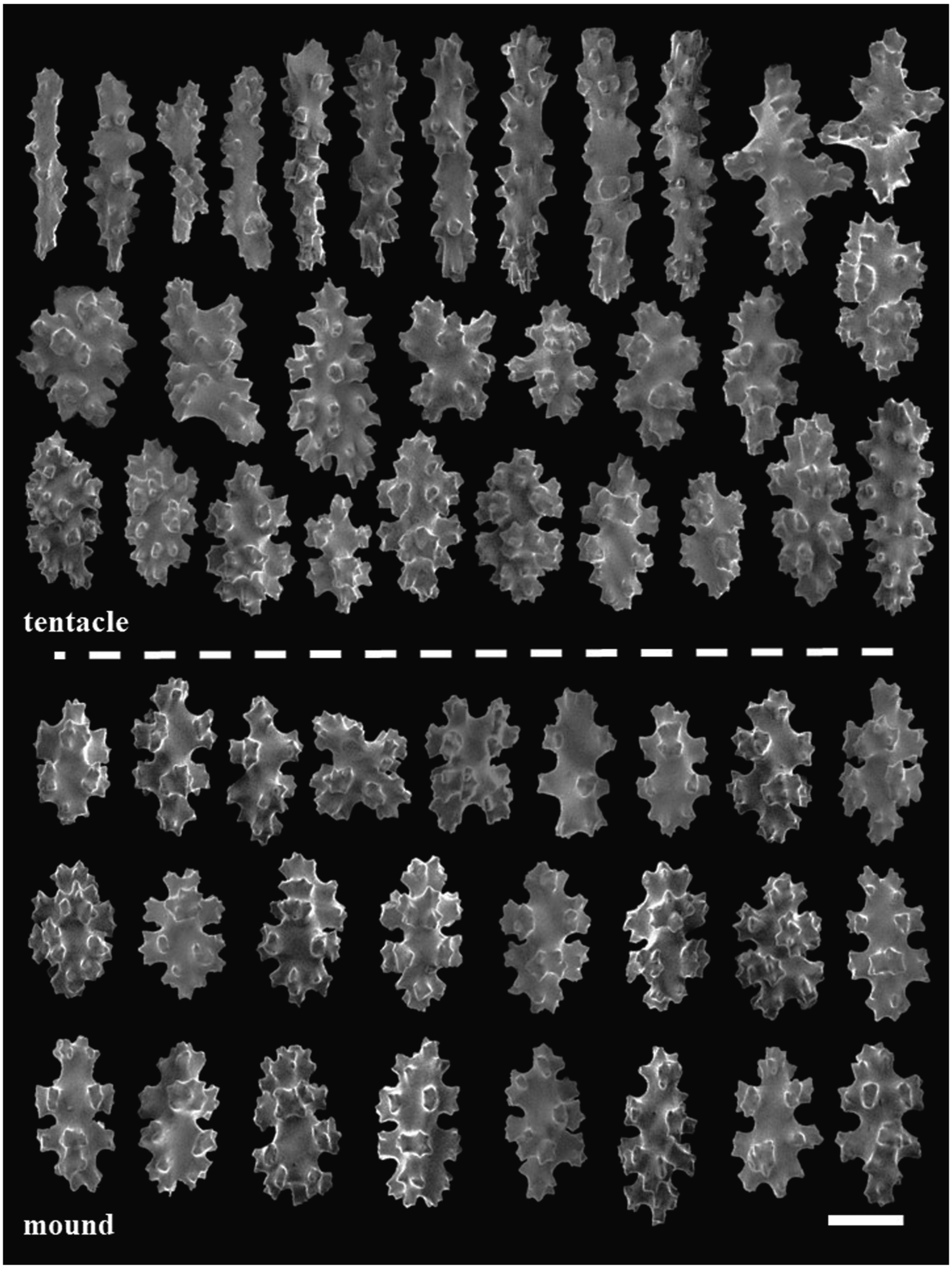

Fig. 15. *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Sclerites: from tentacles and autozooid mounds. Scale bar: 0.05 mm.

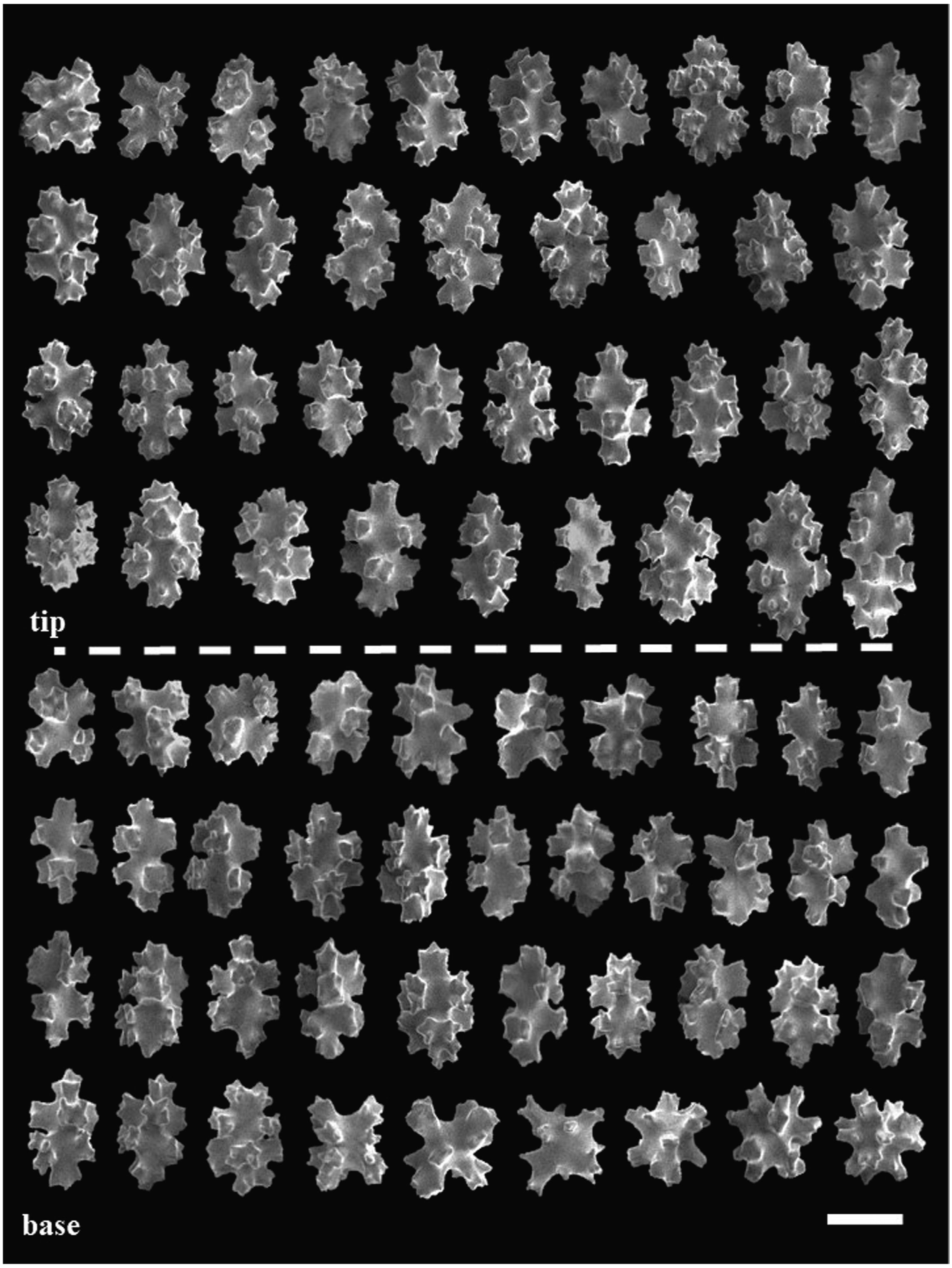

Fig. 16. *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Sclerites: from branch tips and colony base. Scale bar: 0.05 mm.

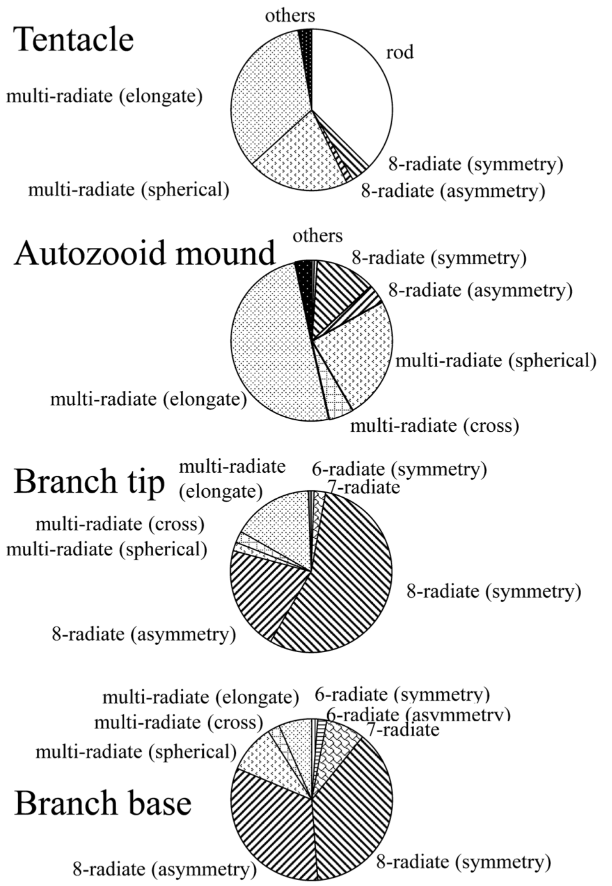

Fig. 17. *Hemicorallium meraboshi* sp. nov., NSMT-Co 1801. Composition of sclerites from each part sampled.

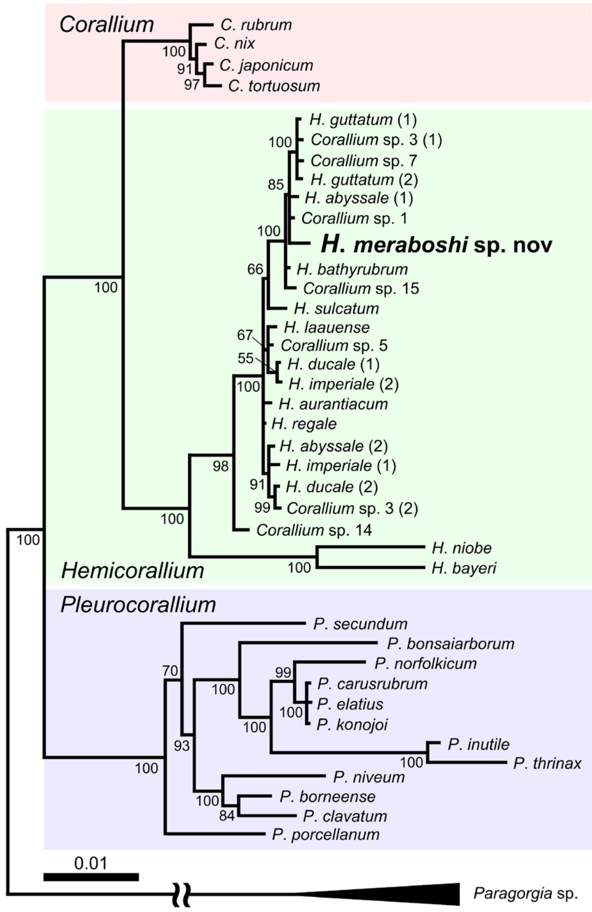

Fig. 18. Bayesian inference tree reconstructed from the concatenated mitochondrial (16S rRNA, ND1, ND2, ND3, ND6, COI, MSH, and IGR1) datasets. Each node in the tree is labeled with Bayesian posterior probabilities (if > 50%). Scale bar indicates number of substitutions per site.

suggested that the genus *Pleurocorallium* be resurrected. Tu et al. (2015) revised the three genera, *Corallium*, *Hemicorallium*, and *Pleurocorallium*, which consisted of 7, 16, and 14 species, respectively. Recently, Tu et al. (2016) described two new species, and Nonaka and Hayashibara (2021) described three new species and stated that 21 species belonged to the genus *Hemicorallium*. Table 3 shows the 13 *Hemicorallium* species recorded from Hawaii and the western Pacific Ocean, and their characteristics compared with *H. meraboshi* sp. nov.

Hemicorallium meraboshi sp. nov. has a unique autozooid arrangement and color. In many species, autozooids are separated, whereas those of *H. meraboshi* sp. nov. are clustered at the tip of the branch (Figs 4–6), which has only been observed in *H. guttatum* (Table 3). Although many species present an autozooid and coenenchyme with the same color, the autozooid of the new species is a brighter red than that of the coenenchyme. Of particular note is the size of the autozooid of *H. meraboshi* sp. nov., as although those of some species are more than 2 mm in height, none reveal this size in diameter (Table 3). The autozooids were bright red, and their size appeared exaggerated. When the specimen was observed for the first time, it appeared to be an undescribed species because of this image. In addition, the presence of multi-radiate sclerites greater than 0.1 mm long in the tentacles and autozooids was an important characteristic of the new species (Table 3). The phylogenetic tree indicated that the new species was included in the *Hemicorallium* clade as described by Tu et al. (2015). Therefore, we propose to assign this new species to the genus *Hemicorallium* based on both morphological and molecular evidence.

Table 4 indicates that *H. meraboshi* sp. nov. is a precious coral specimen from the highest latitude in the Pacific and the fourth highest record globally. Generally, precious corals tend to inhabit tropical to sub-tropical waters; however, species adapted to high latitudes, that is, lower water temperature, have been found recently. Based on these results, the data may require alteration. Further research at higher latitude areas may uncover some undescribed species of the precious corals.

Acknowledgments

We thank Mr. Kei Miyamoto, researcher of Okinawa Churashima Foundation, for help with analyzing the mo-

Table 3. Summary of the genus *Hemicorallium* reported from Hawaii and western Pacific.

Species	Coenenchyme		Autozooid					Axis			Sclerite				Distribution			Reference
	Color	Surface situation	Arrangement	Color	Cluster	Diameter (mm)	Height (mm)	Color	Surface situation	Burrows	Dominant (tentacles)	Dominant (coenenchyme)	Maximum size (mm)	Minimum size (mm)	Region	Latitude	Depth (m)	
H. meraboshi sp. nov.	pale red	smooth	front side	red	2–3	1.7–2.8	1.0–2.3	white	smooth	present	rod	8-radiate, multi-radiate	0.14	0.06	Japan	36.5N	1744–1755	
H. abyssale	pink	prominent papillae	biserial	pink	no	2.0	2.0	pale pink	smooth	absent	rod, spinose rod	8-radiate, double-club	0.12–0.13	0.05	Hawaii	23N	1830–2400	Bayer (1956)
H. aurantiacum	dark pinkish orange	no papillae	front side	dark pinkish orange	no	0.8–1.0	1.3–1.7	pinkish orange	smooth	present	rod	8-radiate	0.08	0.05	New Caledonia	24.4S	562–587	Tu et al. (2016)
H. boushuense	light yellow	—	front side	—	no	—	—	cream white	smooth	present	rod	8-radiate	—	—	Japan	34.9N	550	Kishinouye (1903a, b, 1904)
H. guttatum	yellowish white	protuberance	front side, alternating	pale vermilion red	3–4	1.4–1.6	1.7–2.2	milk white	smooth	present	rod	8-radiate	0.12	0.04	Hawaii	25.4N	942–1509	Tu et al. (2016)
H. halmaheirense	orange-red	scraggy	front side	orange-red	no	1.0–1.5	2–3 0.8–0.9	pale pink to white	smooth	present	rod	8-radiate	0.12	0.035	Celebes Sea	6.0N	1089	Hickson (1907), Tu et al. (2016)
H. kaiyo	red	longitudinal grooved	front side	red	no	0.8–1.5	0.7–1.3	red	smooth	present	rod	8-radiate	0.1	0.6	Emperor Seamount	35.4N	409–942	Nonaka and Hayashibara (2021)
H. laauense	white	conical papillae	front side	—	no	1.5	1.0	white	longitudinal grooves	present	rod, spinose rod	8-radiate	0.145	0.06	Hawaii	23.6N	365–584	Bayer (1956)
H. muzikae	pale pink	small warts	front side	pale pink	no	0.9–1.3	0.7–1.3	pink	longitudinal grooves	present	rod	8-radiate	0.09	0.06	Emperor Seamount	31.7N	682	Nonaka and Hayashibara (2021)
H. regale	pale pink	no papillae	front side	pale pink	no	1.5	1.5–2.0	pale pink	smooth	present	rod	6-radiate, 8-radiate	0.1	0.05	Hawaii	23.5N	365–723	Bayer (1956)
H. reginae	light orange	no papillae	front side	light orange	no	1.3–1.5	1.4–1.6	orange to red	shallow grooves	—	rod	8-radiate	0.1	0.05	Flores Sea	7.7S	122	Hickson (1907), Tu et al. (2016)
H. sulcatum	light red	longitudinal grooves	front side	—	no	1.5	2.0	pinkish	smooth	present	rod	8-radiate	—	—	Japan	34.9N	180–550	Kishinouye (1903a, b, 1904)
H. taiwanicum	dark-pink	smooth	front side	dark-pink	no	1.15	0.9	orange	smooth	absent	rod	8-radiate, double-club	0.11	0.05	Taiwan	22.2N	736–1040	Tu et al. (2012)
H. tokiyasui	pink	granulated	front side, branchtip	pink	no	0.8–1.3	0.6–1.8	pale purple to pinkish white	smooth	present	rod	8-radiate	0.07	0.03	Emperor Seamount	35.4N	414	Nonaka and Hayashibara (2021)

Table 4. List of precious corals recorded at high latitudes (more than 35.00N).

Species	Distribution	Collected latitude	Collected depth	Reference
Pleurocorallium occultum	Northeastern Atlantic	43.59N	767–928 m	Tu et al. (2015)
Hemicorallium bayeri	New England Seamounts	39.39N	1970–2529 m	Simpson and Watling (2011)
Hemicorallium bathyrubrum	New England Seamounts	38.46N	2000–2500 m	Simpson and Watling (2011)
Hemicorallium meraboshi	Japan	36.5N	1744 m	Present study
Hemicorallium kaiyo	Emperor Seamounts	35.4N	409–942 m	Nonaka and Hayashibara (2021)
Hemicorallium tokiyasui	Emperor Seamounts	35.4N	414 m	Nonaka and Hayashibara (2021)

lecular samples. In giving the species name, Mr. Hidenobu Itai, a researcher at the Okinawa Churashima Foundation, provided valuable information on marine culture. We also thank Drs. Ken Fujimoto and Takami Morita (National Research Institute of Fishery Sciences, Japan) for providing an opportunity to join the research cruise, Captain Yasushi Terada and the crew of the research vessel *Soyo-maru*, and researchers aboard for their support during the cruise. Mr. Yukimitsu Imahara, a researcher at Wakayama Laboratory, Biological Institute on Kuroshio, Kuroshio Biological Research Foundation, provided much useful knowledge on octocorals. We would like to thank a contractor for English language editing.

Authors Contributions

Masnaori Nonaka: Conceptualization; Supervision; Investigation; Formal analysis; Visualization; Writing – original draft; Writing – review & editing; Project administration. Nozomi Hanahara: Conceptualization; Investigation; Formal analysis; Writing – original draft. Keiichi Kakui: Resources; Investigation; Writing – review & editing; Project administration.

Declarations

Competing interests. The authors declare no conflicts of interest.

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