

**A new genus of the scleraxonian family Coralliidae
(Octocorallia: Gorgonacea)**

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Abstract.—A new genus of the family Coralliidae is established for seven species having longitudinally grooved axes and autozooids seated in distinctive axial pits with beaded margins.

During the preparation of a projected review of the family Coralliidae it became clear that the species currently assigned to the single genus *Corallium* Cuvier can be grouped in two morphological categories, (1) those having the autozooids seated in deep axial pits with margins conspicuously beaded especially near the tips of twigs, and (2) those without axial pits beneath the autozooids, although a depression without beaded margins may be present as in *C. rubrum*.

As constituted at the present time, the octocoral family Coralliidae consists of a single genus, *Corallium* Cuvier, 1797. Gray (1867) assigned the three species then known to three genera: *Corallium* Cuvier, 1797 for *C. rubrum* (Linnaeus, 1758); *Pleurocorallium* Gray, 1867 for *C. secundum* Dana, 1846; and *Hemicorallium* Gray, 1867 for *Corallium johnsoni* Gray, 1860. Ridley (1882:222) reviewed this arrangement and rejected *Hemicorallium* as a synonym of *Pleurocorallium*. Kükenthal (1924:47) considered both genera to be synonyms of *Corallium*.

Kükenthal (1924:47, 52) accepted the genus *Pleurocoralloides* Moroff 1902 from Japan, which was accepted also by Bayer (1956:70; later with reservations, 1964:466). The original illustrations of *Pleurocoralloides formosum* and *P. confusum*, established by Moroff (1902:405, pl. 17, fig. 10, pl. 18, fig. 20; 404, pl. 17, fig. 8, pl. 18, fig. 19), clearly show that both species, as

well as the genus *Pleurocoralloides*, can be referred to the family Melithaeidae. Although Moroff did not mention axial nodes and internodes, such features are suggested in the photograph of *P. confusum* on his plate 17, fig. 8. Moreover, the sclerites of both species as drawn are strongly suggestive of *Acabaria*. The polyps of *Pleurocorallium confusum* were said to have a fully retractile upper part and a low, projecting, wart-like calicular part; those of *Pleurocoralloides formosum* consisted of tentacular and projecting calicular parts with spindles forming triangular teeth projecting above the calyx margin. These characters do not occur in any coralliid, but are consistent with melithaeids. Consequently, *Pleurocorallium* sensu Moroff, 1902 (not Gray, 1867) becomes a probable synonym of *Acabaria* Gray, 1859. The correct identification of both species remains to be determined.

Seven species of *Corallium* share a skeletal character setting them unambiguously apart from all other species of the genus: the hard axis beneath each autozoid is marked by a distinct pit with a prominently beaded rim (Fig. 1), so there is no condition intermediate between axes with beaded pits and those without beaded pits. There is no ambiguity whatever about placing species in one group or the other, making the genus-group taxa within the Coralliidae more distinctive than many that are accepted in other families without question. The diagnostic character of the beading rim is also

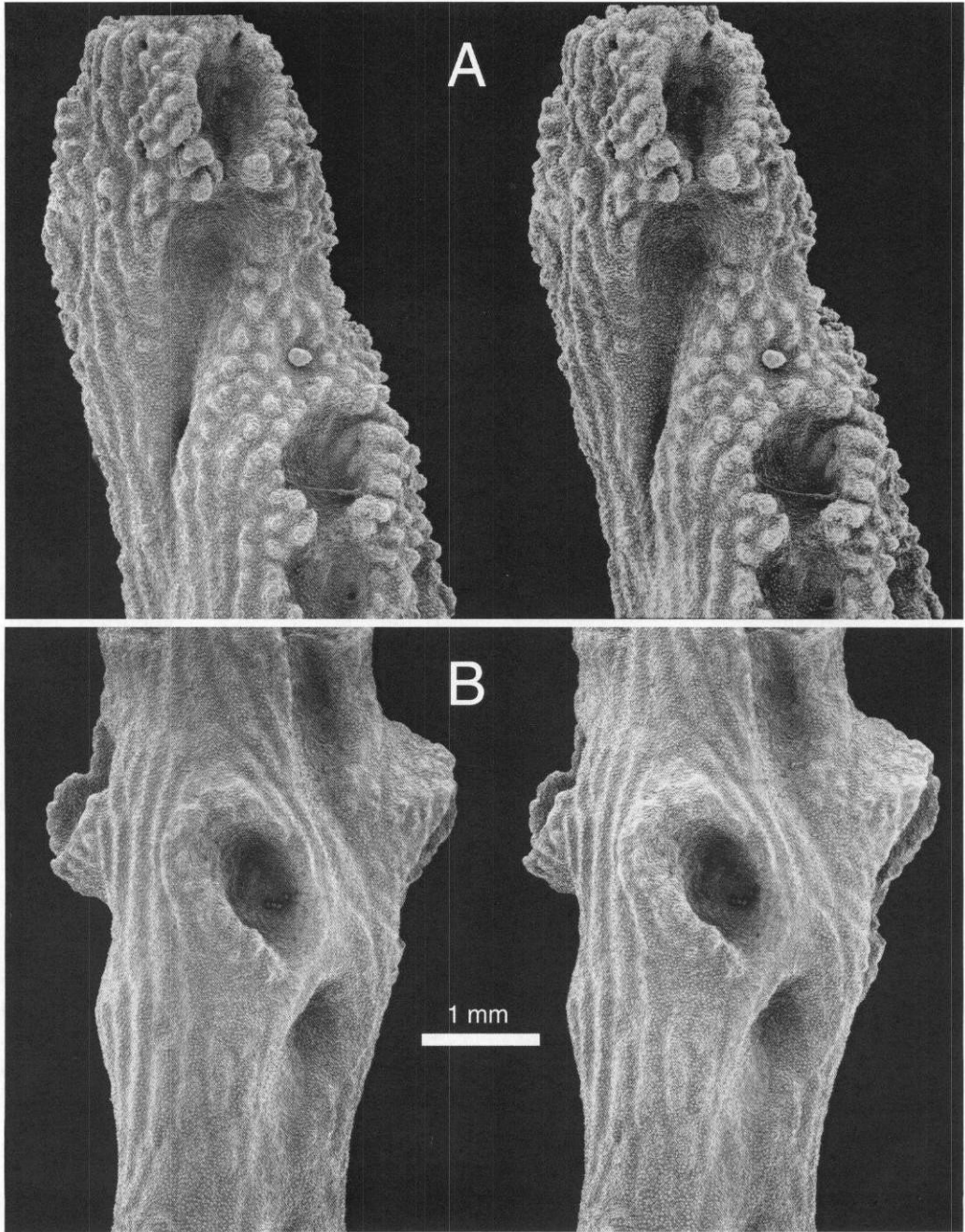


Fig. 1. Two stereo pairs illustrating the deep autozooid pits that are surrounded by beaded margins, and longitudinal grooves on the axis: Upper pair: *Paracorallium thrinax*, paratype, USNM 96511 (SEM 1331); lower pair: *Paracorallium nix*, part of holotype, SEM stub 1334. Both figures $\times 20$.

illustrated for the species *B. tortuosum* by Bayer (1956: figs. 5b, 6c; 1993, pl. 16), for *C. thrinax* by Bayer (1996: figs. 2–3), and for *C. nix* by Bayer (1996: fig. 8).

Removal of the seven species from the genus, results in 19 species remaining in *Corallium*: *C. abyssale* Bayer, 1956 (Hawaii); *C. borneense* Bayer, 1950 (Borneo); *C. ducale* Bayer, 1955 (e. Pacific Mexico); *C. elatius* Ridley, 1882 (Mauritius and Japan); *C. halmaheirensis* Hickson, 1907 (Indonesia); *C. imperiale* Bayer, 1955 (e. Pacific Mexico); *C. johnsoni* Gray, 1860 (northeast Atlantic); *C. kishinouyei* Bayer, 1996 (e. Pacific); *C. konjoi* Kishinouye, 1903 (Japan); *C. laanense* Bayer, 1956 (Hawaii); *C. maderense* Johnson, 1898 (e. Atlantic); *C. medea* Bayer, 1964 (w. Atlantic); *C. niobe* Bayer, 1964 (w. Atlantic); *C. regale* Bayer, 1956 (Hawaii); *C. reginae* Hickson, 1905 (Indonesia); *C. rubrum* (Linnaeus, 1758) e. Atlantic; *C. secundum* Dana, 1846 (Hawaii); *C. sulcatum* Kishinouye, 1903 (Japan); and *C. tricolor* Johnson, 1898 (e. Atlantic).

Paracorallium, new genus

Type species.—*Corallium tortuosum* Bayer 1956.

Seven species of *Corallium* characterized by axial pits with beaded rims are here recognized as members of a new genus morphologically distinct from *Corallium*, here called *Paracorallium*: *P. stylasteroides* (Ridley, 1882), *P. japonicum* (Kishinouye, 1903), *P. inutile* (Kishinouye, 1903), *P. salomonense* (Thomson & Mackinnon, 1910), *P. tortuosum* (Bayer, 1956), *P. thrinax* (Bayer & Stefani in Bayer, 1996), and *P. nix* (Bayer, 1996).

Diagnosis.—Coralliidae with autozooids seated in deep pits in the solid axis, pits with prominently beaded margins especially near branch tips; axis with strong longitudinal grooves. Sclerites including crosses, 6- and 8-radiate capstans that may be more or less asymmetrically developed, forming double clubs in some species. Long spin-

dles have not been found in the autozooids of any species of *Paracorallium*, but otherwise the range of sclerites is the same as in species of *Corallium*.

Etymology.—*Para*, from Greek *para* = near + *Corallium*, from Greek *korallion* = coral. Neuter noun.

Distribution.—Indo-west Pacific, from Hawaii west to Japan and south to New Caledonia in the Pacific, and west to Mauritius and the Chagos Archipelago in the Indian Ocean. At moderate depths, all known records between 136 and 273 m.

In the following summary of nominal species at present referable to *Paracorallium*, the species are arranged according to their significant morphological characters.

I.—Species with smooth double clubs (double carafes, operaglasses) predominating in the coenenchymal sclerites, which also include 6-radiates, sometimes 7-radiates, and crosses; stubby rods in anthocodiae.

A.—Colonies branched on all sides, often anastomosing, major stems tend to remain in one plane, reaching a height of 12 cm. Cortex light red, axis white with pink tints.

Paracorallium inutile (Kishinouye, 1903), new combination

Corallium inutile Kishinouye, 1903:626; 1904:28, pl. 5, figs. 1, 2; pl. 7, fig. 7; pl. 9, fig. 18 (in Japanese); 1905:27, pl. 5, figs. 1, 2; pl. 7, fig. 7; pl. 9, fig. 18 (in English).

Distribution.—Japan: Shikoku, Kashiwajima, Tosa, 100–150 m.

B.—Colonies branched dichotomously, in one plane, reaching a height of 6 cm. Cortex white, axis white.

Paracorallium thrinax (Bayer & Stefani in Bayer 1996), new combination

Corallium thrinax Bayer & Stefani in Bayer 1996:206, figs. 1–6.

Distribution.—New Caledonia, 23°06.50'S, 167°53.74'E, 240 m.

II.—Species with no smooth double clubs in coenenchyme; predominant sclerites are 8-radiate forms but a few radiates may be somewhat asymmetrical, 6- and 7-radiates and crosses more or less abundant.

A.—Largest coenenchymal 8-radiates are 0.07 mm in length.

i.—Species with solid axis white.

a.—Cortex pale orange, calyces of autozooids yellow; many 6- and 8-radiates asymmetrical, tubercles of one side somewhat enlarged but not as smooth spheroids.

Paracorallium stylasteroides

(Ridley, 1882), new combination

Corallium stylasteroides Ridley, 1882:225, pl. 9, figs. 1–4.—Bayer 1996:17, pl. 17.

Distribution.—Mauritius, 136 m.

b.—Cortex white, autozooids white; radiates symmetrical.

Paracorallium nix (Bayer, 1996),

new combination

Corallium nix Bayer, 1996:213, figs. 7–10.

Distribution.—New Caledonia, 23°06.50'S, 167°53.74'E, 240 m.

ii.—Species with solid axis colored pink or red.

a.—Axis dark red with white center, becoming paler distally, branch tips nearly white. Colonies abundantly branched in one plane, with small prickle-like twigs on front and sides of branches; sclerites are 8-radiates and crosses.

Paracorallium japonicum

(Kishinouye, 1903), new combination

Corallium japonicum Kishinouye, 1903: 623; 1904:22, pl. 1, figs. 1, 2; pl. 2; pl. 4, fig. 3; pl. 7, fig. 1; pl. 8, figs. 1–6 (in Japanese); 1905:21, pl. 1, figs. 1, 2; pl. 2; pl. 4, fig. 3; pl. 7, fig. 1; pl. 8, figs. 1–6 (in English).

Distribution.—Japan: Kiushu; off Tosa, Shikoku, 100–150 m.

b.—Axis pale pink, becoming darker distally; cortex pink or salmon-colored, polyps darker. Colonies branched irregularly in one plane, twigs crooked and tortuous. Coenenchymal sclerites are 8-radiates and crosses; anthocodiae with small rods and crosses.

Paracorallium tortuosum (Bayer, 1956),
new combination

Corallium tortuosum Bayer, 1956:82, figs.

5b, 6c, 8e–g.

Corallium salomonense tortuosum.—Bayer, 1993:16, pls. 10, 14–16.

Distribution.—Hawaii: Pailolo Channel, 153–273 m.

B.—Largest coenenchymal radiates reach a length of 0.1 mm or more. Fully developed branching unknown; coenenchyme yellowish, anthocodiae orange, axis presumably white or pale pink in color.

Paracorallium salomonense (Thomson & Mackinnon, 1910), new combination

Symphodium salomonense Thomson & Mackinnon, 1910:168, pl. 12, figs. 11, 12; pl. 13, fig. 15a, b.

Corallium salomonense.—Bayer, 1993:14, pls. 10–13.

Distribution.—Salomon, Chagos Archipelago, Indian Ocean, 217–272 m.

Remarks

Authentic specimens of *P. japonicum* and *P. inutile* received from K. Kishinouye, and Ridley's slide of the sclerites of *P. stylasteroides* were available for examination. Other than *P. tortuosum*, which is represented by numerous specimens from five stations made in the Hawaiian Islands by the U.S. Fish Commission steamer *Albatross*, no species of *Paracorallium* is represented by specimens from more than a single locality. Consequently, nothing can be said about possible individual and geo-

graphical variation. All colonies of *P. tortuosum* from Hawaii (see Bayer 1993: pl. 10, lower figures) are consistent in growth form, and bear a strong resemblance to the unique type specimen of *P. stylasteroides* from Mauritius, now lost (see Ridley 1882: pl. 9, fig. 1), but sclerites of Ridley's slide (see Bayer 1993: pl. 17) are sufficiently distinct from those of *P. tortuosum* (see Bayer 1956:85, fig. 8e-g; 1993, pls. 14, 15) to justify specific separation. However, the sclerites of original material of *P. salomonense* (see Bayer 1993: pls. 11-13, and compare Thomson & Mackinnon 1910: pl. 13, fig. 15a, b) are morphologically so similar to those of *P. tortuosum* that the latter was treated as a geographical subspecies of *P. salomonense*, in spite of the lack of fully developed colonies of the latter. Furthermore, the growth form of *P. nix* from New Caledonia resembles in some ways that of *P. tortuosum* and *P. stylasteroides*, and the sclerites of all three are generally similar. Pending the discovery of additional specimens, these nominal species are maintained as distinct but might in future be treated as a single variable species widely distributed from Hawaii to New Caledonia in the Pacific and Mauritius and the Chagos Archipelago in the Indian Ocean.

Structure of the solid axis.—Investigations of *Corallium rubrum* (Linnaeus) by Grillo et al. (1993), summarized by Allemand (1993), definitively refuted the generally accepted theory of axis formation in *Corallium* proposed by Lacaze-Duthiers (1864), which also had been rejected by Hickson (1907:2), who stated that "It is clearly incorrect, from these [Hickson's] observations, to describe the axis of the Coralliidae as the 'result of spicules fused together' " by cement substance. Hickson held that "the evidence of comparative anatomy suggests very forcibly that [the cement substance] is not formed by the activity of the scleroblasts but by a modification of the chemical character of the mesogloea."

However, the theory of Lacaze-Duthiers

subsequently was accepted by authors as late as Weinberg (1976:99, pl. 20; 1993:51, fig. 11), who published scanning electron micrographs of the axial surface showing presumed sclerites embedded in the calcareous mass.

Lawniczak (1987) presented evidence that in *C. johnsoni* the axis is composed initially of "fibrous" calcite crystals followed by "lamellar" secondary thickening, without participation of sclerites. On the other hand, Grillo et al. showed that in *C. rubrum* the axis is initially composed of coenenchymal sclerites that form a core subsequently overgrown by secondary thickening consisting of sheets of rectilinear calcite crystals produced by an axis epithelium cytologically indistinguishable from the multicellular scleroblasts that produce the free mesogloea sclerites. They "suggest that the axis epithelium treats the incipient skeleton as if it were the core of a single sclerite" and that the scleroblasts are a fragmented axis epithelium.

The discrepancy between the results of Lawniczak's investigation of *C. johnsoni* and those of Grillo et al. of *C. rubrum* led the latter authors to conclude that "the family Coralliidae may exhibit a broad spectrum of octocoral skeletal structures, including those that are independent of sclerites [sic] formation . . ." (1993:127). They conclude that ". . . the further study of this species [i.e., *C. rubrum*] and other coralliids has merit for both systematics and the general process of carbonate skeleton formation in marine invertebrates."

No fully formed sclerites more or less completely incorporated in the axial mass were found on the axial surface, as has been observed in *Corallium kishinoueyi* (Bayer 1996: 218, figs. 16, 17), were seen in any species of *Paracorallium*. The tubercles on the axial surface at the summit of terminal branches of *P. thrinax* and *P. tortuosum* resemble the tubercles of sclerites more closely than axial protuberances. Roughly transverse fractures of axis of *P. inutile* and *P. tortuosum* exposed former surface features

but no morphological features that could be interpreted unequivocally as parts of sclerites even at the center of the axis. Numerous circular structures could as reasonably be interpreted as fragments of axial protuberances as the broken ends of the primary axis of sclerites. Consequently, it is probable that sclerites have an insignificant or even nonexistent role in axis formation in *Paracorallium*, possibly with scleroblasts more integrated and functioning as a fragmented axis epithelium forming the axis as if it were one large sclerite. The bulk of the axial mass consists of fascicles of rectilinear calcite crystal oriented in various directions and commonly appearing "cross bedded."

Acknowledgments

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Literature Cited

- Allemand, D. 1993. The biology and skeletogenesis of the Mediterranean red coral, a review.—*Precious Corals & Octocoral Research* 2:19–39, frontisp. 1; figs. 1–18.
- Bayer, F. M. 1950. A new precious coral from North Borneo.—*Journal of the Washington Academy of Sciences* 40(2):59–61.
- . 1955. Contributions to the nomenclature, systematics, and morphology of the Octocorallia.—*Proceedings of the United States National Museum* 105:207–220.
- . 1956. Descriptions and redescrptions of the Hawaiian octocorals collected by the U.S. Fish Commission steamer "Albatross" (2. Gorgonacea: Scleraxonia).—*Pacific Science* 10(1):67–95, 11 figs.
- . 1964. The genus *Corallium* (Gorgonacea: Scleraxonia) in the western North Atlantic Ocean.—*Bulletin of Marine Science of the Gulf and Caribbean* 14(3):465–478, figs. 1–7.
- . 1993. Generic reassignment and affinities of *Sympodium salomonense* Thomson & Mackinnon (Coelenterata: Octocorallia).—*Precious Corals & Octocoral Research* [Tokyo] 1:14–19, pls. 10–17.
- . 1996. Three new species of precious coral (Anthozoa: Gorgonacea, genus *Corallium*) from Pacific waters.—*Proceedings of the Biological Society of Washington* 109(2):205–228, figs. 1–19.
- Cuvier, G. [1797]. *Tableau élémentaire de l'histoire naturelle des animaux*. Paris, Baudouin. Pp. i–xvi + 1–710, pls. 1–14.
- Dana, J. D. 1846. Zoophytes.—*United States Exploring Expedition during the years 1838, 1839, 1840, 1841, 1842, under the command of Charles Wilkes, U.S.N.* Vol. 7. i–vi + 1–740 pp., 45 text figs. Philadelphia: Lea and Blanchard. Atlas, Zoophytes. 61 pls., 1849.
- Gray, J. E. 1859. Description of some new genera of lithophytes or stony zoophytes.—*Proceedings of the Zoological Society of London* 1859:479–486.
- . 1860. Description of a new coral (*Corallium johnsoni*) from Madeira.—*Proceedings of the Zoological Society of London* 1860:393–394, pl. 18.
- . 1867. Additional note on *Corallium johnsoni*.—*Proceedings of the Zoological Society of London* 1867:125–127.
- Grillo, M.-C., W. M. Goldberg, & D. Allemand. 1993. Skeleton and sclerite formation in the precious red coral *Corallium rubrum*.—*Marine Biology* 117:119–128, figs. 1–5.
- Hickson, S. J. 1905. On a new species of *Corallium* from Timor.—*Proceedings, Koninklijke Academie van Wetenschappen, Amsterdam* 8:268–271.
- . 1907. Die Alcyoniden der Siboga-Expedition I. Coralliidae.—*Siboga-Expeditie Monogr.* 13c: 1–8, pl. 1.
- Johnson, J. Y. 1898. Short diagnoses of two new spe-

- cies of Coralliidae from Madeira.—Annals and Magazine of Natural History (7)2:421–422.
- Kishinouye, K. 1903. Preliminary note on the Coralliidae of Japan.—Zoologischer Anzeiger 26(705):623–626. (27 July).
- . 1904. Sango no kenkyu.—Suisan chosa hokoku 14(1):1–31, pls. 1–9. (25 August).
- . 1905. Notes on the natural history of corals.—Journal of the Imperial Fisheries Bureau 14(1): 1–32, pls. 1–9. (28 Jan 1905).
- Kükenthal, W. 1924. Gorgonaria.—Das Tierreich 47: i–xxviii + 1–478, 209 figs. Berlin and Leipzig, Walter de Gruyter & Co.
- Lacaze-Duthiers, H. de. 1864. Histoire naturelle du corail. Pp. i–xxv + 1–371, pls. 1–20. Paris, J.B. Bailliere et Fils.
- Lawniczak, A. 1987. Les modalités de croissance de l'axe calcaire chez *Corallium johnsoni* (Cnidaria: Gorgonaria: Scleraxonia).—Senckenbergiana maritima 19(3/4):149–161, ill.
- Linnaeus, C. 1758. Systema naturae. Editio decima, reformata. I. Pp. i–iv + 1–824. Holmiae: Impensis Direct. Laurentii Salvii.
- Moroff, T. 1902. Studien über Octocorallien.—Zoologische Jahrbücher (Syst.) 17:363–410, pls. 14–17.
- Ridley, S. O. 1882. On the arrangement of the Coralliidae, with descriptions of new or rare species.—Proceedings of the Zoological Society of London 1882:221–233, pl. 9.
- Thomson, J. A., & D. L. Mackinnon. 1910. Alcyonarians collected on the Percy Sladen Trust Expedition by Mr. J. Stanley Gardiner. Part 2, the Stolonifera, Alcyonacea, Pseudaxonia, and Stelechotokea.—Transactions of the Linnean Society of London (2) 13(2):165–211, pls. 6–14.
- Weinberg, S. 1976. Revision of the common Octocorallia of the Mediterranean circalittoral. I. Gorgonacea.—Beaufortia 24(313):63–104, pls. 1–20.
- . 1993. Il corallo rosso e la ricerca scientifica nei secoli. Pp. 37–60 in F. Cicogna and R. Cattaneo-Viatti, eds., Il corallo rosso in Mediterraneo: Arte, Storia e Scienza. Roma. Ministero delle Risorse Agricole, Alimentarie Forestali.