A New *Distichopora* Species (Cnidaria: Stylasteridae) from the Mesophotic Zone of Palau[1]

Stephen D. Cairns,[2] *and Daniela Pica*[3,4]

Abstract: Stylasterid corals are widely distributed in all oceans from the intertidal zone to the deep sea. They are habitat-forming species, reaching high densities and establishing a wide range of associations with other taxa. In the last decades, many new deep-water stylasterids have been described and the faunas of several regions of the globe have been revised; however, the tropical Pacific Ocean remains relatively understudied. In this paper, a new mesophotic species of *Distichopora*, *D. cryptostylus*, is described from the Republic of Palau, Caroline Islands. The new *Distichopora* is distinguished from congenerics by its uniquely shaped coenosteal pores, a paucity of dactylostyles, and apical dactylotomes.

Keywords: stylasterids, Pacific Ocean, coral reef, taxonomy, *Distichopora*

Stylasterid corals, commonly known as "lace corals," belong to the family Stylasteridae (Cnidaria, Hydrozoa), which is one of the two hydroid families having a hard, calcareous skeleton. Stylasterid colonies are polymorphic, characterized by having gastrozooids, dactylozooids, and gonophores. Coenosarcal canals usually permeate the entire skeleton linking together all these structures and forming a complex tridimensional canal network (Puce et al. 2011, 2012). Stylasterids are widely distributed in all the oceans, except for the Arctic region, at depths ranging from 0 to 2789 m, with a maximum concentration of species between 200 and 500 m (Cairns 2011). They are mainly known from deep water where they originated and diversified, and from where they colonized shallow waters (Lindner et al. 2008). To date, few species are found shallower than 40 m depth and only *Stylantheca papillosa* and an undescribed *Distichopora* species are reported from the intertidal zone (Fisher 1938, Pica et al. 2014). Due to their rigid, branched skeletons, they are considered habitat-forming species in deep water where they constitute important components of the so-called "cold water coral gardens" (Häussermann and Försterra 2007, Cairns 2011). They are also important in shallower waters where they reach high densities and establish a wide range of associations with other taxa (Zibrowius 1981, Goud and Hoeksema 2001, Pica et al. 2012, 2015, 2016, Tribollet et al. 2018).

During the last decades many new deep-water stylasterids have been described and the faunas of several regions of the globe have been revised (i.e., Cairns 1983, 1991, 2005, 2015, Zibrowius and Cairns 1992, Cairns and Lindner 2011, Cairns and Zibrowius 2013). Nevertheless, one area that remains poorly studied with respect to stylasterids fauna is the Pacific Ocean, and particularly the tropical

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[2]Department of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560, USA.

[3]Dipartimento di Scienze della Vita e dell'Ambiente, Università Politecnica delle Marche, Ancona, Italy.

[4]Corresponding author (e-mail: daniela.pica@gmail.com).

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areas. Several species were described during the eighteenth and the beginning of the nineteenth centuries (i.e., Dana 1848, Milne Edwards and Haime 1857, Moseley 1881, Hickson and England 1905), but for many of them the type locality or the depth were not reported. A revision of stylasterids in the Pacific Ocean was done by Boschma (1953), who analyzed all the literature records and recorded the presence of many species in the deep waters of several regions. However, the same author highlighted the absence of recorded stylasterids in many group of islands in the tropical Pacific, such as in the Republic of Palau, although he hypothesized that future research might prove their presence there (Boschma 1953). After this work, no taxonomic papers have been published on shallow-water stylasterids of the tropical Pacific Ocean. However, a few stylasterid records were noted in literature or field guides of the region (Wells 1954, Weber and Woodhead 1972, Veron 2000, Fenner and Miur 2008). The aims of the present paper are to formally record for the first time the presence of stylasterid corals in Palau Island and to describe a new species of *Distichopora*.

MATERIAL AND METHODS

The analyzed materials were obtained from the California Academy of Sciences (CAS) and the Smithsonian National Museum of Natural History (NMNH). The specimens were collected in Palau Island by Pat Colin in three different campaigns in 1998, 2001 and 2008. The morphology of the colonies was first observed using a stereomicroscope, and then selected coral branches were prepared for scanning electron microscopy (SEM) analysis (Cairns 1983). The samples were coated with gold-palladium and photographed with an SEM (Zeiss EVO MA15).

RESULTS

Systematic Account

Class Hydrozoa
Order Anthoathecata
Suborder Filifera
Family Stylasteridae Gray 1847

Distichopora Lamarck 1816

Type Species: *Millepora violacea* Pallas 1766, by monotypy.

Diagnosis. (adapted from Cairns 2015) Colonies branching or flabellate, usually with blunt branch tips. Coenosteum reticulate-granular, reticulate-spinose, linear-imbricate, or lacking coenosteal strips; coenosteum of many colors. Gastropores aligned along branch edge usually within a sulcus, sometimes meandering on branch face. Gastropore row flanked usually on both sides by a row of horseshoe-shaped dactylopore spines, their dactylotomes oriented toward the gastropore row. Gastro- and dactylopores axial; dactylostyles usually absent and in one case a dactyloridge is present. Gastrostyles needle-shaped, elongate, often stabilized by transverse tabulae; a diffuse ring palisade is often present. Ampullae usually superficial and usually clustered.

Distribution. Eocene to recent: recent species are cosmopolitan, except for the eastern Atlantic, Arctic, and Antarctic, 0–1267 m (Cairns 2015).

Remarks. Including *D. cryptostylus*, 26 living species are found in the genus *Distichopora* (see Schuchert 2019), as well as two exclusively fossil species. In a family (i.e., Stylasteridae) in which 89% of its species are found deeper than 50 m (Cairns 2007), the genus *Distichopora* is atypical in that 8 of its 26 species (31%) are confined to shallow water. The species described herein is considered to be a mesophotic species.

Distichopora cryptostylus n. sp.
Figures 1–2

Type Material. Holotype: male colony (CAS 308408) and SEM stub 2643, 7° 16.51′ N, 134° 31.55′ E (Palau, 4 km east of Lighthouse Reef barrier reef, west sheltered side of reef), station Mutremidiu, 122 m depth, coll. P. Colin, 4 September 2008, preserved in 70° alcohol.

Paratype: male colony (USNM 100167) and SEM stubs 2642, 2644–2645 (USNM), Palau, Short Drop Off, 137–153 m, coll. P. Colin, 16 August 1998, preserved dry. One branch, sex undetermined (USNM 1006516) "middle of

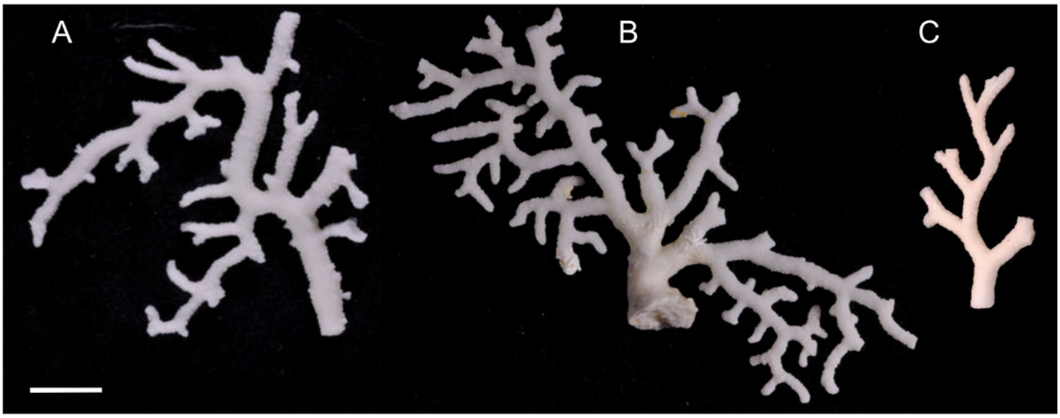

FIGURE 1. (*A*) Holotype CAS 308408; (*B*) paratype USNM 100167; (*C*) paratype USNM 1006516. Scale bar: 1 cm.

three Western Island, south of German Channel," Palau, Deepworker DSR, 213 m, coll. P. Colin, 26 March 2001, preserved 95° ethanol.

TYPE LOCALITY. 7° 16.51′ N, 134° 31.55′ E, Palau, 122 m depth.

DESCRIPTION. The colonies are uniplanar (Figure 1*A*–*C*), with unequal dichotomous branching, and apparently broader than tall, the largest of the two colonies (the holotype) measuring 33 mm in height and 78 mm in width, with a basal branch diameter of 5.1 mm. Distal branches are blunt and somewhat rectangular in cross section, becoming more circular in cross section with greater size toward the base of the colony. Coralla are white and somewhat glisteny. There are no coenosteal strips; rather the coenosteum is uniformly covered with short (up to 0.03 mm in height), squat, pointed spines, which also encircle or partially encircle the gastropores as a low circular rim (Figure 2*A*). The coenosteum is also covered with short (about 0.15 mm in height), discontinuous ridges that are often aligned with the dactylopores, and numerous uniformly distributed coenosteal pores (Figure 2*A*, *B*). The coenosteal pores (0.023–0.055 mm in diameter) are small hemispherical structures that often sit in a slight coenosteal depression (Figure 2*C*–*E*). Coenosteal pores also commonly occur in the gastropore sulcus (Figure 2*A*, *F*). Coralla are white.

The lateral pore rows are 0.75–1.1 mm wide, containing a broad, shallow sulcus in which the linearly arranged gastropores occur (Figure 2*A*, *F*). The gastropores are round in shape and variable in size, ranging from 0.18 to 0.42 mm in diameter (Figure 2*F*). Gastrostyles are rarely seen in unbroken or even broken branches, but do occur and are typically elongate (needle-shaped) and bear a fine supination (Figure 2*G*). The gastropore tubes contain a diffuse ring palisade composed of elongate blunt elements up to 0.1 mm in length and 0.030 mm in diameter (Figure 2*G*). Tabulae were not observed. The gastropores are flanked on either side by a row of thin-walled dactylopores, which are usually elliptical in cross section, the greater axis (up to 0.24 mm) oriented perpendicularly to the gastropore row and united to adjacent dactylopores by a tall (up to 0.23 mm) thin ridge (Figure 2*A*, *E*, *F*). Dactylopores are cylindrical with an apical pore (Figure 2*A*, *E*, *F*, *H*). Up to 23 dactylopores occur per cm, although they are usually more numerous on one side of the gastropore row than the other (Figure 2*A*, *F*). The two inner lateral faces of each dactylopore bear irregularly shaped elements up to 0.020 mm in height and 0.009 mm in diameter, similar to rudimentary dactylostyles (Figure 2*H*, *I*). The irregularly shaped male ampullae are clustered on both branch faces (Figure 2*J*), and are partially submerged in the coenosteum, their external diameter 0.55–0.65 mm, their internal diameter about 0.45 mm. Each ampulla appears to have multiple apical efferent pores, each found at the base of a shallow depression

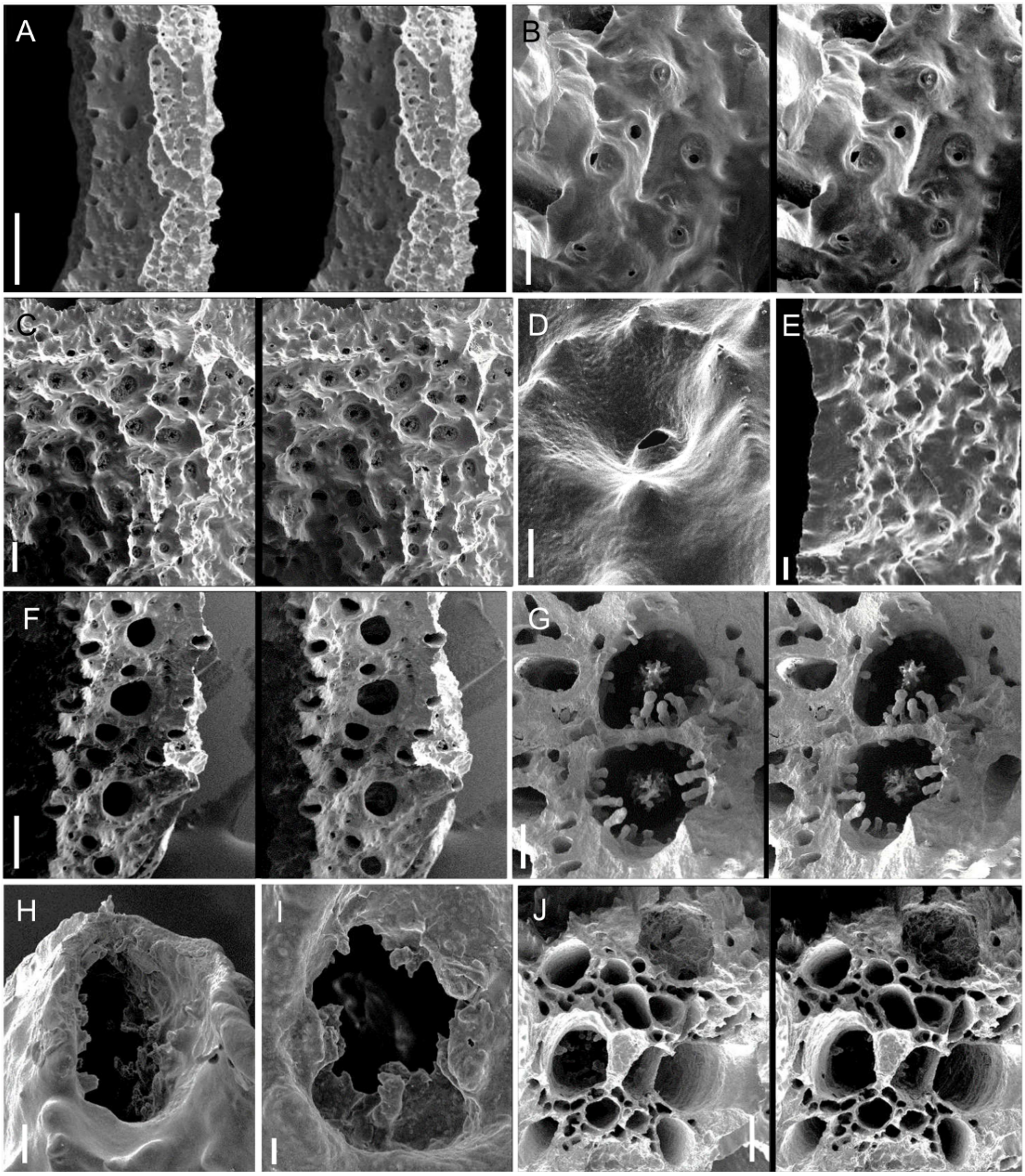

FIGURE 2. (*A*) Stereo views of a branch of the paratype showing the texture and the pore row; (*B*) stereo views of the texture showing coenosteal pores, spines, and ridges; (*C*) stereo views of the coenosteal pores and male ampullae; (*D*) detail of a coenosteal pore; (*E*) spines of the texture and two dactylopores on the ridge; (*F*) stereo views of the gastropores flanked on either side by dactylopores; (*G*) stereo views of the points of the gastrostyles and ring palisade; (*H*) dactylopore with rudimentary dactylostyles; (*I*) detail of rudimentary dactylostyles; (*J*) stereo views of the male ampulla. Scale bars: (*A*) 1 mm; (*B*) 100 μm; (*C*) 200 μm; (*D*) 40 μm; (*E*) 100 μm; (*F*) 400 μm; (*G*) 100 μm; (*H*) 30 μm; (*I*) 10 μm; (*J*) 200 μm.

about 0.25 mm in diameter, the efferent pore being 0.06–0.1 mm in diameter (Figure 2*C*). Each efferent pore is encircled by numerous thin pillars about 0.022 mm in length that project horizontally into the pore. Female ampullae are unknown.

COMPARISONS. *Distichopora cryptostylus* differs from all other congenerics (WoRMS 2019) in several characters: (1) its texture and coenosteal pores are unique in shape; (2) its dactylopores are unique in having apical pores, not lateral dactylotomes; (3) it has very few and inconspicuous gastrostyles; (4) it has rudimentary dactylostyles; (5) although not unique, it is one of only a few species that has a ridge uniting its dactylopore spines. Among the other described species, it is perhaps closest in morphology to *D. contorta* de Pourtalès 1878 (known only from off Cuba, 125–368 m, see Cairns 1986) in that both species have linked dactylopore spines, a ridged coenosteum, and similar-sized male ampullae, but *D. contorta* differs in lacking the unique characters mentioned above, in having discrete coenosteal strips.

ETYMOLOGY. From *kryptos + stylos* (Greek for hidden style), in allusion to the rarity and inconspicuous nature of the gastrostyles.

DISTRIBUTION. Known only from the Republic of Palau, western Pacific, 122–213 m.

DISCUSSION

Stylasterid corals are considered habitat-forming species (Häussermann and Försterra 2007, Cairns 2011), reaching in some areas high density and establishing a wide range of association with many organisms, enhancing the biodiversity of areas where they grow (Zibrowius 1981, Goud and Hoeksema 2001, Pica et al. 2012, 2015, 2016, Tribollet et al. 2018). Paradoxically the distribution and the ecology of this group is poorly known and for some regions unknown. The tropical Pacific Ocean is one of these regions that remains understudied with respect to stylasterid fauna. Many undescribed stylasterids are found in several museums around the world that represent an important reservoir of information about biodiversity and species distribution. Museum specimens collected in the Republic of Palau led to the description of a new species in this region *Distichopora cryptostylus*. In the Archipelago, little published information is available about stylasterid presence and distribution, and most records come from non-taxonomic papers, thus their species identification remain uncertain (Wells 1954, Weber and Woodhead 1972, Veron 2000, Fenner and Miur 2008). In fact, many records and identification of stylasterids from the tropical Pacific Ocean need to be revised and confirmed.

Knowledge about biodiversity and distribution of the stylasterid species is fundamental to defining and understanding their habitat and bathymetric range distribution, understanding how and where these corals could be influenced by climate change and anthropogenic impacts, and for the identification of priority areas for conservation. Hydroids are considered as sentinel species for monitoring climate change and environmental stress (Di Camillo et al. 2008, Puce et al. 2009, Gravili et al. 2017, Topçu et al. 2018). As stylasterids are hydroids they could potentially be used as environmental sentinels: however, the first step is to increase knowledge about their biodiversity, distribution, and ecology.

Stylasterid corals are under CITES regulation as endangered species. Threats include harvesting for souvenirs and jewelry (Häussermann and Försterra 2007, Cairns 2011, Cairns and Zibrowius 2013) and damage by diving activity (Miller et al. 2004). More information about their distribution and ecology is important to inform conservation plans as for other corals (Roberts and Cairns 2014, Anderson et al. 2016).

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Literature Cited

Anderson, O. F., J. M. Guinotte, A. A. Rowden, D. M. Tracey, K. A. Mackay, and M. R. Clark. 2016. Habitat suitability models for predicting the occurrence of vulnerable marine ecosystems in the seas around New Zealand. Deep Sea Res. Part 1 Oceanogr. Res. Pap. 115:265–292.

Boschma, H. 1953. The Stylasterina of the Pacific. Zool. Med. Leiden 32(16):165–184.

Cairns, S. D. 1983. Antarctic and Subantarctic Stylasterina (Coelenterata: Hydrozoa). Antarct. Res. Ser. 38:61–163.

———. 1986. A revision of the Northwest Atlantic Stylasteridae (Coelenterata: Hydrozoa). Smithson. Contrib. Zool. 418:1–131.

———. 1991. The marine fauna of New Zealand: Stylasteridae (Cnidaria: Hydroida), New Zealand Oceanographic Institute Memoir, vol. 98. Wellington: New Zealand Oceanographic Institute

———. 2005. Revision of the Hawaiian Stylasteridae (Cnidaria: Hydrozoa: Athecata). Pac. Sci. 59:439–451.

———. 2007. Deep-water corals: an overview with special reference to diversity and distribution of deep-water scleractinian corals. Bull. Mar. Sci. 81(3):311–322.

———. 2011. Global diversity of the Stylasteridae (Cnidaria: Hydrozoa: Athecatae). PLoS ONE 6(7):e21670.

———. 2015. Stylasteridae (Cnidaria: Hydrozoa: Anthoathecata) of the New Caledonian region. Mém. Mus. natl. hist. nat. 207:1–362.

Cairns, S. D., and A. Lindner. 2011. A revision of the Stylasteridae (Cnidaria, Hydrozoa, Filifera) from Alaska and adjacent waters. Zookeys 158:1–88.

Cairns, S. D., and H. Zibrowius. 2013. Stylasteridae (Cnidaria, Hydrozoa, Filifera) from South Africa. Zootaxa 3691(1):1–57.

Dana, J. D. 1848. Zoophytes. U S Exploring Exp Vol. 7. Lea and Blanchard, Philadelphia.

Di Camillo, C. G., G. Bavestrello, L. Valisano, and S. Puce. 2008. Spatial and temporal distribution in a tropical hydroid assemblage. J. Mar. Biol. Assoc. U. K. 88 (8):1589–1599.

Fenner, D., and P. Miur. 2008. Reef corals of the northwestern lagoon of Grande-Terre, New Caledonia. Pages 18–32 *in* A rapid marine biodiversity assessment of the coral reefs of the northwest lagoon, between Koumac and Yandé, Province Nord, New Caledonia. Conservation International.

Fisher, W. K. 1938. Hydrocorals of the North Pacific Ocean. Proc. U. S. Nat. Mus. 84 (3024):493–554.

Goud, J., and B. W. Hoeksema. 2001. *Pedicularia vanderlandi* spec. nov., a symbiotic snail (Caenogastropoda: Ovulidae) on the hydrocoral *Distichopora vervoorti* Cairns and Hoeksema, 1998 (Hydrozoa: Stylasteridae), from Bali, Indonesia. Zool. Verh. 334:77–97.

Gravili, C., F. Cozzoli, and F. Boero. 2017. The historical reconstruction of distribution of the genus *Halecium* (Hydrozoa: Haleciidae): a biological signal of ocean warming? Mar. Biol. Res. 13 (5):587–601.

Gray, J. E. 1847. An outline of an arrangement of stony corals. Ann. Mag. Nat. Hist. 19:120–128.

Häussermann, V., and G. Försterra. 2007. Extraordinary abundance of hydrocorals (Cnidaria, Hydrozoa, Stylasteridae) in shallow water of the Patagonian fjord region. Polar Biol. 30:487–492.

Hickson, S. J., and H. M. England. 1905. The Stylasterina of the Siboga expedition. Siboga Expedition 8:1–26.

Lamarck, J. B. P. A. 1816. Histoire naturelle des animaux sans vertèbes . . . Il Histoire des polypes. Paris.

Lindner, A., S. D. Cairns, and C. W. Cunningham. 2008. From offshore to onshore: multiple origins of shallow-water corals from deep-sea ancestors. PLoS ONE 3(6):e2429.

Miller, K. J., C. N. Mundy, and W. Lindsay Chadderton. 2004. Ecological and genetic evidence of the vulnerability of shallow-water populations of the stylasterid hydrocoral *Errina novaezelandiae* in New Zealand's fiords. Aquat. Conserv. 14(1):75–94.

Milne Edwards, H., and J. Haime. 1857. Histoire naturelle des coralliaires ou polypes proprement dits 2. Librairie Encyclopédique de Roret, Paris.

Moseley, H. N. 1881. Report on certain Hydroid, Alcyonarian and Madreporarian corals procured during the voyage of H.M. S. *Challenger* in the years 1873–1876. Part 1. On the Hydrocorallinae. Rep. Sci. Res. Voyage H. M. S. *Challenger*, Zool. 2 (7):1–101, 209–230.

Pallas, P. S. 1766. Elenchus zoophytorum sistens generum adumbrations generaliores et specierum cognitarum succinctas descriptions cum selectis auctorum synonymis. Hag.

Pica, D., M. Bertolino, B. Calcinai, S. Puce, and G. Bavestrello. 2012. Boring and insinuating sponges in stylasterids (Cnidaria, Hydrozoa). Ital. J. Zool. 79 (2):266–272.

Pica, D., C. Cerrano, S. Montori, D. M. Makapedua, and S. Puce. 2014. A surviving out-of-water stylasterid. Mar. Biodivers. 44 (4):469–470.

Pica, D., S. D. Cairns, S. Puce, and W. A. Newman. 2015. Southern hemisphere deep-water stylasterid corals including a new species, *Errina labrosa* sp. n. (Cnidaria, Hydrozoa, Stylasteridae), with notes on some symbiotic scalpellids (Cirripedia, Thoracica, Scalpellidae). Zookeys 472: 1–25.

Pica, D., A. Tribollet, S. Golubic, M. Bo, C. G. Di Camillo, G. Bavestrello, and S. Puce. 2016. Microboring organisms in living stylasterid corals (Cnidaria, Hydrozoa). Mar. Biol. Res. 12(6):573–582.

Pourtalès, de L. F. 1878. Report on the results of dredging, under the supervision of Alexander Agassiz, in the Gulf of Mexico, by the U.S. Coast Survey Steamer Blake: Corals. Bull. Mus. Comp. Zool. 5(9): 197–212.

Puce, S., G. Bavestrello, C. G. Di Camillo, and F. Boero. 2009. Long-term changes in hydroid (Cnidaria, Hydrozoa) assemblages: effect of Mediterranean warming? Mar. Ecol. 30(3):313–326.

Puce, S., D. Pica, L. Mancini, F. Brun, A. Peverelli, and G. Bavestrello. 2011. Three-dimensional analysis of the canal network of an Indonesian *Stylaster* (Cnidaria, Hydrozoa, Stylasteridae) by means of X-ray computed microtomography. Zoomorphology 130:85–95.

Puce, S., D. Pica, F. Brun, L. Mancini, and G. Bavestrello. 2012. Genus *Distichopora* (Cnidaria, Hydrozoa): from primary cyclosystem to adult pore rows organization. Coral Reefs 31:715–730.

Roberts, J. M., and S. D. Cairns. 2014. Cold-water corals in a changing ocean. Curr. Opin. Environ. Sustain. 7:118–126.

Schuchert, P. 2019. World Hydrozoa Database. Accessed on 14 February 2019. http://www.marinespecies.org/hydrozoa.

Topçu, N., L. Martell, I. Yilmaz, and M. Isinibilir. 2018. Benthic hydrozoans as potential indicators of water masses and anthropogenic impact in the Sea of Marmara. Medit. Mar. Sci. 19(2):273–283.

Tribollet, A., D. Pica, S. Puce, S. E. Campbell, G. Radtke, and S. Golubic. 2018. Euendolithic *Conchocelis* stage (Bangiales, Rhodophytes) in the skeletons of live stylasterid reef corals. Mar. Biodivers. 48:1855–1862.

Veron, J. E. N. 2000. Corals of the world. Australian Institute of Marine Science. p. 463.

Weber, J. N., and P. M. Woodhead. 1972. Temperature dependence of oxygen-18 concentration in reef coral carbonates. J. Geophys. Res. 77(3):463–473.

Wells, J. W. 1954. Recent corals of the Marshall Islands: bikini and nearby atolls, Part 2, Oceanography (Biologic). Geol. Surv. prof. pap. 260-I:382–486.

WoRMS. 2019. *Distichopora* Lamarck, 1816. Accessed on 14 June 2019. http://www.marinespecies.org/aphia.php?p=taxdetails&id=205513.

Zibrowius, H. 1981. Associations of Hydrocorallia Stylasterina with gall-inhabiting Copepoda Siphonostomatoidea from the south-west Pacific. Part 1. On the stylasterine hosts, including two new species. Bijdr Dierk, Amsterdam 51(2):268–286.

Zibrowius, H., and S. D. Cairns. 1992. Revision of the Northeast Atlantic and Mediterranean Stylasteridae (Cnidaria: Hydrozoa). Mém. Mus. Natl. Hist. nat. (A, Zool) 153:1–136.