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New species of black corals (Cnidaria:Anthozoa: Antipatharia) from deep-sea seamounts and ridges in the North Pacific

DENNIS M. OPRESKO[1] & DANIEL WAGNER[2,*]
[1]*Department of Invertebrate Zoology, U.S. National Museum of Natural History, Smithsonian Institution, Washington, DC 20560.*
[2]*Conservation International, Center for Oceans, Arlington, VA.*
**Corresponding Author:*
[1] *dmopresko@hotmail.com; https://orcid.org/0000-0001-9946-1533*
[2,*] *dwagner@conservation.org; https://orcid.org/0000-0002-0456-4343*

Abstract

Three new species of antipatharian corals are described from deep-sea (677–2,821 m) seamounts and ridges in the North Pacific, including *Antipathes sylospongia, Alternatipathes venusta*, and *Umbellapathes litocrada*. Most of the material for these descriptions was collected on expeditions aboard NOAA Ship *Okeanos Explorer* that were undertaken as part of the Campaign to Address Pacific Monument Science, Technology, and Ocean Needs (CAPSTONE). One of the main goals of CAPSTONE was to characterize the deep-sea fauna in protected waters of the U.S. Pacific, as well as in the Prime Crust Zone, the area with the highest known concentration of commercially valuable deep-sea minerals in the Pacific. Species descriptions and distribution data are supplemented with *in situ* photo records, including those from deep-sea exploration programs that have operated in the North Pacific in addition to CAPSTONE, namely the Hawaii Undersea Research Laboratory (HURL), the Ocean Exploration Trust (OET), and the Monterey Bay Aquarium Research Institute (MBARI).

Key words: Black corals; morphology; taxonomy; Antipathidae, Schizopathidae, Hawaii, Johnston Atoll, new species

Introduction

The North Pacific Ocean includes some of the most remote areas on Earth. As a result, the marine fauna of this expansive region has been greatly undersurveyed, particularly in its deeper waters (Parrish *et al.* 2017; Leonardi *et al.* 2018; Kennedy *et al.* 2019). To address this knowledge gap, the National Oceanic and Atmospheric Administration (NOAA) in collaboration with several partners, launched the Campaign to Address Pacific Monument Science, Technology, and Ocean Needs (CAPSTONE), a multi-year research initiative focused on exploring deep-sea habitats in the U.S. Pacific and adjacent international waters (Leonardi *et al.* 2018; Kennedy *et al*. 2019). Two of the main goals of CAPSTONE were to characterize deep-sea habitats on seamounts located in the Prime Crust Zone, the region on Earth with the highest known concentrations of commercially-valuable cobalt-rich ferromanganese crusts, and to explore deeper portions of Monuments and Sanctuaries in the U.S. Pacific (Leonardi *et al.* 2018; Kennedy *et al*. 2019). A total of 187 remotely operated vehicle (ROV) dives were conducted as part of CAPSTONE, during which high-quality video footage and 786 biological specimens were collected, many of which because they were suspected of being new species or new records for the region (Kennedy *et al*. 2019). This includes 32 samples of antipatharians, commonly known as black corals, which were collected from deep waters around Hawaii, Johnston, Palmyra, Wake, Kiribati and American Samoa. The purpose of this study is to provide taxonomic descriptions of three new black coral species that were collected as part of the CAPSTONE efforts.

Material and methods

Specimens evaluated in this paper are all deposited in the invertebrate zoology collections of the U.S. National

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Museum of Natural History, Smithsonian Institution in Washington, DC (NMNH), and the Bernice P. Bishop Museum in Honolulu, HI (BPBM). The material was collected primarily by the ROV *Deep Discoverer* during research expeditions aboard NOAA Ship *Okeanos Explorer* around the Hawaiian Islands and Johnston Atoll. This collection was supplemented by limited specimens collected by the manned submersible *Pisces* IV operated by the Hawaii Undersea Research Laboratory (HURL), as well as by ROV *Tiburon* operated by Monterey Bay Aquarium Research Institute (MBARI).

The specimens were examined at the NMNH. Photographs of the skeletal spines were made using a *Zeiss EVO MA 15* scanning electron microscope (SEM) housed at the NMNH. The specimens were coated with a 30–40 nm thick layer of 60% gold and 40% palladium. Analysis of the skeletal spines was conducted from direct examination of the material using a low-power ocular microscope or by examination of photomicrographs taken with the SEM.

The size of the polyps, referred to as the transverse diameter, was measured as the distance between the distal edge of distal lateral tentacles and the proximal edge of the proximal lateral tentacles of the same polyp. The distance between spines was measured as the distance between centers of the bases of adjacent spines in the same axial row, and the height of a spine was measured as the distance between the apex and the center of the base of a spine. Based on convention, the number of axial rows of spines was determined as the number of complete rows (those in which the base of the spines is visible) that can be counted in one lateral view (also referred to as "one aspect").

In situ photographs of black coral colonies were retrieved from the NOAA National Database for Deep-Sea Coral and Sponges Version 20191217-0 (https://deepseacoraldata.noaa.gov/). Photos of colonies that matched the external features of the described species were used to supplement the distribution records, but it should be noted that identifications to species usually requires examination of the microscopic skeletal features of the specimens

Results and discussion

Order Antipatharia Milne Edwards, 1857

Family Antipathidae Ehrenberg, 1834

The family Antipathidae is characterized by polyps with six primary and four secondary mesenteries, and a transverse polyp diameter ranging from 1 mm to as much as 3 mm. The expanded tentacles of the polyps narrow to a fine tip and are as much as three times longer than the polyp diameter, and the sagittal tentacles are usually longer than lateral tentacles. The corallum can be unbranched or sparsely to densely branched (i.e., bramble-like, bushy, broom-like or fan-shaped), but is never truly pinnulated, although flabellate colonies with bilateral branching can appear so. The skeletal spines are triangular or conical in lateral view; smooth or covered to varying degrees with small, roundish to oblong papillae, and the apex of spines can be simple (acute or rounded), bifurcated or multiply lobed.

Genus *Antipathes* Pallas, 1766

Type species. *Antipathes dichotoma* Pallas, 1766 (see Opresko 2003: 481–493).

Diagnosis. Corallum sparsely to densely branched. Branching bushy, bramble-like, broom-like or fan-shaped. End-branchlets of varying length; arranged irregularly, or bilaterally. Spines triangular or cone-shaped in lateral view; smooth or covered, to varying degrees, with small papillae; apex of spines simple or with one or more lobes or bifurcations. Polyps from less than 1 to 3 mm in transverse diameter.

Remarks. The genus contains a large number of nominal species. DNA studies (Brugler *et al*. 2013; Bo *et al*. 2019) suggest that it might be subdivided on the basis of whether the spines are smooth-surfaced or have distinct papillae and whether they are simple, forked or multiply lobbed at the apex. Species are usually differentiated by colony morphology, as well as size, shape, and surface ornamentation of the skeletal spines.

Distribution. The genus is known primarily from tropical and subtropical waters in all oceans; usually at depths less than 200 m. However, some species may occur much deeper.

***Antipathes sylospongia* sp. nov.**
(Fig. 1–5)

Material examined. *Holotype*: USNM 1404494 (SEM 506), Northwestern Hawaiian Islands, off Lisianski, 26.8266°N, 175.608°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1504L2_D2_DIVE08_SPEC01BIO, on hexactinellid sponge *Farrea occa,* 1,299 m, NOAA, 9 Aug 2015. ***Paratype***: USNM 1467600, Musician Seamounts, Paganini Seamount, 28.68°N, 162.61°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1708_D2_DIVE13_SPEC02BIO_A01, on unidentified hexactinellid sponge in the family Tretodictyidae, 1,764.94 m, NOAA, 19 Sep 2017.

***Other material examined*:** BPBM C449, Northwestern Hawaiian Islands, French Frigate Shoals, M/V *Mohicana*, shrimp traps, on hexactinellid sponge *Farrea occa,* 676.66 m, coll. P. Struhsaker 3 Nov 1981; HURL-P4-228-Spec. 2, Northwestern Hawaiian Islands, off Nihoa, 22.74052°N, 161.16455°W, R/V *Ka'imikai-o-Kanaloa*, DSR/V *Pisces* IV, Dive 228, Specimen 2, on sponge *Farrea occa*, 1,425 m, coll. C. Kelley, 3 Dec 2009.

Underwater photo records: EX1504L2_IMG_20150809T211338Z, Northwestern Hawaiian Islands, off Lisianski, 26.82241°N, 175.60681°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1708_D2_DIVE08, on hexactinellid sponge *Farrea occa,* 1,357 m, NOAA, 9 Aug 2015; EX1504L2_IMG_20150809T212320Z, Northwestern Hawaiian Islands, off Lisianski, 26.82257°N, 175.60701°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1708_D2_DIVE08, on hexactinellid sponge *Farrea occa,* 1,347 m, NOAA, 9 Aug 2015; EX1504L2_IMG_20150808T022010Z, Northwestern Hawaiian Islands, West Northampton Seamount, 25.08627°N, 172.49081°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1708_D2_DIVE06, on hexactinellid sponge *Farrea occa*, 1,800 m, NOAA, 7 Aug 2015.

Diagnosis. Colonies found in association with glass sponges (Fig. 1); to date only recorded growing on *Farrea occa* and an unidentified sponge in the family Tretodictyidae. Corallum loosely branched, without a noticeable main stem or major branches. Branches very thin, extending out in all directions. End-branchlets small, mostly less than 2 cm, varying distances apart; tending to be arranged bilaterally along individual branches; but the arrangement can be quite irregular, in some places alternating, and often in subopposite pairs. Spines small, triangular in lateral view, with rounded apex; polypar spines up to 0.03 mm, abpolypar spines 0.01 to 0.02 mm. Polyps mostly about 1.5 mm in transverse diameter (maximum about 2 mm); arranged uniserially with 5 polyps per cm.

Description of holotype. The holotype was found attached to a *Farrea occa* sponge that was approximately 15 cm tall and 20 cm wide at the time of collection (Fig. 1A). The sponge broke into several pieces after collection. Much of the outer surface of the *Farrea occa* sponge host is overgrown by the coral (Fig. 1A). A loose network of coral branchlets cover the surface (Fig. 2A) and penetrate the tissue to attach to the very fine siliceous matrix of the sponge (Fig. 3). The branchlets do not anastomose. The colony is bramble-like to bushy with very thin, short branches extending out in all directions from the sponge. Based on the *in situ* photos (Fig. 1A), it is estimated that the branches extend out 5 to 10 cm from the surface of the sponge. Branches are arranged irregularly on all sides of the lower order branches. Because of the growth form of the colony, it is difficult to determine if there is a main stem or how many orders of branching there are. End-branchlets are up to 2 cm long and 0.08 mm in basal diameter. An end-branchlet 1 cm long is 0.047 mm in diameter in the middle, and 0.066 mm in diameter near the base. Some of the smallest end-branchlets are in subopposite pairs. These pairs of branchlets are 4–5 mm apart.

The skeletal spines (Fig. 4) are very small, triangular in lateral view, with rounded apex. Some of the spines are slightly misshapen, especially near their tip, and there are a few double spines. The polypar spines are slightly larger than the abpolypar spines. On branchlet sections that are 0.05 to 0.11 mm in diameter, the polypar spines are up to 0.03 mm tall and the abpolypar spines are mostly about 0.01 mm tall, but can be up to 0.02 mm. Three to five axial rows of spines are visible in lateral view. The spacing between the rows and between the spines within the rows varies from being very regular to quite irregular, the latter occurring especially on the thick branches adjoining the skeleton of the sponge. The number of rows of spines does not increase on the larger branches that are in contact with the sponge matrix.

The polyps (Fig. 2B) are mostly about 1.5 mm in transverse diameter (range: 0.7–2 mm); and are arranged uniserially with five polyps per cm. *In situ* photos of what appear to be fully expanded polyps suggest that all the tentacles are cylindrical, subequal in length, and usually not much longer than the transverse diameter of the polyps. This is also apparent in preserved polyps of the holotype.

Description of the paratype. The paratype (USNM 1467600) was found growing on an unidentified hexac-

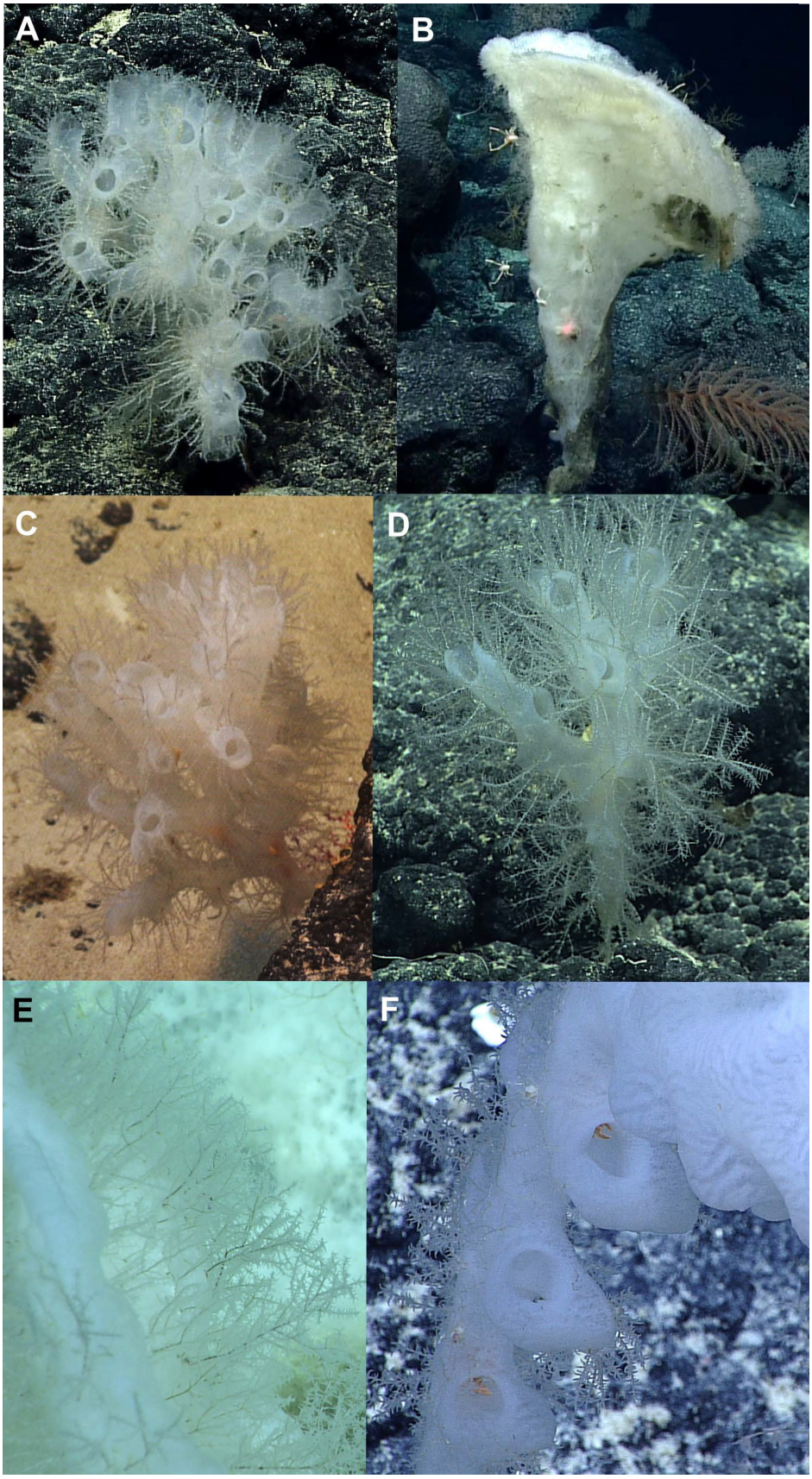

FIGURE 1. *Antipathes sylospongia* **sp. nov**., *in situ* photographs: **A**. holotype; **B**. paratype; **C**. HURL-P4-228-Spec. 2; **D**. colony photographed at 1,357 m off Lisianski (specimen not collected); **E**. Close-up *in situ* photograph of the paratype; **F**. Close-up photograph of colony at 1,800 m at West Northampton Seamount specimen not collected). Photos courtesy of NOAA Office of Ocean Exploration and Research.

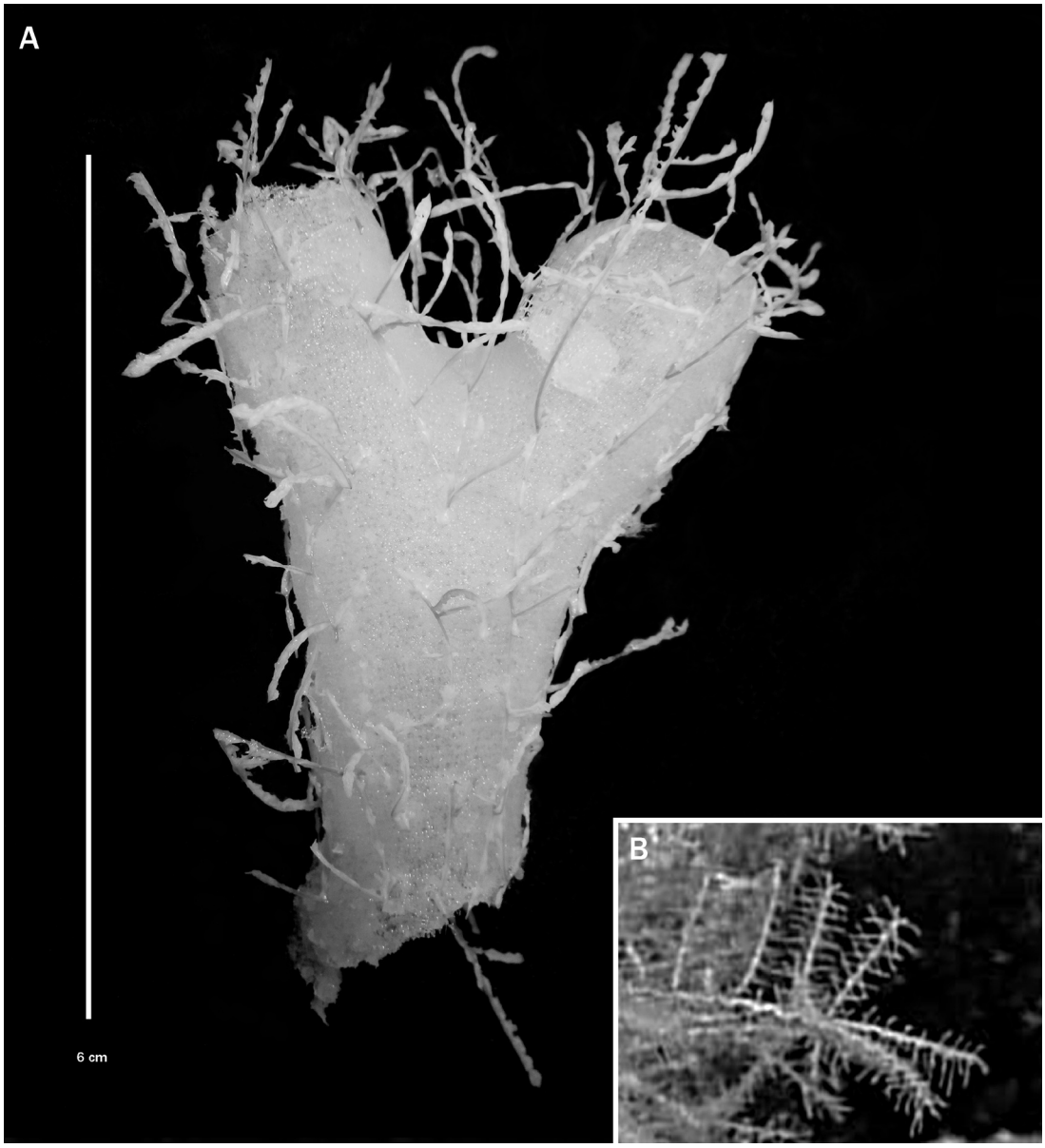

FIGURE 2. *Antipathes sylospongia* **sp. nov. A**. part of holotype on *Farrea occa* sponge. **B**. polyps with expanded tentacles photographed *in situ*.

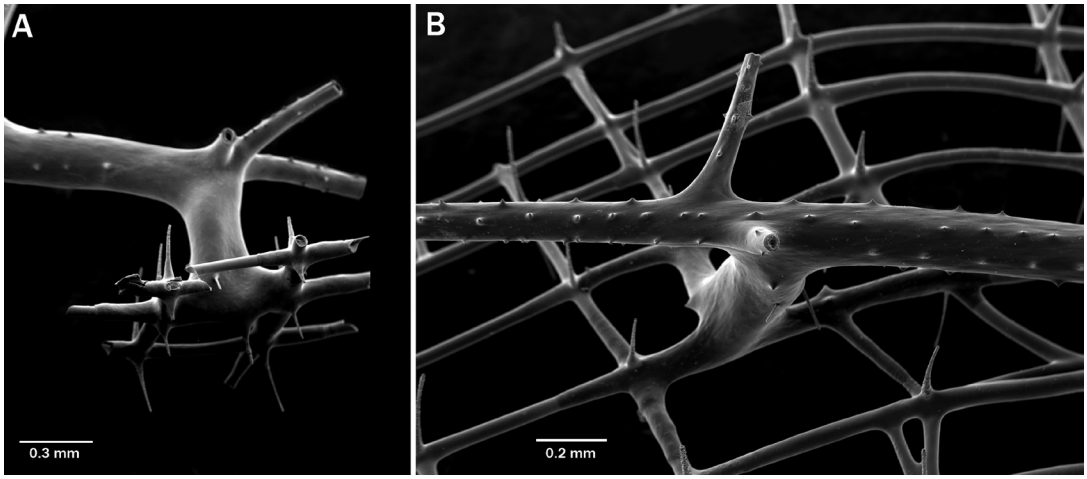

FIGURE 3. *Antipathes sylospongia* **sp. nov.** holotype, USNM 1404494. Attachment of antipatharian sclerenchyme to sponge skeletal matrix.

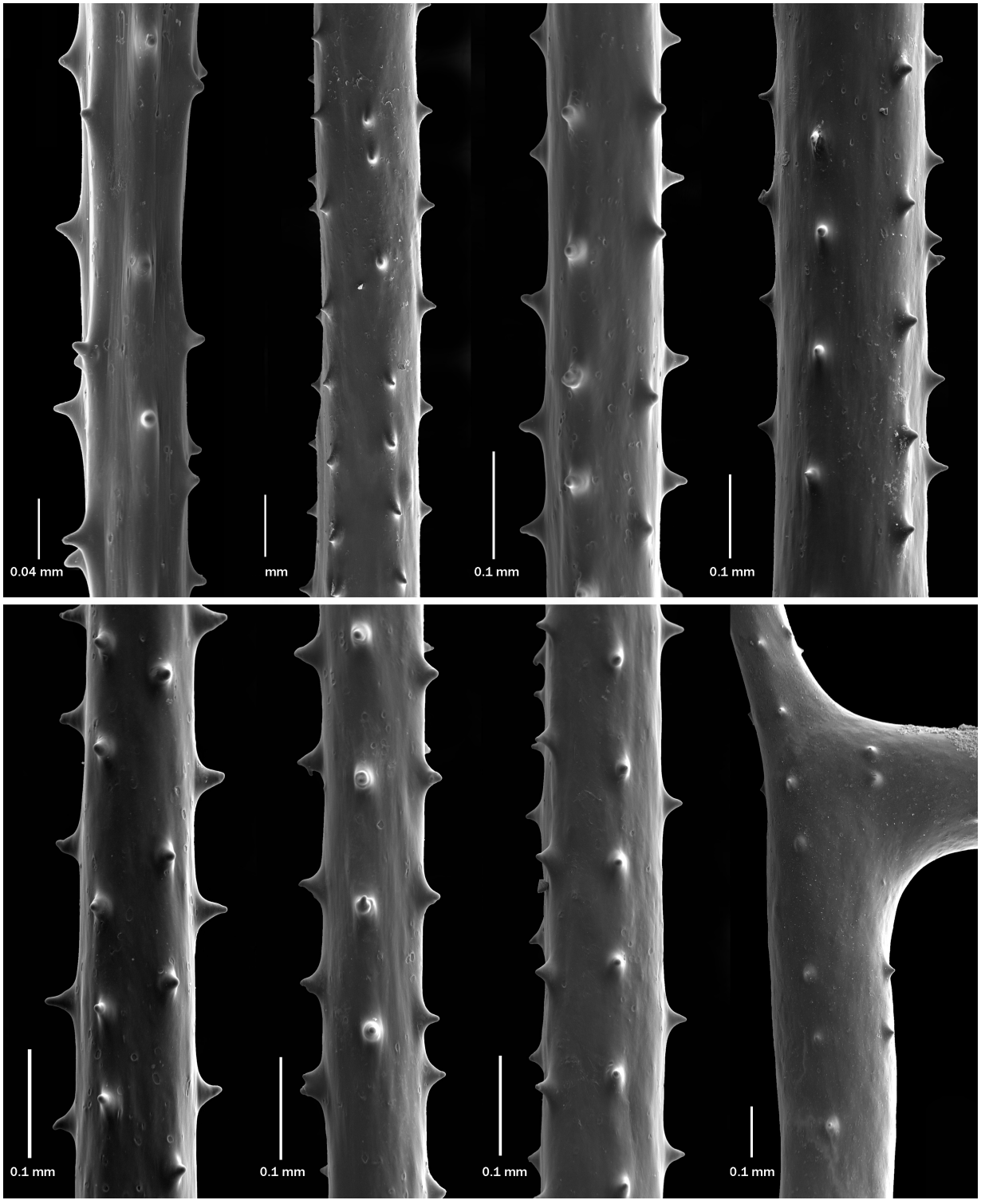

FIGURE 4. *Antipathes sylospongia* **sp. nov.** holotype (USNM 1404494); sections of end-branchlets and lower order branches.

tinellid sponge in the family Tretodictyidae (Fig. 1B). The intact sponge from which the coral was collected was approximately 1 m tall and 60 cm wide (Fig. 1B); however, only a distal portion of the sponge was collected. The collected portion of the sponge broke into several pieces, the two largest of which measure 9 cm x 5.5 cm, and 14 cm x 7 cm, respectively. The paratype is similar to the holotype in most features of the sclerenchyma. The end-branchlets in the preserved colony are mostly 1 cm or less in length and about 0.08 mm in diameter. The branchlet density is about 6 per cm. On branchlets 0.12 to 0.21 mm in diameter, the polypar spines are no more than about

0.03 mm tall and the abpolypar spines about half that size. Three or four rows of spines are visible in lateral view, and the spine density is 7 to 8 per mm. The transverse diameter of the polyps ranges from about 1.1 mm to 1.3 mm, slightly smaller than that in the holotype. The interpolypar space is up to 0.8 mm wide, resulting in four to six polyps per cm.

Remarks. The size of the polyps, the relative lengths and shape of the tentacles, and the tendency for the end-branchlets to be arranged in subopposite pairs raises the possibility that this species might actually belong in the family Stylopathidae. DNA analysis would be needed to confirm this supposition, and it may require the use of advanced sequencing techniques such as those based on ultra conserved elements (Quattrini *et al*. 2019, Horowitz *et al*. 2020) to establish the relationship of this taxon to others in the family Stylopathidae. Pending future DNA analyses, this species is tentatively placed in the genus *Antipathes* based on general morphological similarities. It is important to note, however, that most species in the genus *Antipathes* are typically found at much shallower depths (~200 m or less) than *A. sylospongia* (677–1,800 m).

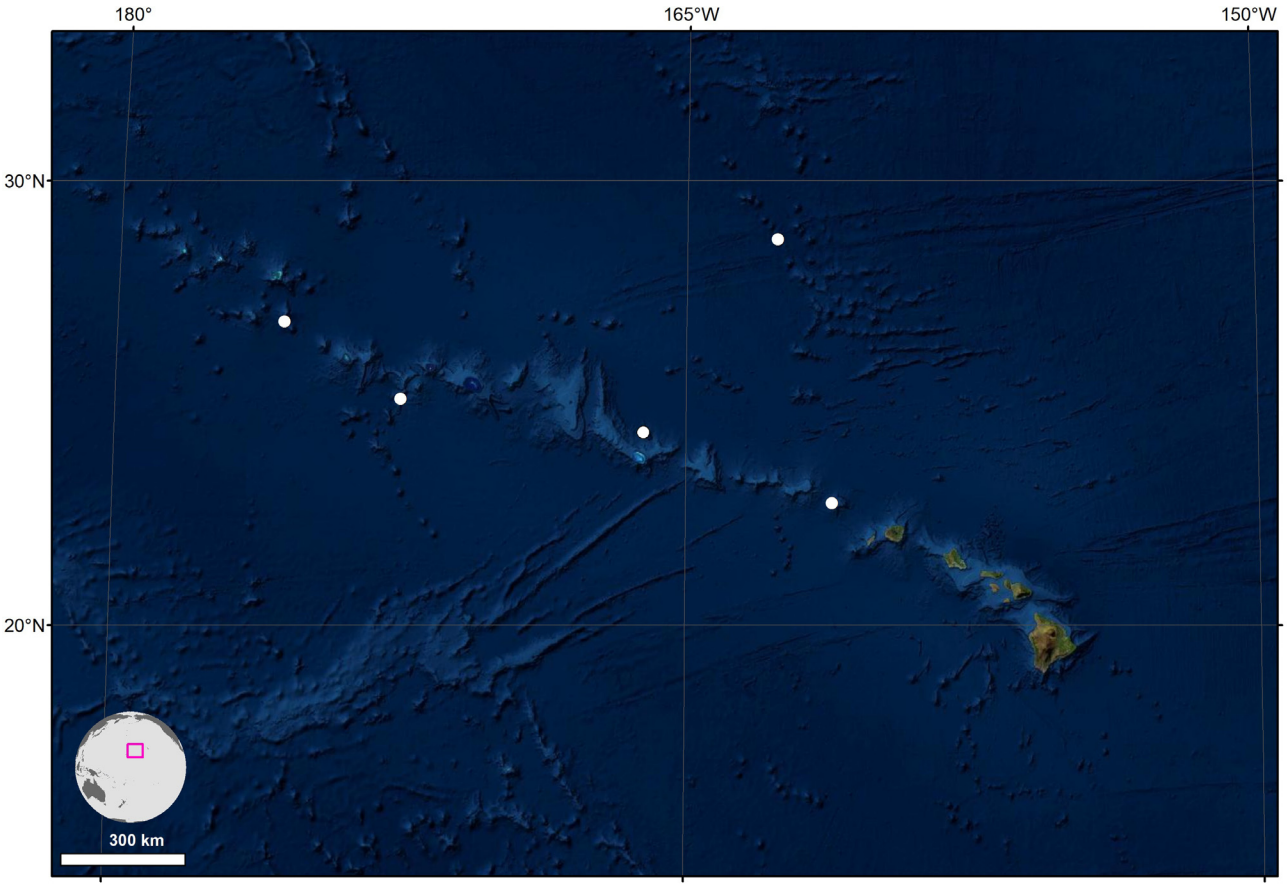

FIGURE 5. Map showing the known geographical distribution of *Antipathes sylospongia* **sp. nov**. To date, this species has only been recorded from the Musician Seamounts and the Northwestern Hawaiian Islands between the islands of Nihoa and Lisianski at 677–1,800 m depths.

Comparisons. Four Pacific antipatharian species have been described that form small colonies with very thin branches and very small spines. These include *Antipathes simplex* (Schultze, 1896), *A. chamaemorus* Pax and Tischbierek, 1932, *A. pauroclema* Pax and Tischbierek, 1932, and *A. polyhedra* Opresko, 2019. None of these have been reported to be associated with hexactinellid sponges, and in none of them do the end-branches occur suboppositely. The type specimen of *A. simplex* is a small colony only 10 cm tall, with thin, sparse, distally directed and irregularly arranged branchlets about 0.2 mm in diameter, with narrow distal branch angles, triangular, acute spines up to 0.085 mm tall, and polyps 1 mm in transverse diameter resulting in 10 polyps per cm. The types of *A. chamaemorus* and *A. pauroclema* consist of only small fragments. In the type of *A. chamaemorus*, the branching is irregularly bilateral and loosely alternating, with wide distal branch angles; the spines are up to 0.08 mm tall; and the polyps are about 1 mm, with 6–7 polyps per cm. In the type of *A. pauroclema*, the branching is quite irregular; the distal branch angles are quite wide; the spines are up to 0.1 mm tall; and the polyps are about 1 mm in transverse diameter, with 5–6

polyps per cm. *Antipathes polyhedra* forms small, thin-branched, bramble-like colonies with multiple holdfasts. In this regard, it is similar to *A. sylospongia* **sp. nov.**, which forms multiple attachment points on the sponge. However, *A. polyhedra* has much larger spines (up to 0.15 mm) and smaller polyps (0.7 mm in transverse diameter).

Genetic Data. Genetic data are not available for the holotype or paratype.

Etymology. The species name "*sylospongia"* is derived from the Greek prefix "*syl"* meaning "*with*", the connecting vowel "*o*" and "*spongia*" for the sponge hosts. To date, all known records of this species are in strict association with hexactinellid sponge hosts, either *Farrea occa* or an unidentified species in the family Tretodictyidae.

Distribution. Currently only known from the Musician Seamounts and the Northwestern Hawaiian Islands between Nihoa and Lisianski at depths ranging between 677–1,800 m (Fig. 5).

Family Schizopathidae Brook, 1889

The family Schizopathidae is characterized by polyps with ten internal mesenteries (six primary and four secondary) and a transverse polyp diameter ranging from 2 mm to as much as 17 mm. Regardless of genus, colonies are usually pinnulate to some degree (see Opresko 2002). Genera are distinguished by characteristic patterns of pinnulation and subpinnulation (i.e., number of rows of primary or secondary pinnules, number of orders of subpinnules, restriction of subpinnules to only certain lower order pinnules).

Alternatipathes Molodtsova and Opresko, 2017

Diagnosis. Corallum attached to substrate; monopodial, unbranched or with a few basal branches, and pinnulate. When present, pinnate branches of first order develop from lowermost pinnules of stem. Pinnules simple, arranged alternately in two lateral rows. Length of pinnules on stem and branches usually decreasing in a distal direction forming a triangularly shaped outline. Striatum absent. Spines conical, smooth, simple (or rarely forked), with acute to slightly rounded apex and flared base. Spines often larger on polypar side of pinnule. Polyps 2–7 mm in transverse diameter.

Type species. *Umbellapathes bipinnata* Opresko, 2005.

Remarks. Three species are currently assigned to this genus; *A. bipinnata* (Opresko, 2005), *A. alternata* (Brook, 1889), and the new species described below.

Alternatipathes venusta sp. nov.

(Fig. 6–8)

Material examined. ***Holotype***: USNM 1404492 (SEM stub 406), Hawaiian Islands, McCall Seamount, 18.977ºN, 157.1107ºW, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1504_L3_D2_DIVE04_SPEC06BIO, 2,638 m, NOAA, 1 Sep 2015. ***Paratype***: USNM 1234537, Northeast Pacific, Gorda Ridge, Gorda Transform, 41.6701ºN, 127.317ºW, R/V *Western Flyer*, ROV *Tiburon*, Sta. T-193-A4, 2,821.1 m, MBARI, 12 Aug. 2000.

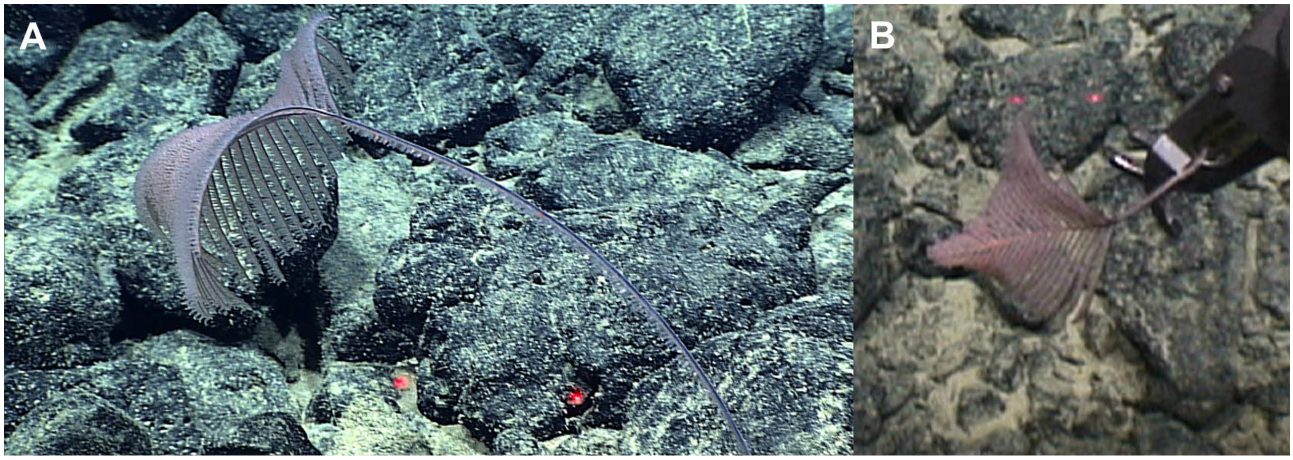

FIGURE 6. *In situ* photographs of *Alternatipathes venusta* **sp. nov.** holotype (USNM 1404492) photographed near McCall Seamount at 2,638 m. Photos courtesy of NOAA Office of Ocean Exploration and Research.

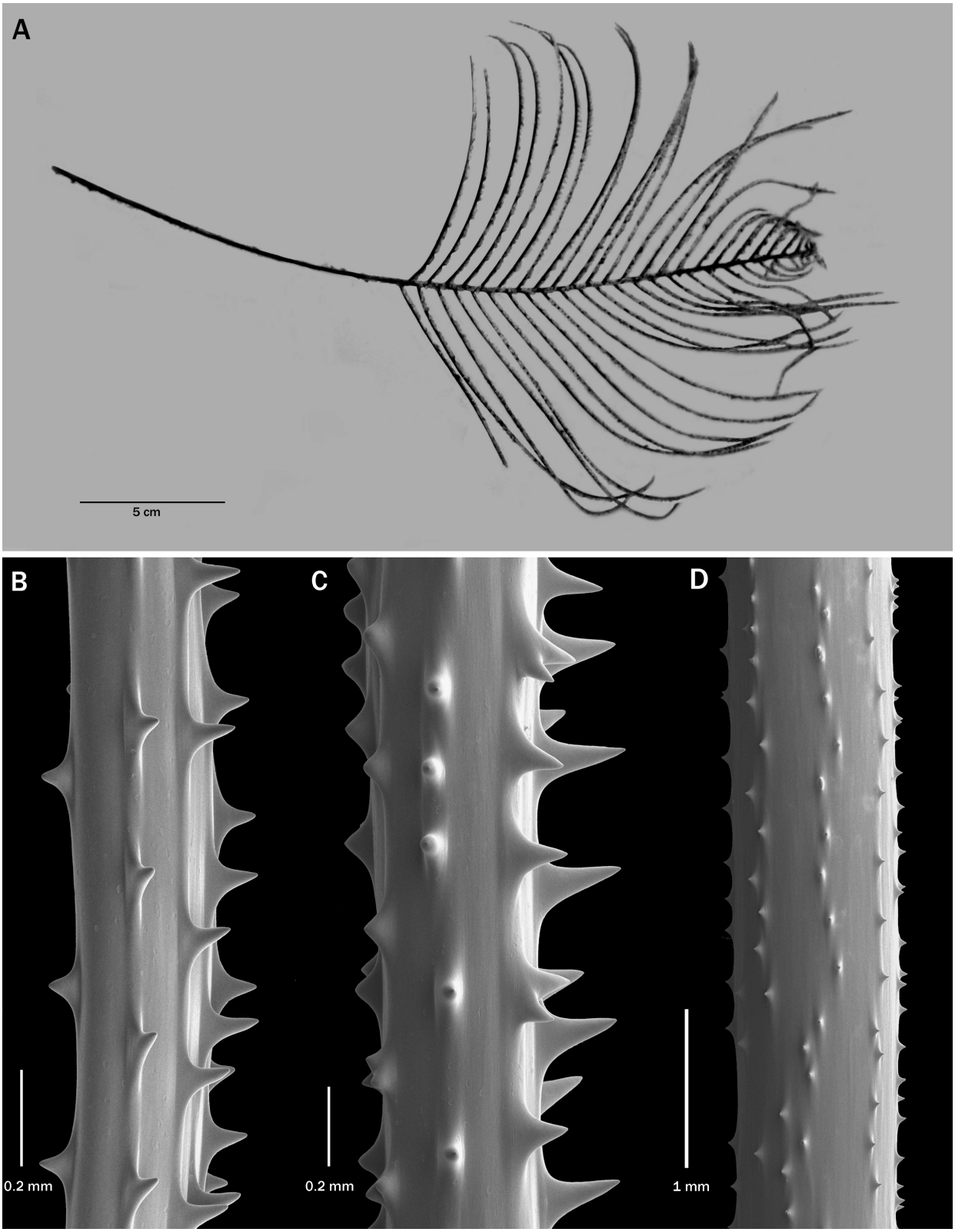

FIGURE 7. *Alternatipathes venusta* **sp. nov.** holotype (USNM 1404492). **A.** colony; **B–C.** skeletal spines on pinnules; **D.** spines on stem (B-D from SEM stub 406).

Type locality. Hawaiian Islands, McCall Seamount, 2,638 m.

Diagnosis. Colony attached, monopodial, unbranched, and pinnulate. Pinnules simple, arranged alternately in two lateral rows along upper part of stem. Lower unpinnulated section of the stem up to two times longer than upper pinnulated section. Pinnules generally decreasing in length proximally (>13 cm) to distally (~3 cm) in a colony with

a 17 cm long pinnulated section. Pinnules 4–6 mm apart on either side of axis; nine to 11 pinnules (total for both rows) per 3 cm. Polypar spines on pinnules, conical, smooth, acute, and up to 0.22 mm tall; a few are bifurcated. Abpolypar spines short, triangular, up to 0.08 mm tall. Five to six rows of spines visible in lateral view; with 4 spines per mm within each row on polypar side; 3–4 spines per mm on abpolypar side. Polyps about 5 mm in transverse diameter, with 2 polyps per cm.

Description of holotype. The holotype (USNM 1404492) is a relatively large monopodial colony with a long unpinnulated stalk and a shorter upper pinnulated section (Fig. 6A–B, 7A). Although the collected specimen is missing the lowermost part of the stem, *in situ* photos indicate that the colony was attached to the hard substrate by a basal plate. The length of the stem of the collected specimen is 29 cm, with the upper 17 cm containing simple pinnules arranged alternately in two lateral rows. The total length of the unpinnulated part of the stem was estimated from *in situ* images of the colony to be about 40 cm; therefore, the total length of the stem in the intact colony is estimated to have been 57 cm. The stem diameter at its broken end is 1.2 mm. A striatum was not found on the 12 cm section of stem still remaining; however, on this section the spines often occur along the crests of axial ridges.

On the collected specimen the pinnules in the lowest four pairs are broken off, therefore, their length cannot be determined. The next highest ones are 13 cm long with a basal diameter of about 0.9 mm. The pinnules in the twelfth pair from the apex are about 10 cm long. The spacing of the pinnules varies slightly along the stem (4 to 6 mm apart in each row), such that there are ten to 11 pinnules total per 3 cm. The lowest pinnule is on the left side of the colony (the polyp side being the front side of the corallum) and alternates with the one on the right. Distal angles that the pinnules form with the stem are near 60° on the lower and middle parts of pinnulated section of the stem; decreasing to about 30° near the tip. The interior angle formed by the two rows of pinnules is close to 90°on the lower part of the pinnulated section of the stem; increasing to near 180° near the tip.

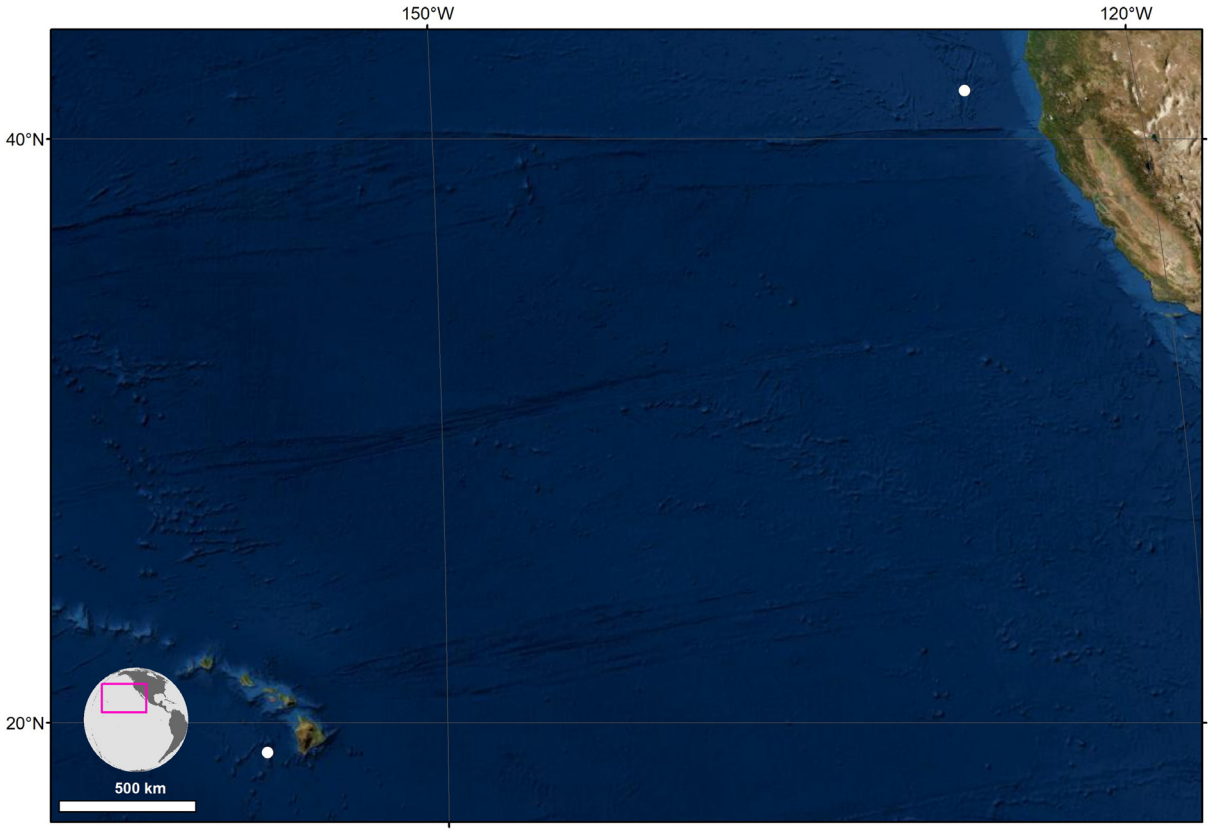

FIGURE 8. Map showing the known geographical distribution of *Alternatipathes venusta* **sp. nov**. To date, this species is only known from the Hawaiian Islands and Gorde Ridge at depths ranging between 2,638–2,821 m.

The skeletal spines on the pinnules (Fig. 7B–C) are distinctly different on the polypar and abpolypar sides of the axis. On the polypar side they are tall, conical, smooth, with a sharp or slightly rounded apex. The abpolypar spines are short, triangular in lateral view, and rounded at the apex. On a section of pinnule where the axial diameter is 0.24 mm, the polypar spines are 0.11 mm and the abpolypar spines are 0.06 mm. On a section of pinnule where the axial

diameter is 0.4 mm, the polypar spines are 0.22 mm and the abpolypar spines are 0.08 mm. The polypar spines are at right angles to the axis or are angled distally or proximally slightly. The spines are in axial rows, five to six of which can be seen in lateral view. The spacing of the spines within the rows ranges from 0.2 to 0.46 mm; on average, there are about 4 spines per mm on the polypar side and slightly less on the abpolypar side. In some places the rows of spines appear to originate on axial ridges running in a proximal to distal direction. The polypar spines, and some on the sides of the axis, are forked, and appear to eventually lead to the formation of double spines. On the stem the spines (Fig. 7D) are reduced in size and usually not more than 0.06 mm tall. They are often very shallowly sloped at the base in both a basal and distal direction. The number of rows and the density within the rows is similar to that on the pinnules, but the rows are not as uniform as those on the pinnules and scattered spines also occur between the rows.

The polyps near the base of the pinnules are 3.5–4 mm in transverse diameter with 2–2.5 polyps per cm. Polyps along most of the remaining sections of the pinnules are close to 5 mm in transverse diameter and the interpolypar space is about 1 mm, resulting in a polyp density of 2 polyps per cm or 6 polyps per 3 cm.

Description of the paratype. The paratype (USNM 1234537) consists only of the upper pinnulated part of a colony, the lower unpinnulated stalk was not collected. The remaining pinnulated section is about 20 cm long. This specimen is similar to the holotype in the length of the pinnules (up to 14.5 cm), in the density of the pinnules (9–10 per 3 cm), and in the size of the polypar spines (mostly 0.11 to 0.15 mm, but up to 0.19 mm tall), but it has smaller polyps (3–4 mm in transverse diameter with a density of 2.6–3 polyps per cm).

Comparisons. *Alternatipathes venusta* is morphologically similar to *A. alternata* (Brook, 1889). Both species form a monopodial, unbranched corallum. Although the type of *A. venusta* is larger than that of *A. alternata* and has longer pinnules, the ratio between pinnule and stem length is similar in both species. Thus, the length of the pinnules on the upper 10 cm of the *A. venusta* corallum are proportionally similar to those on the type of *A. alternata*, whose pinnulated section is only 10 cm long. The basal-most pinnules (twelfth pair from the apex) in *A. alternata* are 10.5 cm in length, and in *A. venusta* the pinnules in the twelfth pair from the apex are also about 10 cm long. Differences between the types of both species are in the length of the non-pinnulated stalk (about four times longer in *A. venusta*), in the density of the pinnules (9–11 pinnules total for both sides per 3 cm vs. 7–8 pinnules total per 3 cm in *A. alternata*), and in the size of the spines (polypar spines up to 0.22 mm in *A. venusta* and only 0.06 mm in *A. alternata*).

The type species of the genus, *A. bipinnata* (Opresko, 2005) has spines that are very similar to those of *A. venusta* in both shape and size. The polypar spines in *A. bipinnata* are up to 0.3 mm in height, whereas the abpolypar spines are half that size or smaller. The two species can be differentiated however, by the fact that in *A. bipinnata* the pinnules are much shorter (4.5 cm vs. 13 cm or more), the lowermost pinnules are developed into pinnulated branches, and the polyps are smaller (2–3 mm in transverse diameter vs. up to 5 mm).

The unpinnulated section of *A. venusta* is longer than its pinnulated section, a trait that is also present in the genus *Umbellapathes*. However, species of *Umbellapathes*, *a*lways have more than one order of pinnulated branches developing from the lowermost primary pinnules.

Etymology. From the Latin "*venusta*" meaning beautiful.

Distribution. Currently only known from the Hawaiian Islands and Gorda Ridge at depths ranging between 2,638–2,821 m (Fig. 8).

Umbellapathes Opresko, 2005

Diagnosis. Corallum monopodial and pinnulate, with long unpinnulated stalk; one or more orders of pinnulated branches developing from lowermost primary pinnules. Unpinnulated stalk usually longer than pinnulated section of stem. Pinnules on upper part of stem and on larger branches in two lateral or anterolateral rows, arranged alternately. Secondary pinnules present or absent. Spines conical and smooth, simple or rarely forked, and up to 0.1 mm tall. Polyps 3–4.5 mm in transverse diameter.

Type species. *Umbellapathes helioanthes* Opresko, 2005.

Remarks. Two species are currently assigned to the genus *Umbellapathes*; *H. helioanthes* Opresko, 2005, and the new species described below. Another species, *Bathypathes tenuis* Brook, 1889, might also belong to *Umbellapathes*; however, the type material consists of two specimens that are too small and incomplete to provide sufficient information to be certain of such an assignment.

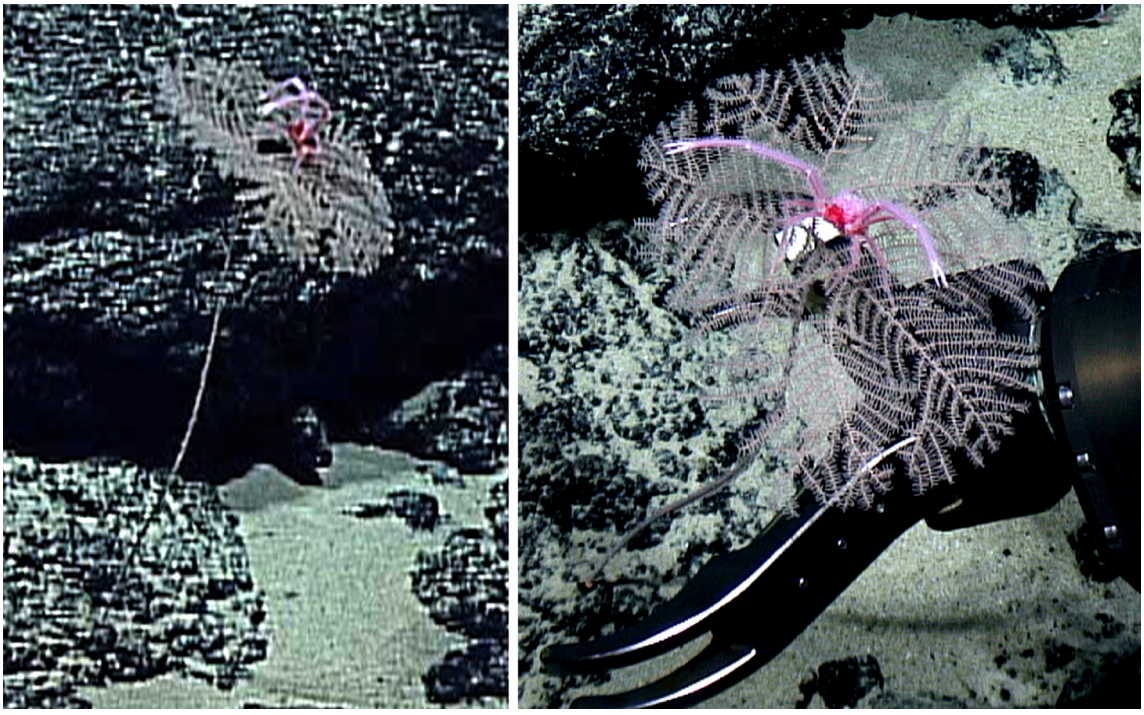

FIGURE 9. *Umbellapathes litocrada* **sp. nov.** holotype photographed *in situ* on Hutchinson Seamount at 1,529 m. Photos courtesy of NOAA Office of Ocean Exploration and Research.

Umbellapathes litocrada sp. nov.
(Fig. 9–12)

Material examined. ***Holotype*****:** USNM 1404092, Hutchinson Seamount, South of Johnston Atoll, 15.47°N, 169.07°W, R/V *Okeanos Explorer* EXP1504L4_D2_DIVE06_SPEC03BIO, 1,528.62 m, NOAA, 19 Sep. 2015. ***Paratype*****:** USNM 1468988, Musicians Seamounts, Wagner Seamount, 31.85°N, 162.9°W, R/V *Okeanos Explorer,* ROV *Deep Discoverer*, EX1708_D2_DIVE08_SPEC02BIO_A02, 2,352.47 m, NOAA, 14 Sep. 2017. ***Other material examined***: USNM 1467527, Hawaiian Islands, Tropic of Cancer Seamount, R/V *Okeanos Explorer,* ROV *Deep Discoverer*, 23.3085°N, 158.358°W, EX1708_D2_DIVE01_SPEC04GEO_A01, 1,773.49 m, NOAA, 7 Sep. 2017. **Underwater photo records.** EX1504L2_03_20150804T181251Z, Northwestern Hawaiian Islands, St. Rogatien Bank, 25.62617°N, 167.24109°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1504L2_D2_DIVE03, 1,984 m, NOAA, 4 Aug. 2015; EX1504L2_06_20150807T200232Z, Northwestern Hawaiian Islands, West Northhampton Seamount, 25.0817°N, 172.48898°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1504L2_D2_DIVE06, 1,993 m, NOAA, 7 Aug. 2015; EX1504L4_06_20150919T181659Z, Johnston Seamounts, Hutchinson Seamount, 15.46722°N, 169.07112°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1504L2_D2_DIVE06, 1,607 m, NOAA, 19 Sep. 2015; EX1504L4_06_20150919T181659Z, Johnston Seamounts, Hutchinson Seamount, 15.46831°N, 169.07161°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1504L2_D2_DIVE06, 1,527 m, NOAA, 19 Sep. 2015; EX1504L4_06_20150919T181659Z, Johnston Seamounts, Hutchinson Seamount, 15.46471°N, 169.07863°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1504L2_D2_DIVE06, 1,504 m, NOAA, 20 Sep. 2015; EX1504L4_07_20150920T182043Z, Johnston Seamounts, unnamed seamount, 15.20901°N, 168.06245°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1504L2_D2_DIVE07, 1,940 m, NOAA, 20 Sep. 2015; EX1706_14_20170728T195500Z, Johnston Seamounts, Keli Ridge Seamount (unofficial), 15.09462°N, 167.95984°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1706_D2_DIVE14, 2,373 m, NOAA, 29 Jul. 2017; EX1706_15_20170729T193000Z, Johnston Seamounts, New Seamount, 15.16062°N, 167.03595°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1706_D2_DIVE15, 2025 m, NOAA, 29 Jul. 2017; EX1708_08_20170914T194500Z, Musicians Seamounts, Wagner Seamount, 31.85186°N, 162.8951°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1708_D2_DIVE08, 2,413 m, NOAA, 14 Sep. 2017; EX1708_17_20170923T193000Z,

Musicians Seamounts, Rapano Ridge, 26.59703°N, 160.6707°W, R/V *Okeanos Explorer*, ROV *Deep Discoverer*, EX1708_D2_DIVE17, 1,973 m, NOAA, 23 Sep. 2017; NA101_H1717_20180921T060359Z, Northwestern Hawaiian Islands, Naifeh Seamount, 26.86292°N, 168.08038°W, E/V *Nautilus*, ROV *Hercules*, NA101_DIVEH1717, 1,839 m, 21 Sep. 2018; NA101_H1717_20180921T060359Z, Northwestern Hawaiian Islands, Naifeh Seamount, 26.86331°N, 168.08089°W, E/V *Nautilus*, ROV *Hercules*, NA101_DIVEH1717, 1,807 m, 21 Sep. 2018; NA101_H1723_20180926T120412Z, Northwestern Hawaiian Islands, Unnamed Seamount 3, 25.55511°N, 164.20308°W, E/V *Nautilus*, ROV *Hercules*, NA101_DIVEH1723, 1,968 m, 26 Sep. 2018; NA101_H1723_20180926T120412Z, Northwestern Hawaiian Islands, Unnamed Seamount 3, 25.55611°N, 164.20497°W, E/V *Nautilus*, ROV *Hercules*, NA101_DIVEH1723, 1,924 m, 26 Sep. 2018.

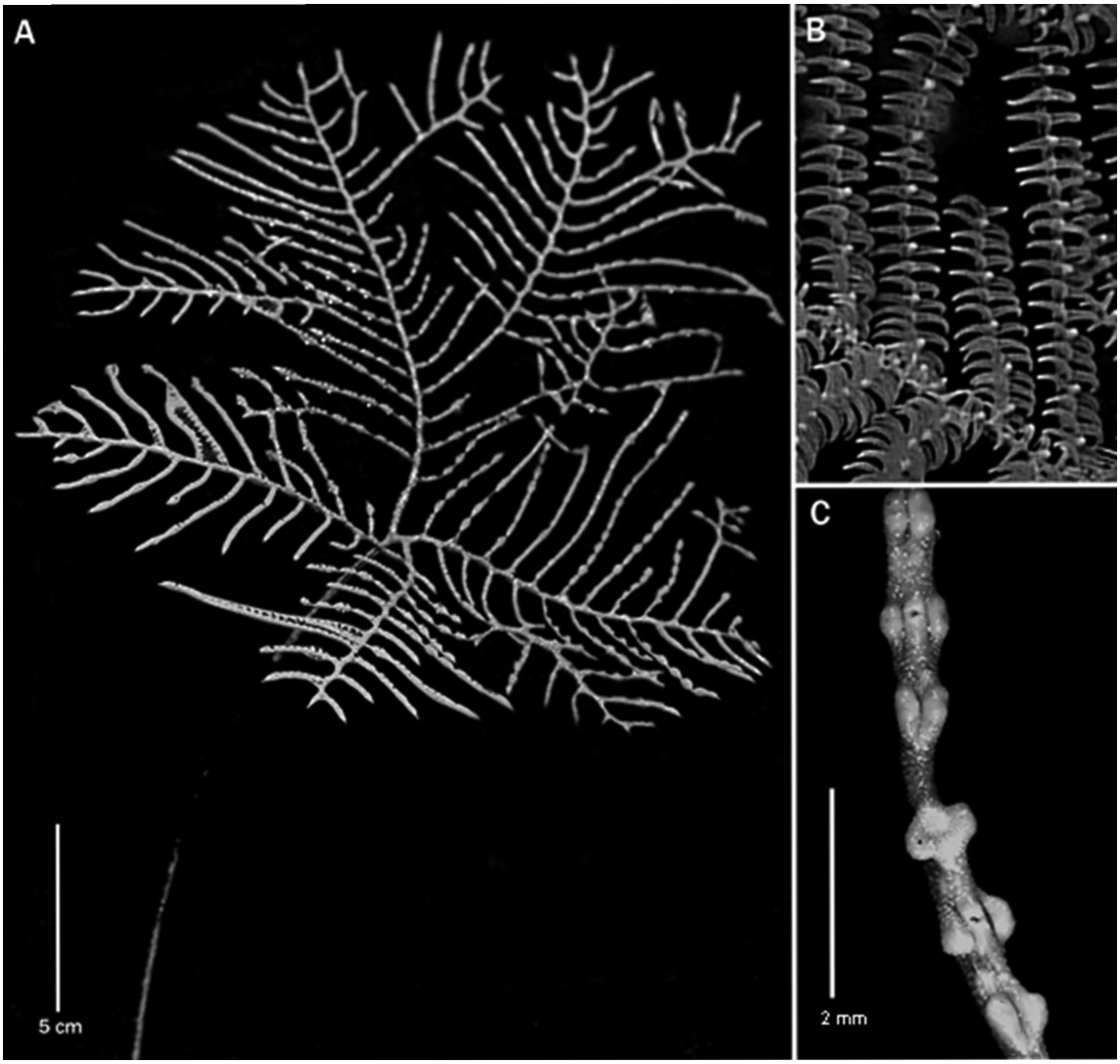

FIGURE 10. *Umbellapathes litocrada* **sp. nov**., holotype, USNM 1404092. **A.** colony; **B.** expanded polyps; **C.** contracted polyps on the preserved colony.

Type locality. Hutchinson Seamount, South of Johnston Atoll, 1,528 m.

Diagnosis. Corallum monopodial, branched and pinnulate. Stem consisting of long lower unpinnulated section (stalk) and upper distal section with simple bilateral primary pinnules some of which develop into branches showing same pinnulation pattern as stem, and which together form a discoidally shaped crown. Secondary pinnules not present on primary pinnules of stem or branches. Branches developing mainly from basal-most pinnules on stem and a varying number of more distal ones. Corallum has up to three orders of branches. Pinnules on stem generally arranged alternately in two anterolateral to lateral rows. Pinnules not uniform in length; longest ones often in middle or on distal part of branch. Pinnular density 9–11 per 3 cm. Spines on pinnules short, triangular to semispherical in shape. Polypar spines up to 0.08 mm tall from midpoint of base to apex. Spines arranged in very irregular axial

rows, five or six rows visible in lateral view, with about 4 spines per mm in each row. Polyps 3–4.5 mm in transverse diameter; with 2 to 3 polyps per cm.

Description of holotype. The holotype (USNM 1404092, Fig. 9 and 10A) was collected with the basal holdfast intact. The colony consists of a stem about 62 cm tall, including a 52 cm long unpinnulated lower portion, and a 10 cm long branched and pinnulated upper section. The diameter of the stem near its basal end is 2.5 by 3 mm. The pinnulated section of the stem consists of two rows of lateral and alternating pinnules, the two basal-most ones and three smaller more distal ones are developed into pinnulated branches (Fig 10A). *In situ* photos (Fig. 9) indicate that the unpinnulated part of the stem was relatively straight and upright; however, at the point where it becomes pinnulated it is sharply curved to one side, and the two lowermost stem pinnules that are developed into pinnulated branches are also curved or bent, and therefore lie in almost the same plane as the stem. These and the other pinnulated branches thus form a somewhat flattened discoidal plane. When viewed from the polyp side of the corallum, this discoidal crown has an irregularly circular shape roughly 21 by 19 cm in dimension. *In situ* photos indicate that the crown was tilted slightly to one side. The lowermost pinnulated branch is about 15 cm long and 1.3 mm in basal diameter.

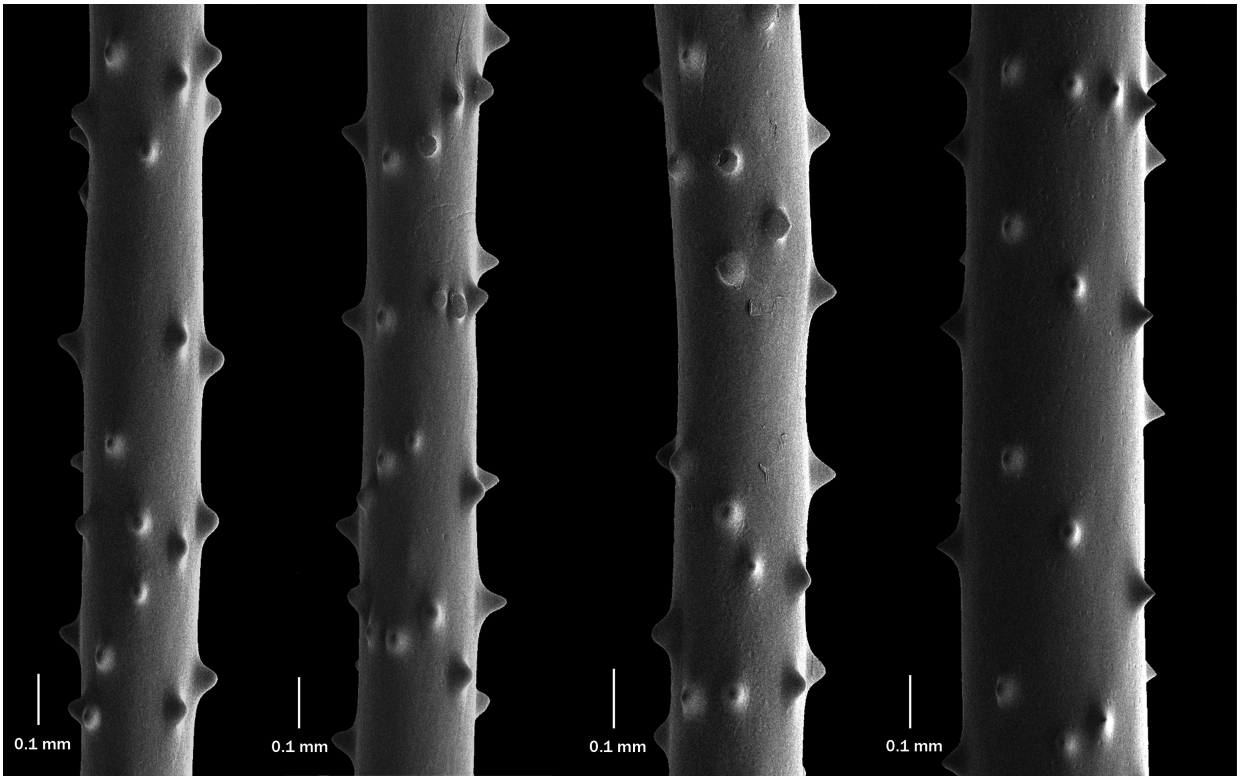

FIGURE 11. *Umbellapathes litocrada* **sp. nov**. holotype (USNM 1404092); sections of pinnules.

The pinnules are not uniform in length, nor do they decrease regularly in length from the base to the distal end. Instead, the longest pinnules are often found in middle of a branch and are up to 7.5 cm long and 0.5 mm in basal diameter. On a branch 7.5 cm long, the longest pinnule is about 4.5 cm. There are about 13 pairs of pinnules on the stem, most of these occur in alternating pairs, although this pattern is not strictly maintained at the distal end of the stem. On the branches the pinnules start 1.5–4.0 cm from the base. Pinnules are spaced mostly 7 mm apart on one side of the axis, resulting in a pinnular density of 8–10 (total) per 3 cm. The interior angle formed by the two rows of lateral pinnules is very wide, such that the pinnules lie in much the same plane. The distal angle that the pinnules form with the stem or branches near their base is 70–90°, but distally this angle becomes less.

The spines on the pinnules are very small, and triangular to somewhat semispherical (Fig. 11). Polypar spines can be up to twice as tall as the abpolypar spines (as measured from the midpoint of base to apex); however, in most places abpolypar and polypar spines are nearly equal in size. On sections of pinnules 0.23–0.31 mm in diameter, the polypar spines are 0.046 mm to 0.051 mm tall, whereas the abpolypar ones are mostly 0.025–0.03 mm tall, but can be up to 0.05 mm. The spines on the branches and stem are similar in size to those on the pinnules and generally not more than 0.05 mm tall. The abpolypar spines on the pinnules often appear more flattened, button-shaped, and

in some cases more flared out along the base. The arrangement of the spines in longitudinal rows and the spacing of the spines within each row is very irregular; there are 4–6 rows of spines visible in lateral view of the axis, and where the spacing of the spines is uniform, there are four spines per millimeter in each row.

Polyps (Fig. 10B–C) occur in a single series, mostly facing out of the discoidal plane formed by the branches and pinnules. They are transversely elongated; 2.0–4.5 mm in diameter from the proximal edge of the proximal tentacles to the distal edge of the distal tentacles. The polyp density is 2 to 2.5 per cm. *In situ* photos (Fig. 9) indicate that, when expanded, the tentacles are subequal in length and about as long as the transverse diameter of the polyp. The tips of the tentacles are curved in an abpolypar direction and the oral cone is quite distinct. After preservation the tentacles and oral cone can be extremely contracted (Fig. 10C).

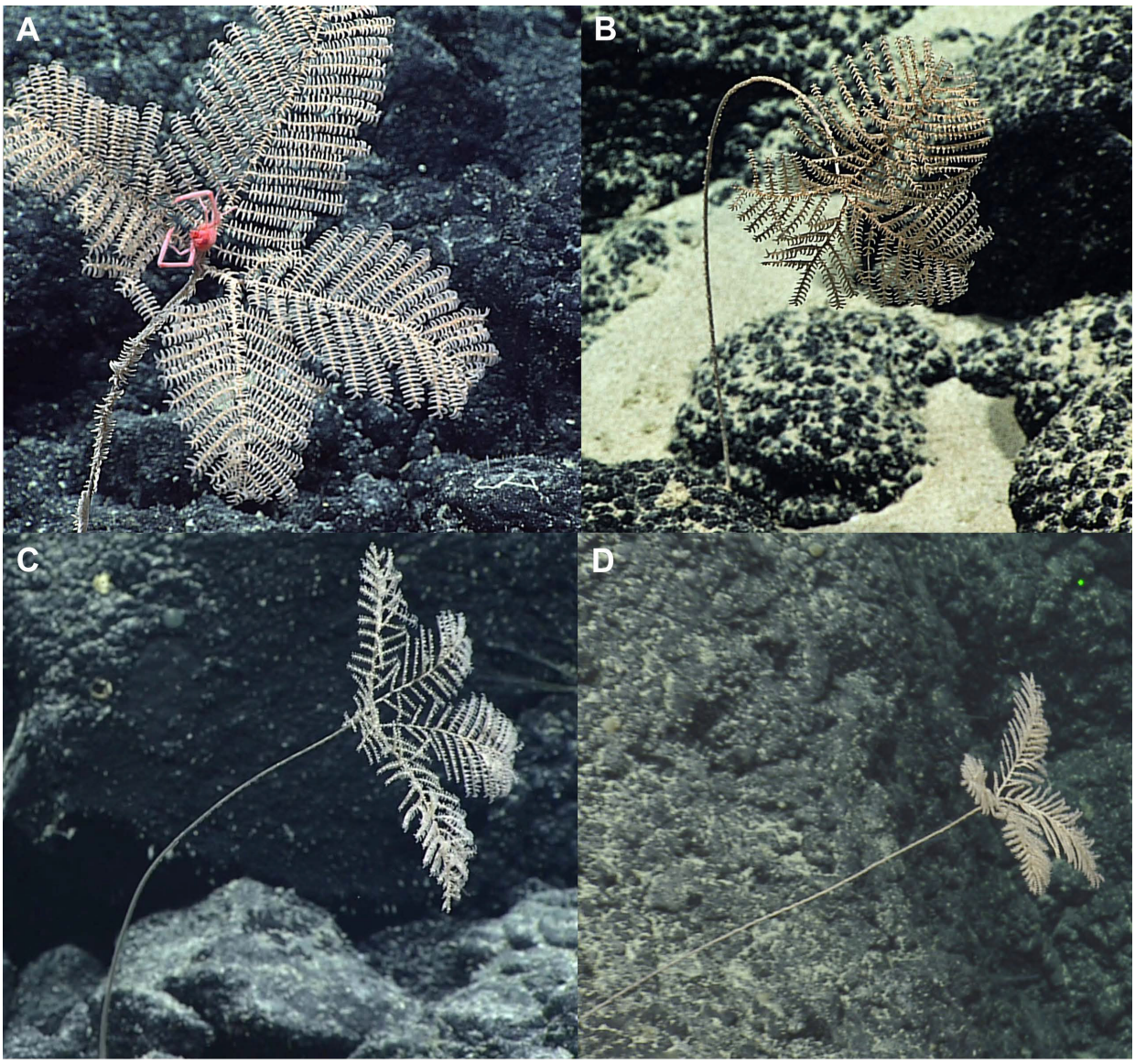

FIGURE 12. *In situ* photographs of colonies presumed to be *Umbellapathes litocrada* **sp. nov**. (specimens were not collected): **A**. colony on Hutchinson seamount at 1,504 m; **B**. colony on unnamed seamount north of Johnston Atoll at 1,940 m; **C**. colony on Rapano Ridge at 1,973 m. **D**. colony on Naifeh Seamount at 1839. Photos courtesy of NOAA Office of Ocean Exploration and Research (A–B) and Ocean Exploration Trust (C–D).

Description of paratype. The paratype (USNM 1468988) is an almost complete specimen, but broken in two pieces. It is a smaller colony than the holotype. The stem is about 23 cm long, but broken off at the tip. The unpinnulated stalk is 16.5 cm and the pinnulated section 6.5 cm long. Only the two lowermost stem pinnules are developed into branches and one of these has a small sub-branch. The pinnules are of variable lengths up to 4.2 cm, and there are no subpinnules. The pinnules are mostly 5–6 mm apart within each lateral row, and the pinnular density is about

11 per 3 cm. The spines are larger than those in the holotype; the polypar spines are 0.06 to 0.08 mm tall, and the abpolypar spines 0.03–0.04 mm. Three rows of spines are visible in lateral view and there are 3 spines per mm in the rows. The polyps are 3–4 mm in transverse diameter, with about 3 polyps per cm.

Remarks. A large number of colonies superficially resembling *U. litocrada* **sp. nov.** have been photographed in and around the Hawaiian Islands (see list of underwater photo records and Fig. 12). Some of these colonies appear to differ from the holotype in having fewer orders of branches, and pinnules that are more uniform in length. Further study is needed to determine whether any of these morphotypes represent a species distinct from *U. litocrada*.

Comparisons. This species differs from *Umbellapathes helioanthes* Opresko, 2005, in not having secondary pinnules. It also has smaller spines (polypar spines up to 0.05–0.08 mm vs. up to 0.1 mm) and slightly larger polyps (up to 4.5 mm in transverse diameter vs. up to 3.6 mm), although a larger suite of specimens is needed to clearly define these parameter in both species.

Etymology. From the Greek "*litos*" meaning "simple" and "*crada*" meaning "branch", referring to the fact that the pinnules are not subpinnulate, as in *U. helioanthes*.

Distribution. Currently only known from the Hawaiian Islands, the Musician Seamounts and seamounts near Johnston Atoll at depths ranging between 1,504–2,413 m (Fig. 13).

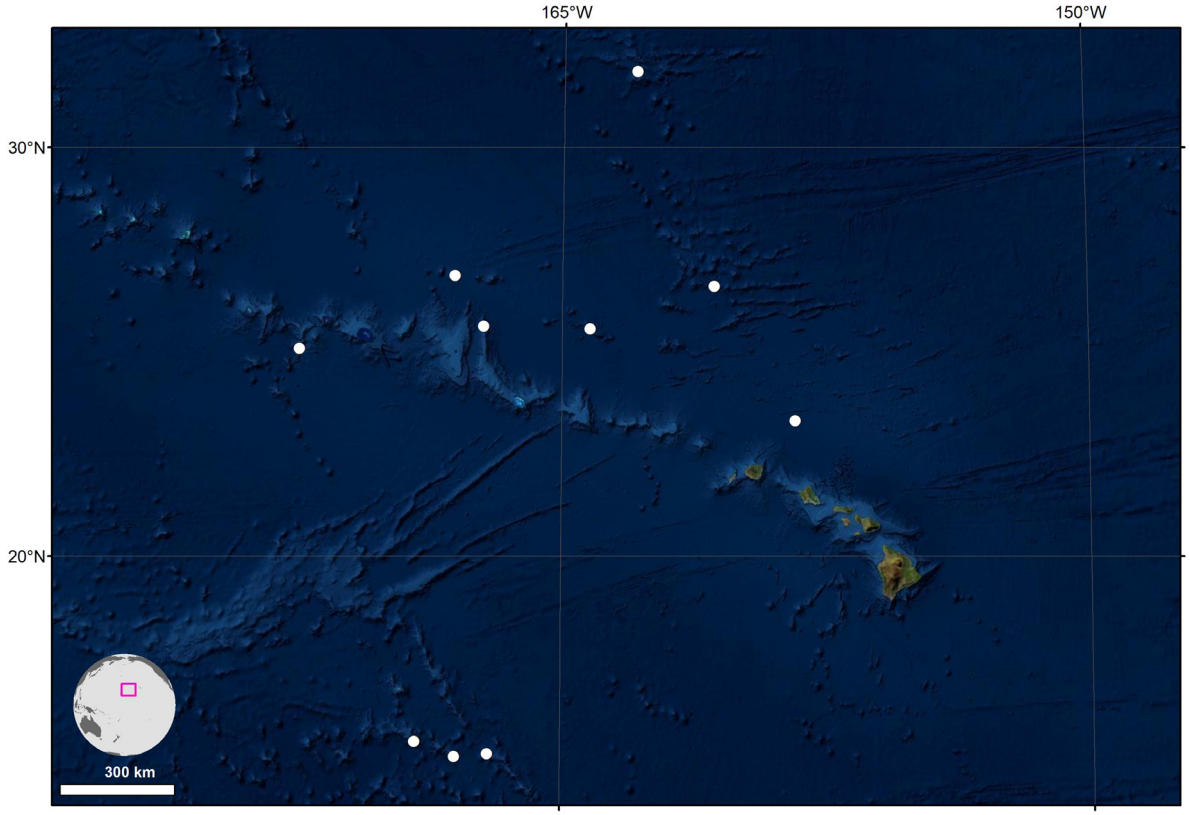

FIGURE 13. Map showing the geographical distribution of colonies known or presumed to be *Umbellapahtes liticrada* **sp. nov**. To date, this species is only known from the Hawaiian Islands, the Musician Seamounts and seamounts near Johnston Atoll at depths ranging between 1,504 and 2,413 m.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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