PROCEEDINGS OF THE BIOLOGICAL SOCIETY OF WASHINGTON
111(3):535–550. 1998.

Pentamera rigida and *P. pediparva,* two new species of sea cucumber from the west coast of North America (Echinodermata: Holothuroidea)

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Abstract.—Two new species of the genus *Pentamera* from the west coast of North America are described, and all known species from the west coast of North and South America are reviewed. *Pentamera rigida* is a slender, stiff, U-shaped species with five rows of podia. It occurs in sand-gravel substrata from 18 to 421 m between British Columbia and California. The table ossicles of the skin have an angular disc with a broad, low, convoluted spire. *Pentamera pediparva* has a soft, curved body with five rows of fine podia. It is known from central British Columbia to northern California from 8 to 120 m in mud-gravel or sand-gravel. The table ossicles are small and oval with small, two pillared spires. The taxonomic characters of fourteen species of *Pentamera* are summarized.

Twelve species of *Pentamera* have been described from the west coast of North and South America (Stimpson 1851, 1864; Ludwig 1886a, 1886b; Clark 1924; Deichmann 1938a, 1938b). Panning (1949) placed the genus *Pentamera* in Thyoninae, a new subfamily of Cucumariidae. Based on the presence of posterior processes composed of a mosaic of small pieces, Pawson & Fell (1965) transferred Thyoninae Panning to the family Phyllophoridae. No new species of *Pentamera* have been added to the west coast fauna since Deichmann (1938a, 1938b), with the exception of those transferred to the genus by Panning (1949). The purpose of this paper is to describe two new species of *Pentamera* from the Pacific coast of North America and present a summary table of morphological characters for species from the west coast of North and South America.

Materials and Methods

Ossicle slides were prepared by the method described in Lambert (1985). At least 30 ossicles per specimen were measured on transects across each slide. Length and width of disc, and width of central spire were recorded for tables. Length, height of curve, and height of spire were recorded for supporting tables (Fig. 7). Only ossicles that were totally within the field of vision, lying flat, and not broken, were measured. Via a drawing tube attached to a Wild M20 microscope, the image of each ossicle was visualised on a digitising tablet (Summasketch II, Summagraphics Corporation). Measurements were made with the cursor and automatically saved to a file using SigmaScan software (Jandel Scientific). That file was then transferred to a statistical package (Systat, Systat, Inc.) for analysis. External measurements of the whole specimen were made with an ocular micrometer, calipers, or in the case of strongly curved specimens, a string was used to trace the distance from the base of the tentacles to the anus, around the outer side of the curve, usually the ventral side.

Institutions mentioned in this paper are abbreviated as follows: Allan Hancock

Fig. 1. Preserved specimen of *Pentamera rigida* dredged from type locality, 115 m, off Nootka Sound, B.C., length 7 cm, RBCM 984-199-3.

Foundation (AHF) now housed at LACM; California Academy of Sciences, San Francisco (CASIZ); Fisheries Research Board of Canada (FRB) now known as Department of Fisheries and Oceans, (DFO); Canadian Museum of Nature, Ottawa (CMNI or NMC); Natural History Museum of Los Angeles County (LACM); Royal British Columbia Museum, Victoria (RBCM); National Museum of Natural History (USNM), Washington, D.C.

Results

Order Dendrochirotida Grube

Family Phyllophoridae Oestergren

Diagnosis.—Dendrochirotid holothurians without a test. Tentacles 10–25 (usually 10 or 20), well branched. Pedicels either restricted to the ambulacra or scattered, but fewer and usually papilliform dorsally. Calcareous ring complex, often tubular, with long or short posterior processes, both ring and processes always composed of a mosaic of small pieces. Ossicles usually plates or buttons, rods, tables or derivatives of tables (after Thandar 1990).

Remarks.—Thandar modified the diagnosis of Pawson (1982) by adding that the podia may be in rows or scattered and that the ossicles may be tables or derivatives of tables in the form of plates, rods or buttons.

Subfamily Thyoninae Panning, 1949

Diagnosis.—Small to medium-sized phyllophorids, rarely more than 100 mm long. Body soft. Pedicels numerous, usually scattered all round, but often most crowded ventrally. Tentacles 10, ventral two always reduced. Calcareous ring tubular with long paired posterior processes on radial plates. Ossicles of body wall usually in the form of tables or plates (buttons), or absent (after Thandar 1990).

Genus *Pentamera* Ayres, 1852

Diagnosis.—Small to medium sized forms. Ten tentacles with two smaller ventral tentacles. Nonretractile podia in five series, not scattered. Radials of the calcareous ring with long forked tails. In the skin two pillared tables or derivatives of these with the spire reduced or absent. Podia with large endplates and curved supporting tables with spires varying from low to high. Tentacles usually with rods, plates or both. (After Deichmann 1941)

Type species: *Pentamera pulcherrima* Ayres

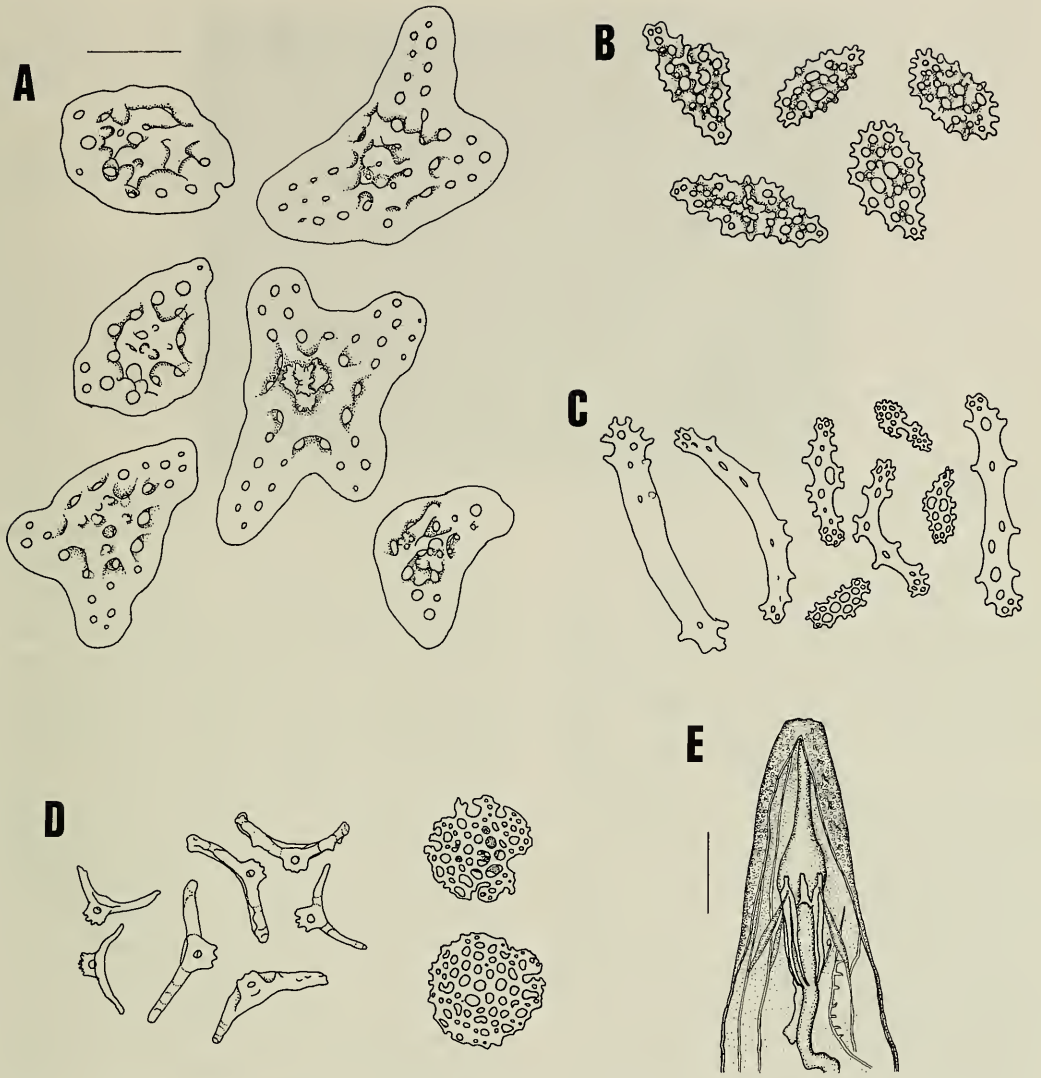

Fig. 2. Ossicles and calcareous ring of *Pentamera rigida.* (A) Tables of the dorsal skin. (B) Plates from the introvert. (C) Tentacle ossicles. (D) Supporting tables and end plates of podia. (E) Calcareous ring and retractor muscles; scale bar 5 mm. All from holotype (RBCM 997-123-1) except for the podial end plates (RBCM 983-1658-30) and the calcareous ring of paratype (RBCM 984-199-3). Top scale bar 100 μm applies to all ossicles.

Pentamera rigida, new species
Figs. 1–3

Pentamera lissoplaca.—Bergen 1996 (partim):239, fig. 9.23B. Specimens described as having "large tables" may be *P. rigida.*

Pentamera sp. A Lambert, 1997:101, figs. 52–53, photo 24.

Diagnosis.—Body U-shaped; skin usually stiff and white. Podia in five series, longer and more abundant in midventral region than distally. Ten small dendritic tentacles including smaller ventral pair; often speckled with brown. Calcareous ring long and tubular with forked tails on the radials; made up of a mosaic of smaller pieces; ratio of radial to interradial length approximately 4:1. Skin ossicles circular, triangular or star-shaped tables (100–300 μm) with a broad

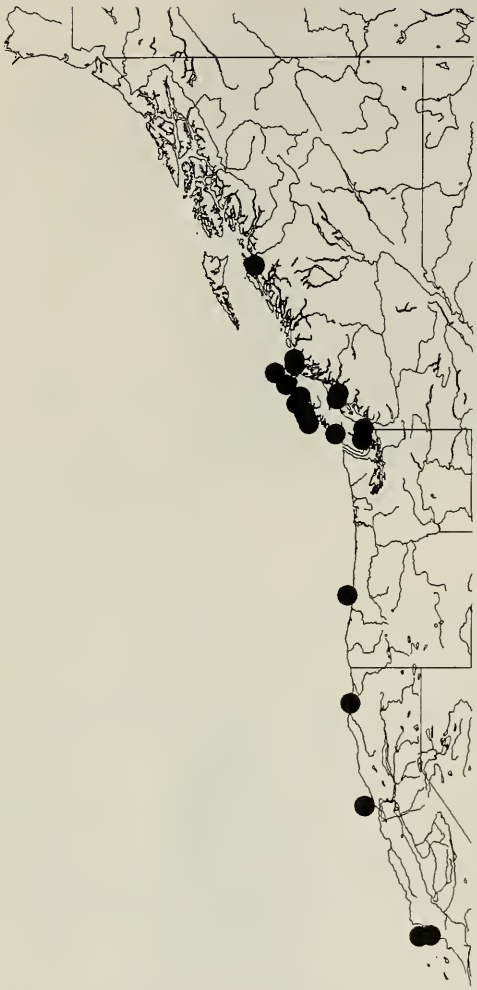

Fig. 3. Collection sites for *Pentamera rigida.*

convoluted spire covering about one-half width of disk; small, curved supporting tables (100 μm) with low spire. Introvert with oval knobbed perforated plates, some with remnant of a spire. Tentacle ossicles in two forms, finer curved oval plates and large robust rods with a few holes.

Material examined.—Eighty-one specimens from 15 localities in British Columbia, one locality in Oregon, four in California, and one from an unknown locality on the west coast of U.S.A. Number of specimens in parentheses after the catalogue number; depth in metres (m).

Holotype.—RBCM 997-123-1 (1), collected by F. Bernard and T. C. Lambert, FRB station 63-91, 8 Sep 1964, length 6.8 cm (measured along the outside of the curved body), female.

Type locality.—British Columbia, Vancouver Island, Nootka Sound, 49°32′N, 127°03′W, 115 m, sandy mud.

Paratypes.—RBCM 984-248-1 (1), collected by D. B. Quayle, FRB Haul No. 1, 7 Jul 1962, British Columbia, Kitkatla Inlet, Porcher Island, 53°51′N, 130°W, 37 m, sand and gravel, specimen 10.8 cm long. RBCM 984-200-1 (7), FRB station 63-204, 10 Sep 1964, British Columbia, Vancouver Island, Quatsino Sound, 50°19.6′N, 128°06.5′W, 119 m, sand, specimen lengths from 2.8 to 5.1 cm. RBCM 984-199-3 (12), collected by F. Bernard and T. C. Lambert, FRB station 63-91, 8 Sep 1964, British Columbia, Vancouver Island, Nootka Sound, 49°32′N, 127°03′W, 115 m, sandy mud, from same lot as holotype, specimen lengths from 3 to 8 cm (mean 5.5). USNM E16915 (32), collected by A. Carey, Oregon State University, Cruise C 700810, BMT 239, 17 Aug 1970, Oregon, off Hecata Head Light, 44°08.8′N, 124°24′W, 100 m, specimen lengths from 1.5 to 5.7 cm. CASIZ 50227 (1), Sta. 20, 28 Sep 1949, California, off Point Reyes, south of Cordell Bank, 37°55.75′N, 123°19.25′W, 110–113 m, specimen 6 cm long. AHF 440.61 (1), Velero 6131-59, California, Ventura Co., Oxnard, Port Hueneme Lighthouse, 34°8.1′N, 119°21.5′W, 165 m.

Other collections.—British Columbia: RBCM 989-564-4 (1), collected by D. B. Quayle, FRB station 70-24, Jul 1970, Bramham Island near Pine Island, 51°05′N, 27°39′W, 82 m. RBCM 984-213-1 (1), collected by D. B. Quayle, FRB station 71-14, Apr 1971, Gordon Channel, near Nigei Island, 50°53.1′N, 127°36.5′W, 421 m. RBCM 990-939-11 (2), FRB station 67-66, Aug 1967, Vancouver Island, Cape Scott, 50°39.8′N, 128°47.2′W, 200 m, gravel. RBCM 984-249-1 (1), collected by J. Fleury, FRB Drag #7 + #8, 27 Jun 1962, Baker Pass, near Cortes Island, 50°04.0′N,

Fig. 4. Holotype of *Pentamera pediparva* collected by scuba from 7.5 m in Quatsino Sound, B.C., length 8 cm, RBCM 997-124-1.

124°59.0′W, 117 m, gravel. RBCM 980-344-1 (1), collected by P. Lambert, station L80-61, 6 Jul 1980, Vancouver Island, Kyuquot Channel, Sandy Bay, Rugged Point, 49°58.2′N, 127°14.6′W, 9 m, clean sand and algae. RBCM 55-56 (1), collected by D. Ellis, 16 Aug 1965, Strait of Georgia, 49°54.05′N, 125°04′W, 178 m, sand. RBCM 983-1658-30 (3), collected by Gordon Green, 23 Nov 1983, Vancouver Island, off Kyuquot Sound, 49°45.7′N, 127°30.1′W, 150 m, sand. RBCM 974-570-6 (3), FRB station 2231-33, 17 Jul 1934, Vancouver Island, Estevan Point, 49°22.3′N, 126°55′W, 137 m, sand. RBCM 986-93-27 (3), collected by P. Lambert, on Endeavour, Station L86-9, 19 Mar 1986, Vancouver Island, Estevan Point, 49°11′N, 126°45.2′W, 120 m, sand. RBCM 983-1397-1 (1), collected by M. Byrne, 11 Feb 1983, east of Galiano Island, 49°01.48′N, 123°29.45′W, 50–230 m. RBCM 991-10-1 (2), collected by S. Carson, 22 Feb 1990, Barkley Sound, Trevor Channel, 48°52′N, 125°08′W, 54 m, mud. RBCM 988-758-10 (1), collected by P. Lambert, G. Green, D. Bright, Station L88-27, 22 Jun 1988, Satellite Channel, Boatswain Bank, 48°42.2′N, 123°32.1′W, 18 m.

California: CASIZ uncatalogued (1), 9 Aug 1940, 2.5 mi. off Mad River, Eureka, 37 m. USNM E2371 (4), Albatross St. 2902, California, Channel Islands, Santa Cruz Channel, Santa Rosa Island, 34°6.0′N, 120°2.0′W, 97 m. USNM 30563 (1), Albatross St. unknown, West Coast United States, depth unknown.

Description.—Total length 1.5–10.5 cm (measured along the outer curve of the body); mean length (cm ± 1 *SD*) 4.6 ± 1.6 cm (n = 72). Holotype 6.8 cm long. Body typically bent in a tight U-shape with long slender anterior and posterior ends (Fig. 1). Skin stiff with ossicles. Podia slender and probably non-retractile because of their heavy complement of ossicles. Podia form five bands, each consisting of two rows, crowed together in the middle of the body on ventral side but sparse distally and on dorsal side. Specimens typically white in life and in alcohol. Ten tentacles arranged in five pairs with a smaller ventral pair.

Madreporite in dorsal mesentery about two-thirds of distance from anterior end of calcareous ring. Semi-circular madreporite with a long narrow stone canal, connects to the ring canal near posterior tip of calcareous ring. One polian vesicle usually on ventral side of ring.

Two respiratory trees emerge from cloaca on left and right sides; each one splits into a dorsal and ventral branch; dorsal

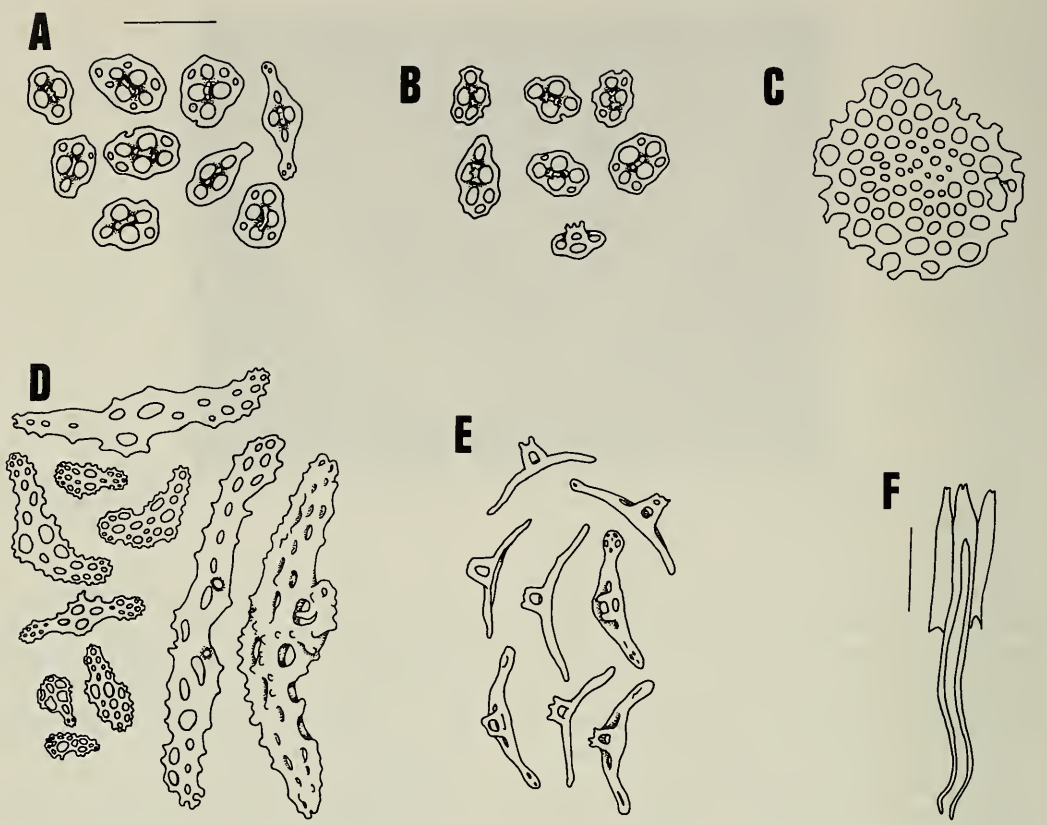

Fig. 5. Ossicles and calcareous ring of *Pentamera pediparva*. (A) Tables of the dorsal skin. (B) Plates from the introvert. (C) End plate of podia (D) Tentacle ossicles. (E) Supporting tables of podia (F) Calcareous ring; scale bar, 5 mm. All from holotype (RBCM 997-124-1). Top scale bar (100 μm) applies to all ossicles.

branch runs full length of body, ventral branch only to mid body. Respiratory trees usually brown, with a main trunk and simple, short side branches. Cloaca occupies most of narrow "tail."

Gonad has two tufts of unbranched tubules, one tuft on each side of dorsal mesentery where it joins the dorsal body wall.

Thin retractor muscles attach to body wall at a point level with posterior end of calcareous ring. Five thin longitudinal muscles. Radial plates of calcareous ring with long posterior prolongations; interradials with no tails, shaped like an elongate triangle (Fig. 2E). Transverse thickenings indicate joints between mosaic of pieces that make up the tails. Ratio of interradial to radial length about 1:4.

Tables of mid skin circular to roughly triangular or star-shaped, with a mean diameter (μm ± 1 *SD*) of 194 ± 45 (n = 141) with a complex central spire (width 102 ± 32, n = 140) that covers about one-half the surface area of table (Fig. 2A). Supporting tables of podia small (length 110 ± 15, n = 90) and tightly curved with a low spire (height 16 ± 5, n = 90) with three or four teeth. Ratio of length (L) to total height (TH) of supporting tables 1.9 ± 0.3, n = 90 (see Fig. 7 for explanation of dimensions). Podial end plates small (diameter 115–135 μm, n = 5) (Fig. 2D). Ossicles in tail region not significantly different from mid skin. In juveniles (<2 cm) tables tend to be more star-shaped and spires not as robust. Introvert has oval perforated plates with two larger central holes and knobs on the surface of plate (Fig. 2B). In tentacles,

Fig. 6. Collection sites for *Pentamera pediparva.*

ossicles range in size from large flat rods (length 230 μm) with a few knobs and holes to smaller curved perforated plates with scalloped edges (Fig. 2C).

Etymology.—The species name, *rigida,* is based on the Latin word *rigidus,* meaning stiff or inflexible and refers to the typically stiff ossicle-filled body of this species.

Distribution and habitat.—*Pentamera rigida* is known from Porcher Island near Prince Rupert, British Columbia (53°51′N, 130°W) south to Santa Cruz Channel, Santa Rosa Island, Channel Islands, California (34°6.0′N, 120°2.0′W) (Fig. 3). It ranges in depth from 18 to 421 m on the continental shelf. The majority of collections are from less than 200 m. The one specimen from 421 m is from a deep trench between Vancouver Island and the mainland. So far none have been collected on the continental slope or deeper. Usually occurs in sand or gravel substrata.

Pentamera pediparva, new species
Figs. 4–6

Pentamera sp. B Lambert, 1997:104, figs. 54, 55, photo 25.

Diagnosis.—Body curved; up to 7 cm long; skin usually soft; colour white to

Table 1.—*Pentamera* of the west coast of North and South America (ossicle measurements in micrometers ± 1 *SD*; L = length, H = height of spire, TH = total height, *n* = 15 unless otherwise indicated).

Pentamera species	Distribution	Body shape	Podia	Colour
P. beebei Deichmann 1938	Costa Rica	Small form	Typical	White
P. calcigera (Stimpson 1851) as *Pentacta*	Arctic; eastern Russia; Alaska, Bering Sea, Chukchi; 7–25 fm; 33–80 m	Curved with tapered posterior; 50–60 mm	Single pairs in 5 rows; non-retractible	White or yellowish
P. charlottae Deichmann 1938	Monterey Bay to southern California (Bergen); intertidal to 642 m	Few cm long; body straight. Up to 6.5 cm, cylindrical (Bergen)	5 double rows; cylindrical, non-retractile	White or coffee (preserved)
P. chierchia (Ludwig 1886) as *Cucumaria*	Panamic region; Mexico and Costa Rica; shallow water	Small 3–6 cm; soft-skinned	Numerous cylindrical feet in 5 bands	Dark brown almost black.
P. chiloensis (Ludwig 1886) as *Cucumaria*	Cape Horn to Lower California; 8–60 fm (Deichmann)	Curved, about 5 cm; skin thin and wrinkled	"Resembles genus type"; conspicuous cylindrical podia in 5 well-defined bands	White
P. lissoplaca (Clark 1924) as *Cucumaria*	Southeast Alaska south to Baja California; 9–82 m	Curved, tapering to posterior	5 crowded double series; non-retractile stiff with ossicles	Yellowish white in preservative
P. montereyensis Deichmann 1938	Pacific Grove, Long Beach & Santa Rosa I. California, intertidal & shallow on rocks	Moderate-size form, up to 5 cm; cylindrical	5 bands, cylindrical, non-retractile	White, tentacles and introvert with few pigment spots

Table 1.—Extended.

Calcareous ring	Mid-dorsal Ossicles	Introvert	Tentacles
Not stated in original description	Minute tables (L = 37, n = 2) with four+ holes, 2-pillared spire with tuft of spines; curved support tables (L = 65 ± 9, n = 6) with tall spire, ratio of L to TH 0.8 ± 0.3; large endplate. Data from illustrations.	Unknown	As for genus
Radial with long posterior processes; shorter inter-radial	Mostly oval plates (L = 162 ± 35); fewer oval or squarish tables with central spire. Curved supporting tables (L = 163 ± 20) with moderate spire (H = 36 ± 6), ratio of L to TH = 1.8 ± 0.3 Well developed end plates with indented perimeter (136–177, n = 7).	Oval perforated plates with meshwork at center (this study)	Ten; 8:2 small
Radials with long posterior processes; interradial ½ length, no tails	Small oval tables (L = 91 ± 9) with 2-pillared spire. Curved supporting tables similar to tables but with a taller spire (H = 59 ± 9), having 2 or 3 crossbeams and topped with a few teeth. Large end-plates (130–225, n = 7).	Tables with oblong disk, dentate margin and low spire	Ten (8:2); with rods, plates, and tables
Long posterior processes	Ossicles vary in number but not crowded; tables (L = 70, n = 3) with 4 central holes and dentate margin, low 2 pillared spire often lacking; few spectacle rods, trace of spire; podia with large end-plate.	No specimen examined; introvert unknown	Ten (8:2); curved perforated plates and rods
Not stated in original description	Tables with oval to squarish disk (L = 69 ± 13, n = 6) with 4 or 8 holes; 2 pillared spire, and 1 or 2 crossbeams short teeth on top; podia with large end-plate & curved supporting tables (L = 90 ± 105, n = 2) with low spire few flat teeth; ratio of L to TH = 1.5; data derived from illustrations of ossicles.	Rosettes	Tentacles missing in type, Deichmann—typical for genus; with delicate rods
Ring rather high; interradials about 2 mm high and half as wide concave behind, radials with posterior processes. Interradial to radial 1:3	Ossicles in two layers; scattered delicate tables (diameter 30–50) with fine spire; inner layer smooth, crowded, diamond-shaped plates (L = 120 ± 15); curved supporting tables (L = 103 ± 10) with moderate spire (H = 36 ± 6), ratio of L to TH = 1.9 ± 0.3; podia end plates 90–110, n = 4.	Oval perforated plates (100-200) with 2 larger central and numerous smaller holes, many knobs on surface	Ten (8:2); ossicles of two classes: large (~300) robust perforated rods and delicate (~100) oval perforated plates with 2 large central holes, wavy edge
?	Small oval buttons (diameter 25–55 μm) with 2 central and up to 8 marginal knobs; supporting tables with marginal knobs, reduced spire; well developed end-plates (235–275, n = 4), perforated rods.	Round to oblong perforated plates with 2 larger central holes and 6–20 other holes; 2 central knobs	Ten (8:2)

Table 1.—Continued.

Pentamera species	Distribution	Body shape	Podia	Colour
P. populifera (Stimpson 1864) as *Pentacta*	Kodiak I. to southern California perhaps Baja; to 60 fm	Thick fusiform up to 6 cm, skin thin and flexible; curved with tapering posterior or nipple-like	5 bands small numerous podia full length of body	Creamy white
P. pseudocalcigera Deichmann 1938	Southeast Alaska to San Benitos Island, Baja California, 7–250 fm	Medium sized, U-shaped, tapering to blunt ends, rather stiff	In 5 raised bands, podia conical in shape, non-retractile	Podia usually lighter than the pinkish inter ambulacrum
P. pseudopopulifera Deichmann 1938	Southern California; shallow water to 57 fm (Bergen)	Medium size to 6.5 cm variable fusiform curved and skin usually wrinkled	5 crowded bands of podia, up to 8 across; non-retractile; cylindrical	Straw-colored podia, beige in alcohol
P. trachyplaca (Clark 1924) as *Cucumaria*	Queen Charlottes to Channel Is, California, to 33 m	Small cylindrical, up to 3 cm; blunt subequal ends	5 bands stout podia	Yellowish white in alcohol, tentacles darker
P. zacae Deichmann 1938	Tangola Bay, Mexico; 23 fm	Small (few cm) with strongly curved body tapering toward ends	Numerous cylindrical, non-retractile podia in 5 bands, more on ventrum than at oral or anal ends	Dirty white
P. rigida, new species	Porcher I., B.C. south to Santa Rosa I., Channel Islands, California	U-shaped, stiff, elongate, fatter in middle and tapering at both ends, posterior more so	5 bands fine, stiff podia, usually more abundant midventrally	Whitish

Table 1.—Continued. Extended.

Calcareous ring	Mid-dorsal Ossicles	Introvert	Tentacles
Radials with long posterior processes about twice length of interradials	Oval to star-shaped tables (L = 213 ± 58) a few reduced in size, with scalloped edge; 25–40 holes; narrow central spire (width at base 48 ± 14); curved supporting tables (L = 119 ± 14) with a tall spire (H = 41 ± 7) topped with teeth, ratio of L to TH = 1.4 ± 0.2; podia have smallish endplates with notched perimeter (90–105, *n* = 6).	Elongate diamond-shaped plates with 2 larger central holes, some with bumps or low pillar arch	Ten (8:2); ossicles long thin curved rods and narrow perforated plates
Long posterior processes	Skin filled mostly with large, oval or triangular plates (L = 228 ± 41), rarely star-shaped tables; supporting tables (L = 143 ± 11) with moderate spire (H = 23 ± 11), ratio of L to TH = 2.1 ± 0.4; podia endplates (130–160).	Oval perforated plates with serrated edge and blunt spines on surface	Ten; 8:2 small, 1 spec had 9:1 small. Dark around mouth, brown specks on oral disk and tentacles
Radials with long posterior processes, radial about 3 times longer than interradial	Usually small (L = 111 ± 18) circular tables with small two-pillared spire; supporting tables (L = 96 ± 11) with medium spire (H = 19 ± 5) often topped with 2 "horns"; ratio of L to TH = 2.1 ± 0.4; podia endplates (114–123, *n* = 3).	Delicate perforated plates with a few knobs; approaching rosettes	8:2 small; brown spots; oblong plates and rods (Bergen)
Posterior processes of medium length, interradials an elongate triangle	Thick oval, knobbed, perforated plates (L = 147 ± 34, *n* = 20) with meshwork of bumps covering one side; curved supporting tables with wide low spire covering half length; well developed end-plates (120–140, *n* = 4).	Oblong reticulated plates (Bergen)	8:2 tentacles; various sized plates often with two enlarged central holes
No calcareous ring in type	Crowded layer of acornlike cups (~60) with 2 pillared, tapering spire rising from a cupshaped base; curved supporting tables with medium tall spire topped with few blunt teeth; podia with large endplates.	Unknown	Tentacles missing
Typical *Pentamera* with very long posterior processes; approximately 1:4	Circular to triangular or star-shaped tables (L = 194 ± 45, *n* = 140) with a wide central spire (width at base 102 ± 32, *n* = 140); supporting tables (L = 110 ± 15, *n* = 90) with low bumpy spire (H = 16 ± 5, *n* = 90), ratio of L to TH 1.9 ± 0.3; podia endplates (115–135, *n* = 5).	Elongate oval perforated plates with numerous bumps and in some, raised central rods; two larger central holes	8:2 small; speckled brown; ossicles of two forms, finer curved, elongate oval plates and large robust rods with a few holes

Table 1.—Continued.

Pentamera species	Distribution	Body shape	Podia	Colour
P. pediparva, new species	Fitz Hugh Sound, B.C. to northern California; 7–120 m	Curved and tapering at ends; skin wrinkled; not as stiff as *P. rigida*	Numerous fine podia in 5 bands, reduced at oral and anal ends	Whitish

brown in preserved state. Podia in five series, of up to 8 rows each at the midbody. Ten small dendritic tentacles including smaller ventral pair. Calcareous ring long and tubular with forked tails on the radials; a mosaic of smaller segments; ratio of interradials to radials approximately 1:3. Skin ossicles small oval tables (<100 μm diameter) with a simple, two-pillared spire in the form of a low arch; 4 central holes adjoin the spire. Curved supporting tables (length about 150 μm) with low spire. Introvert has smaller oval tables with spires having a spiny tip. Tentacle ossicles in two forms, finer, curved oval plates and large robust rods with a few larger holes. End plates of podia 200–250 μm in diameter.

Material examined.—Twenty-five specimens from 12 localities in British Columbia, two localities in Washington and one in California. Number of specimens in parentheses after the catalogue number; depth in metres (m).

Holotype.—RBCM 997-124-1 (1), length 8 cm, female, collected by Philip Lambert with SCUBA, station L80-50, 29 June 1980.

Type locality.—British Columbia, Vancouver Island, Quatsino Sound, Forward Inlet, Hall Bank, 50°29.7′N, 128°1.5′W, 7.5 m, cobble-gravel.

Paratypes.—RBCM 980-333-10 (1), length 8.2 cm, male, collected by P. Lambert with scuba, station L80-50, 29 Jun 1980, British Columbia, Vancouver Island, Quatsino Sound, Forward Inlet, Hall Bank, 50°29.7′N, 128°1.5′W, 7.5 m, cobble-gravel. RBCM 981-197-2 (1), length 2.5 cm, male, collected by P. Lambert aboard Strickland, Station L81-13, 20 Aug 1981, British Columbia, Fitz Hugh Sound, Fairmile Pass, 51°38′N, 127°51′W, 70 m. CMNI 1998-0001 (1), length 7.4 cm, female, collected by D. B. Quayle, 14 Jul 1946, British Columbia, Klucksiwi, Seymour Inlet, 51°05′N, 127°39′W, 82 m, sand-gravel. RBCM 973-235-24 (1), length 3.5 cm, sex undet., collected by P. Lambert with scuba, 14 Aug 1973, British Columbia, Barkley Sound, Treble Island, 48°56′N, 125°16.9′W, 9–12 m, sand-shell slope. RBCM 987-253-11 (1), length 3.2 cm, collected by G. Green and K. Sendall on Parizeau, Station G87-17, 23 Jul 1987, Washington, off Cape Flattery, 48°20.9′N, 125°21.39′W, 115–120 m, gravel. CASIZ 50222 (2), collected by Lloyd Barker, 13 Nov 1970, California, Eureka, west of Big Lagoon, 41°10.7′N, 124°7.0′W, 18–37 m.

Other collections.—British Columbia: RBCM 982-326-2 (1), on G. B. Reed, FRB station 70-24, Jul 1970, Bramham Island, 51°05′N, 127°39′W, 82 m, sand-gravel. RBCM 977-444-8 (4), collected by D. B. Quayle, FRB station 63-2, 12 Jan 1963, Cormorant Channel, Malcolm Island, 50°36.9′N, 126°57.7′W, 26 m, sand. NMC 1979-1529 (1), FRB St. 18, Comox Bay 49°39′N, 124°55′W, 27 m. RBCM 975-189-5 (1), formerly BMS 496 (1), St.91/75, 18 Apr 1975, Barkley Sound; Verbeke Reef, 48°52.2′N, 125°22.6′W, 31–46 m, cobble and gravel. RBCM 984-246-1 (6), FRB #8, 23 Jun 1961, Vancouver Island, Barkley Sound, 48°49′N, 125°34.3′W, 73 m, mud-gravel. RBCM 106-49 (1), collected by D. Ellis, 11 Mar 1965, Saanich Inlet, Mill Bay, 48°38.8′N, 123°32.3′W, 18 m, sand. RBCM 975-294-5 (2), collected by D. Ellis, 3 Nov

Table 1.—Continued. Extended.

Calcareous ring	Mid-dorsal Ossicles	Introvert	Tentacles
Very long posterior processes; 1:3	Small, round tables (L = 70 ± 11, *n* = 70) with 4 main holes and 4 or more smaller holes, low 2-pillared spire; in addition, larger diamond-shaped tables (L = 123 ± 21, *n* = 29); slightly curved supporting tables (L = 139 ± 18, *n* = 100) with low spire (H = 19 ± 8, *n* = 100); ratio of L to TH 2.7 ± 0.6, *n* = 100; podia with large endplates (205–215, *n* = 3).	Tables similar to skin but slightly smaller and with teeth on spire	8:2; 2 types of ossicles: finer oblong, curved, perforated plates with 2 larger central holes; and large robust curved rods with holes

1965, Vancouver Island, Saanich Inlet, Mill Bay, 48°38.8′N, 123°32.3′W, 18 m, sand.

Washington: 1 specimen, Station WP215N Rep A, collected by Alan Fukuyama, 7 Oct 1996, 66 m north of West Point outfall, Seattle, Puget Sound, 47°39.6′N, 122°26.8′W, 230 m. 1 specimen, AL172N Rep A, collected by Alan Fukuyama, 7 Oct 1996, 52.4 m north of Alki Point outfall, Seattle, Puget Sound, 47°34.2′N, 122°25.3′W, 143 m.

Description.—Total length 1.3—8.2 cm (measured along the outer curve of the body); mean length 3.3 cm for 16 specimens. Holotype 8 cm long (Fig. 4). Body curved with a blunt anterior end and tapering posterior end. Skin of interambulacral area soft with transverse wrinkles. Five bands of podia each with 4 irregular crowded rows more sparse distally. Podia cylindrical, non-retractile and bristling with ossicles.

In alcohol, small specimens white with yellowish podia; larger specimens off-white.

Ten dendritic tentacles including small ventral pair. Brown spots near base of tentacles and in entrance to mouth.

Madreporite in shape of a flattened hemisphere lies in the dorsal mesentery usually two-thirds of the distance from the anterior end of the calcareous ring. Narrow, convoluted stone canal attaches to the circular water ring at the posterior tips of the calcareous ring. One polian vesicle, usually on the ventral side. Two respiratory trees emerge from cloaca and immediately split into two branches, the dorsal branch longer than the ventral. Thin-walled cloaca about one-third of body length and attached to the body wall by numerous strands or muscles.

Retractor muscles fairly stout compared to *P. rigida*; attached to longitudinal muscles about ¼ of the distance from anterior end of body.

Two tufts of unbranched gonadal tubules attach to dorsal body wall about one-third of the way from anterior end of body, one tuft on each side of the dorsal mesentery.

Calcareous ring takes up a large proportion of internal body cavity and in severely contracted specimens may appear to span the length of the cavity. Posterior tails of radials long and thin; may be bent back on themselves at posterior end. Transverse thickenings indicate joints between mosaic of pieces. Ratio of interradial to radial length about 1:3 (Fig. 5F).

Ossicles of mid-skin small oval or squarish tables (diameter 70 μm ± 11 *SD*, *n* = 71) with a low spire consisting of two pillars (Fig. 5A). Pillars may be joined at the top and have one or two side branches, or appear as just two bumps. Most tables have four main holes around the spire with one to several secondary holes. Among oval tables are diamond-shaped tables (length 123 ± 21, *n* = 30) with a spire shaped like a low arch. Toward anterior and posterior ends and in the introvert, spires of tables

have multiple spines at apex and tables slightly smaller on average (Fig. 5B). Supporting tables of podia curved rods (length 139 ± 18, n = 100) with a low central spire (height of spire 19 μm ± 8, n = 100) with two or three bumps, in side view (Fig. 5E). Podia have large end-plates (diameter 205–215, n = 3) (Fig. 5C). Five anal teeth surround anus.

Tentacles have two types of ossicles: large, elongate, curved perforated rods and more delicate elongate-oval or curved plates perforated with smaller holes and serrated around edges (Fig. 5D).

Etymology.—The species name, *pediparva,* is based on the Latin words *pedis* meaning foot and *parvus* meaning small or little, referring to the numerous, small podia.

Distribution and habitat.—*P. pediparva* is known from Fitz Hugh Sound, on the central British Columbia coast (51°38′N, 127°51′W), south to Eureka, California (41°10.7′N, 124°7.0′W) (Fig. 6). It ranges in depth from 8 to 120 m on the continental shelf. Usually dredged from firm substrata such as mud-gravel and sand-gravel.

Discussion

Table 1 compares the features of 14 species of *Pentamera* from the west coasts of North and South America, including the two new species described in this paper. New information, not included in original descriptions, has been added to complete the table.

Pentamera rigida is allied to *P. populifera* in the shape of the table ossicles, but those of *P. rigida* have a broad low spire and a more triangular rather than star-shaped plate. *P. rigida* seems to prefer a firm sand or gravel substratum while *P. populifera* is usually more common in mud. *P. rigida* also resembles *P. pseudopopulifera* in general appearance, but the tables are about one-half the diameter of *P. rigida* and the central spire is much smaller and more delicate.

In general appearance, *Pentamera pediparva* resembles *P. lissoplaca* with soft skin and fine podia in five rows, but the skin ossicles of the two species differ. *P. lissoplaca* has a few, tiny tables scattered among the dominant diamond-shaped plates without spires. *P. pediparva* has approximately equal proportions of oval tables and diamond-shaped tables of similar size. The curved supporting tables of *P. lissoplaca* have a moderately tall spire while those of *P. pediparva* have a low spire. *Pentamera constricta* (Ohshima 1915) from Japan has tables similar to *P. pediparva* but it also possesses large smooth plates and the skin is stiff and rough to the touch.

The known distributions of *P. rigida* and *P. pediparva* are within the Oregonian Province with a southern boundary near Point Conception, California. The northern boundary of this region is poorly defined and varies with the taxa being considered (see Lambert 1996) for discussion. The cluster of specimens in the British Columbia region is probably more indicative of collecting pressure than true abundance. I suspect that these two species may be mixed in with specimens of the three closely related species *P. populifera, P. pseudopopulifera* and *P. lissoplaca* in other museum collections. Also, a lack of collecting along the outer coasts of Washington and Oregon could explain the distribution gap for *P. pediparva.*

The two new species are included in the following key to the 14 species of *Pentamera* of the west coast of North and South America. This key is based primarily on ossicles. See Fig. 7 for explanation of dimensions of supporting tables used in the key. All measurements in μm.

Key to the *Pentamera* of the West Coast of North and South America

1(0) Mostly round to oval plates without spires, in skin; table ossicles rare or absent. 2

– Mostly large angular or star-shaped plates without a spire; occasional tables ..... *Pentamera pseudocalcigera*

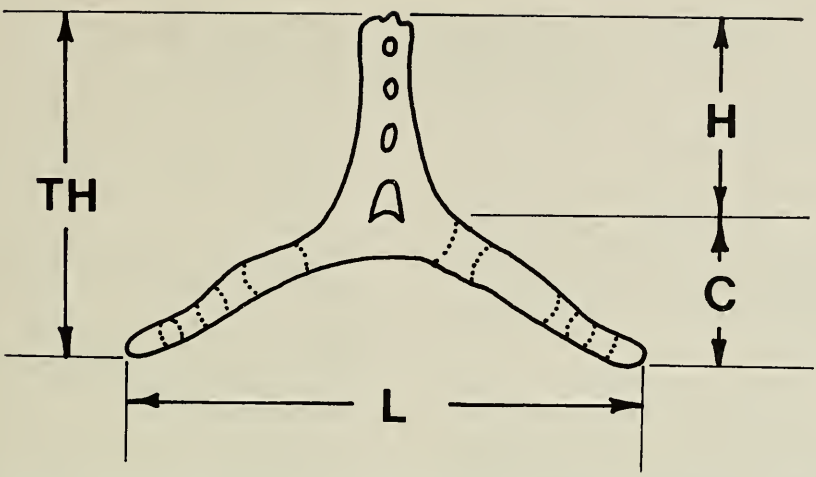

Fig. 7. Abbreviations for dimensions of supporting tables: TH, total height; H, height; C, height of curve; L, length.

– Mostly diamond-shaped plates; a few minute tables .... *Pentamera lissoplaca*
– Only table ossicles with spires in skin 3
2(1) Small oval plates with 2 central and up to 8 marginal knobs. Length of plates between 0 and 99 μm ..... *Pentamera montereyensis*
– Thick, oval, knobbed, perforated plates; mean length 100 to 149 μm; diameter of podial end-plates 100 to 149 ..... *Pentamera trachyplaca*
– Mostly oval plates; mean length between 150 and 199; diameter of podial end-plates 150 to 199 ..... *Pentamera calcigera*
3(1) Supporting tables present in podia .. 4
– Supporting tables absent ..... *Pentamera chierchia*
4(3) Spire of supporting table low, less than 24 μm 5
– Spire medium high, between 25 and 49 6
– Spire tall, between 50 and 74 8
5(4) Supporting tables with L:TH ratio of 1.5 to 1.9; mean length of tables 150 to 199; introvert with oval plates ... . *Pentamera rigida*
– Supporting tables with L:TH ratio of 2 to 2.4; mean length of tables 100 to 149; introvert with rosettes .... *Pentamera pseudopopulifera*
– Supporting tables with L:TH ratio of 2.5 to 2.9; mean length of tables 50 to 99; introvert with tables .... *Pentamera pediparva*
6(4) Supporting tables with L:TH ratio of 1 to 1.4 7
– Supporting tables with L:TH ratio of 1.5 to 1.9 ..... *Pentamera chiloensis*
7(6) Mean length of supporting tables 50 to 99; body U-shaped .... *Pentamera zacae*
– Mean length of supporting tables 100 to 149; body curved .... *Pentamera populifera*
8(4) Mean length of tables less than 50; width of spire at base less than 25 .. .. *Pentamera beebei*
– Mean length of tables 50 to 99; Width of spire at base 25 to 49 .... *Pentamera charlottae*

Acknowledgments

I am grateful to G. Green and K. Sendall of the Royal B. C. Museum for the field assistance. Many specimens in the RBCM were collected by the late Dan Quayle and Frank Bernard of the Pacific Biological Station, who diligently collected marine invertebrates in the 1950's and 60's. I would like to pay tribute to them for their foresight and contributions to our knowledge of invertebrates in British Columbia. Thanks also to

G. Hendler and K. Groves, LACM and B. van Syoc and E. Kools, CASIZ, for loans of specimens. A. Fukuyama of the University of Washington kindly loaned me two lots of *Pentamera* from one of his surveys. Thank you to Dr. D. Pawson and an anonymous reviewer for their constructive comments. Support from the Executive Director of the Royal British Columbia Museum for this taxonomic research is gratefully acknowledged.

Literature Cited

Ayres, W. O. 1852. Description of a new species of Holothuria.—Proceedings of the Boston Society of Natural History 4:207–208.

Bergen, M. 1996. 9. Class Holothuroidea: Including keys and descriptions to all continental shelf species from California. Pp. 195–250 *in* J. A. Blake, P. H. Scott, & A. Lissner, eds., Taxonomic atlas of the benthic fauna of the Santa Maria Basin and the Western Santa Barbara Channel, Santa Barbara Museum of Natural History, Santa Barbara, 305 pp.

Clark, H. L. 1924. Some holothurians from British Columbia.—Canadian Field Naturalist 38:54–57.

Deichmann, E. 1938a. Eastern Pacific expeditions of the New York Zoological Society. XVI. Holothurians from the western coasts of Lower California and Central America, and from the Galápagos Islands.—Zoologica (New York) 23: 361–387.

———. 1938b. New holothurians from the western coast of North America and some remarks on the genus *Caudina*.—Proceedings of the New England Zoological Club 16:103–115.

———. 1941. The holothurioidea collected by the Velero III during the years 1932 to 1938. Part 1, Dendrochirota.—Allan Hancock Pacific Expeditions 8:61–195.

Lambert, P. 1985. Geographic variation of calcareous ossicles and the identification of three species of eastern Pacific sea cucumbers (Echinodermata: Holothuroidea). Pp. 437–443 *in* B. F. Keegan & B. D. S. O'Connor, eds., Echinodermata: Proceedings of the Fifth International Echinoderm Conference, Galway, A. A. Balkema, Rotterdam, 662 pp.

———. 1996. *Psolidium bidiscum*, a new shallow-water psolid sea cucumber (Echinodermata: Holothuroidea) from the northeastern Pacific, previously missidentified as *Psolidium bullatum* Ohshima.—Canadian Journal of Zoology 74: 20–31.

———. 1997. Sea cucumbers of British Columbia, Puget Sound and Southeast Alaska. Royal BC Museum and University of BC Press, Vancouver, 192 pp.

Ludwig, H. 1886a. Echinodermen des Beringsmeeres.—Zoologiscen Jahrbüchern. Zeitschrift für Systematik, Geographie und Biologie der Thiere 1886:275–296.

———. 1886b. Die von G. Chierchia auf der Fahrt der Kgl. Ital. Corvette "Vettor Pisani" gesammelten Holothurien.—Zoologiscen Jahrbüchern. Zeitschrift für Systematik, Geographie und Biologie der Thiere 1886:1–36.

Ohshima, H. 1915. Report on the holothurians collected by the U.S. fisheries steamer "Albatross" in the N.W. Pacific during the summer of 1906.—Proceedings of the United States National Museum 48:213–291, pls. 8–11.

Panning, A. 1949. Versuch einer Neuordnung der Familie Cucumariidae (Holothurioidea, Dendrochirota).—Zoologische Jahrbücher Abteilung für Systematik, Oekologie und Geographie der Tiere 78:404–470.

Pawson, D. 1982. Holothuroidea. Pp. 813–818 *in* S. P. Parker, ed., Synopses and classification of living organisms, McGraw-Hill, Toronto, 1232 pp.

———, & H. B. Fell. 1965. A revised classification of the Dendrochirote Holothurians.—Breviora 214:1–7.

Stimpson, W. 1851. Descriptions of new species of holothurians.—Proceedings of the Boston Society of Natural History 4:67.

———. 1864. Descriptions of new species of marine invertebrata from Puget Sound, collected by the Naturalists of the North-west Boundary Commission, A. H. Campbell, Esq., Commissioner.—Proceedings of the Academy of Natural Sciences of Philadelphia 16:153–161.

Thandar, A. S. 1990. The phyllophorid holothurians of southern Africa with the erection of a new genus.—South African Journal of Zoology 25: 207–223.