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Four new species of *Haplostoma* (Copepoda: Cyclopoida: Ascidicolidae) living in compound ascidians from Madagascar

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Abstract.—Four new species of the genus Haplostoma (Haplostomatinae) are described on the basis of females living in compound ascidians from Madagascar. These copepods and ascidian hosts are as follows: 1) Haplostoma bispinosum, in Polyclinum ?macrophyllum Michaelsen; 2) H. elongatum, in P. diaphanum von Drasche; 3) H. madagascarensis, in P. ?insulsum Sluiter; and 4) H. junctum, in Eudistoma sp. In these copepods, the armature on the antenna and legs 1–4 exopods consists of bifurcate spines, representing the main primary diagnostic features of subgroup 2 of the genus. The four new species are distinguished from the three known species of subgroup 2 primarily by the armature formulas for legs 1–4 exopods and by the characters of the genus whose caudal rami are medially fused. The diagnosis of subgroup 2 is revised on the basis of a comparative study of seven species (three previously known, four new).

The genus Haplostoma, which consists of 14 known species (females), was divided into two subgroups by Ooishi (1998, 2004a, 2004b). In subgroup 1, the armature on the antenna and legs 1-4 exopods consists of simple spines, and the leg exopods have a seta posterior to the spines. In addition, the leg endopods are fused laterally with about half of the medial margin of the exopods, and the distal margin is protruded. In subgroup 2, the armature on the antenna and leg exopods consists of bifurcate spines, and the leg exopods do not have a seta posterior to the spines; the leg endopods are fused with much of the medial margin of the exopods, and form the distal margin sloping from lateral to medial.

Four new species, which belong to the Humes collection from Madagascar (see Ooishi 1995) and described herein, have the above-mentioned primary diagnostic features of subgroup 2, including three known species. For this paper, it has been confirmed that the four new and three known species are characterized by many more common morphological features with respect to the cephalosomal appendages, fifth leg, and caudal ramus. Therefore, the primary diagnosis of subgroup 2 is revised; a key to species is also given. The three known species of subgroup 2 are as follows: 1) *H. canui* Chatton & Harant, 1924; 2) *H. humesi* Ooishi, 1995; and 3) *H. dudleyae* Ooishi, 1998. *Haplostoma canui* was redescribed by Ooishi (1994).

The genus *Haplosoma* now consists of 18 species: subgroup 1 with 11 (see Ooishi 2004b, for the species names); subgroup 2 with seven, including the four new species. The genus is placed in the family Ascidicolidae Thorell, 1859, sensu Illg & Dudley (1980) and the order Cyclopoida Sars, 1886 based on Damkaer (2002).

From the Humes collection mentioned above, *Haplostoma humesi* and *Haplostomides gottoi* have already been described, respectively, by Ooishi (1995, 2008). Thus, the material of the subfamily Haplostomatinae (sensu Ooishi & Illg 1977) of the Humes collection consists of six species (*Haplostoma 5*; *Haplostomides* 1).

Materials and Methods

Data concerning the source of specimens of the four new species are based on Humes field notes (see Ooishi 1995); those for each new species are given under the *Material examined* section of the description; the ascidian hosts (Aplousobranchia: Polyclinidae) were identified by the late Dr. R. H. Millar.

For dissection, measurements, drawings, and photomicrographs, selected specimens of each new species were immersed in lactic acid (with a small amount of methylene blue). Drawings were made with the aid of a drawing tube.

In the armature formula for legs 1–4, the total number of spines (Roman numerals) is given first and connected by a dash with the number of setae (Arabic numerals) on each leg. The total number (T) of these elements is given in parentheses for the basis and exopod. Abbreviations used are: A1 = antennule, A2 = antenna, L = labrum, MD = mandible, MX2V = vestigial maxilla, MXP = maxilliped, R = rostrum.

Systematics

Family Ascidicolidae Thorell, 1859 Subfamily Haplostomatinae Chatton & Harant, 1924

Genus Haplostoma (Canu, 1886) Haplostoma bispinosum, new species Figs. 1–3

Material examined.—Humes collection no. 725: ascidian host *Polyclinum ?macrophyllum* Michaelsen, flat, smooth, soft colonies, gray to translucent, attached under surface of rocks, low tide, at Nosy Bé (Nosy N'Tangam), Madagascar, 5



Fig. 1. *Haplostoma bispinosum*, female, photomicrographs. a, female with egg sacs, left side; b, posterior urosome with caudal rami, dorsal, showing caudal ramus with 2 unequal blunt small spines on rounded terminal margin.

October 1963; females with dark red eye, yellowish gut, and opaque gray ovarian eggs. Holotype Q (USNM 1127142) and paratypes 5 QQ (USNM 1127143) deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Description of female.—Body (Figs. 1a, 2a–c) vermiform, with distinct dorsal curvature. Body length, measured along



Fig. 2. *Haplostoma bispinosum*, female. a, body form, dorsal; b, body form, left side (arrow indicates location of copulatory pore); c, body form, ventral; d, cephalosome, ventral, showing rostrum, labrum, and appendages; e, cephalosome, left side; f, cephalosome, anterodorsal, showing cephalic sclerite and rostrum between antennules; g, rostrum, anterior, showing longitudinal low of 3 conical spinules on each sclerotized lateral margin; h, left antennule, ventral; i, right antenna, anterior; j, left antenna, medial, showing third segment with 4 graduated bifurcate spines.

body axis (dorsal side), 1.54 mm. Proportional lengths of cephalosome, metasome, and urosome 1:6:1. Ratio of length of prosome to that of urosome 7:1. Range of body lengths, based on 5 females, 1.17 to 1.64 mm. Egg sacs (Fig. 1a) slightly shorter than body length; eggs (embryos) arranged multiserially.

Cephalosome (Fig. 2a-c) as long as wide, anterior margin rounded. Appendages (Fig. 2d, e) comprising antennules, antennae, mandibles, and maxillipeds; maxillules absent, and maxillae vestigial. Dorsal cephalic sclerite (Fig. 2f) inverted V-shaped, with fewer than 50 small unsclerotized areas, these mostly symmetrically arranged; each area with 1 small hairlike sensillum. Rostrum (Fig. 2f, g) oval, as long as wide. Distal and lateral margins sclerotized and connected proximally with anterior dorsal cephalic sclerite. Each sclerotized lateral margin with longitudinal row of 3 small conical spinules. Central portion unsclerotized; upper surface slightly expanded (Fig. 2d).

Metasome (Fig. 2a-c) consisting of first to fifth thoracic segments; fourth and fifth segments fused dorsally, forming fourth metasomal section with posterolateral subconical lobes of fifth segment. Each of first to fourth segments slightly longer than wide. Each of second to fourth segments, measured at mid-portion of segment, 0.28 mm wide. Posterior fourth metasomal section with posterolateral lobes 0.30 mm wide. Ventrally, right and left legs widely separated, without intercoxal sclerite. Long fourth segment distinguished from short fifth segment by small midventral sclerite (= location of tendon). Fifth segment indistinctly articulated posteriorly with genital segment of urosome.

Urosome (Figs. 2a–c, 3g, h, j) dorsally 4-segmented (genital, 2 abdominal, anal), gradually narrowed posteriorly. In genital segment, gonopores dorsolateral and copulatory organs midventral. Second abdominal segment distinctly short and anal segment constricted proximally, bearing small caudal rami terminally (Fig. 1b); anus terminal on dorsal side.

Antennule (Fig. 2d, h) lobate, unsegmented, with longer anterior and shorter posterior margins, and directed laterally. Narrowed and rounded distal margin with 9 small simple setae (6 long, 3 short).

Antenna (Fig. 2d, i, j) 3-segmented; proportional lengths, measured along central axis (anterior side), 1:1.4:0.5. Small third segment directed laterally; most of lateral margin close to distal margin of second segment, and medial margin with 4 graduated bifurcate spines (2 lateral, subterminal, terminal). Terminal spine more than 3 times as large as proximalmost lateral spine.

In labrum (Figs. 2d, e, 3a), broad distal margin slightly protruded posteroventrally; internal edge with transverse row of minute filiform elements. (Filiform elements were studied by SEM images in *H. humesi* by Ooishi 1995.)

Mandible (Figs. 2d, e, 3a) located posterolateral to labrum, consisting of indistinctly 2-segmented small conical lobe with 1 simple apical seta.

Vestigial maxilla (Fig. 2d, e) anterolateral to maxilliped. (Details of the vestigial maxilla were studied by SEM images in *H. dudleyae* by Ooishi 1998.)

Maxilliped (Figs. 2d, e, 3b) consisting of large coxa, smaller basis (no setae on medial margin), and small endopod. Endopod, comprising 2 short proximal segments and clawlike terminal spine, directed medially.

Legs 1–4 (Fig. 3c–f) modified, alike in shape; leg 1 smallest. Sclerotized basis beltlike, with 1 simple seta on lateral margin. Width of basis approximately as long as exopod. Unsclerotized large endopod fused laterally with much of narrow and longer exopod. Distal margin of endopod sloping evenly from lateral to medial, without armature. Distal onethird of sclerotized lateral margin of exopod armed with bifurcate spines,



Fig. 3. *Haplostoma bispinosum*, female. a, oral area, ventral, showing labrum and mandibles; b, right maxilliped, posterior; c, left leg 1, anterolateral; d, left leg 2, anterolateral; e, left leg 3, lateral; f, left leg 4, lateral; g, posterior fourth metasomal section with fifth leg (indicated by dot) and urosome with caudal ramus, left side (arrow indicates location of copulatory pore); h, urosome with caudal rami, dorsal; i, left gonoporal area, dorsal, showing medial margin of gonopore with 2 rows of spines (external row with 2 unequal sharp conical spines, internal row with 5 conical spines); j, urosome with caudal rami, ventral, showing location of copulatory organs in genital segment; k, copulatory organs, ventral; l, anal segment with caudal rami, dorsal; m, same specimen, left side.

lacking seta posterior to spines. Legs 1, 3, and 4 with 5 spines (3 lateral, subterminal, terminal); leg 2 with 4 spines (2 lateral, subterminal, terminal). Largest terminal spine close to smaller subterminal spine posteriorly; subterminal and lateral spines subequal in size. Armature formula for legs 1–4 as follows:

	Basis (T)	Exopod (T)
Leg 1	0-1 (1)	V = 0 (5)
Leg 2	0-1 (1)	IV-0 (4)
Leg 3	0-1 (1)	V-0 (5)
Leg 4	0-1 (1)	V-0 (5)

Leg 5 (Figs. 2a, 3g) represented by 2 subequal short simple setae (proximal, terminal) on dorsal side of subconical lobe of fifth thoracic segment.

Dorsal genital segment (Fig. 3h) between gonopores sclerotized, with 2 hairlike sensilla medially and slightly anteriorly. Medial margin of gonopore (Fig. 3i) armed with 2 rows (external, internal) of spines. External row consisting of 2 unequal sharp conical spines; unarticulated large distal spine twice as large as articulated small proximal spine. Internal row with 5 merely conical spines. Sclerotized dorsal cuticle lateral to gonopore with 3 or 4 hairlike sensilla.

In ventral genital segment (Fig. 3g, j), wide copulatory pore located close to posterior margin of segment, opening internally into seminal receptacle. Seminal receptacle (Fig. 3k) anteriorly widened (in ventral view), and distinctly depressed between anterolateral protrusions of receptacle. Slender receptacle ducts diverging from lateral margins of protrusions toward lateral antra; ventral surface of seminal receptacle with more than 10 scattered, small round elements. (See Ooishi 1994, fig. 3d, for the relationship of the copulatory pore to the antra.)

Anal segment (Fig. 3l, m) slightly wider (mid-portion) than long, expanded dorsally and laterally; 1 large mammiform sensillum midway on each lateral margin. Caudal ramus (Figs. 1b, 3l, m) subconical lobe, slightly longer than wide (at base). Armature consisting of 1 simple seta midway on lateral margin and 2 unequal blunt small spines (larger lateral, much smaller medial) on rounded terminal margin.

Male.—Unknown.

Etymology.—The species name *bispino-sum* refers to the caudal ramus, which has two unequal terminal spines.

Remarks.—Haplostoma bispinosum is distinguished from six congeneric species of subgroup 2 by the armature formula for legs 1–4 exopods (5,4,5,5) and by the characters of the caudal ramus (with 1 lateral seta and 2 unequal terminal spines), second abdominal segment (distinctly short), and anal segment (constricted proximally).

Haplostoma elongatum, new species Figs. 4–7

Material examined.—Hume collection no. 964: ascidian host *Polyclinum ?diaphanum* von Drasche, reddish brown, attached under surface of rocks, intertidal, Nosy Be (Befifika), Madagascar, 7 October 1964. Female with dark red eye, egg sacs gray. Holotype Q (USNM 1127144) and paratypes 8 QQ (USNM 1127145) deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Description of female.—Body (Figs. 4a– c, 7a) vermiform, elongated, with slight dorsal curvature. Body length, measured along body axis (dorsal side), 1.90 mm. Proportional lengths of cephalosome, metasome, and urosome 1:6.8:0.8. Ratio of length of prosome to that of urosome approximately 9:1. Range of lengths, based on 5 females, 1.42 to 1.90 mm. Egg sac (left, Fig. 4d) 1.8 mm long; eggs (embryos) arranged multiserially.

Cephalosome (Fig. 4a–c) small, subconical, longer than wide. Appendages (Fig. 4e, f) consisting of antennules, antennae, mandibles, and maxillipeds; max-



Fig. 4. *Haplostoma elongatum*, female. a, body form, dorsal; b, body form, left side (arrow indicates location of copulatory pore); c, body form, ventral; d, left egg sac, dorsal; e, cephalosome, ventral, showing rostrum, labrum, and appendages; f, cephalosome, left side, showing labrum and appendages.



Fig. 5. *Haplostoma elongatum*, female. a, inverted V-shaped cephalic sclerite, dorsal; b, rostrum, anterior, showing sclerotized lateral margin with 4 small conical spinules and 1 small hairlike sensillum on distal part and 1 hairlike sensillum rather proximally, and sclerotized basal portion with 2 similar sensilla; c, rostrum between proximal antennules, ventral; d, left antennule, ventral; e, left antenna, medial; f, left antenna, lateral; g, left mandible, lateral; h, right maxilliped, anteromedial; i, left leg 1, anterior; j, left leg 1, anterolateral; k, left leg 2, anterolateral; l, left leg 3, anterolateral; m, left leg 4, anterolateral.



Fig. 6. *Haplostoma elongatum*, female. a, right leg 5, dorsal; b, genital area, dorsal, showing sclerotized cuticle between gonopores with 2 hairlike sensilla medially and slightly anteriorly; c, left gonoporal area, dorsal, showing medial margin of gonopore with 2 rows of spines (external row with 2 unequal sharp conical spines; internal row with 5 conical spines) and cuticle lateral to gonoporal medial margin with 1 small conical spine; d, urosome with caudal ramus, left side (arrow indicates location of copulatory pore); e, urosome with caudal rami, ventral, showing location of copulatory organs in genital segment; f, copulatory organs, ventral; g, anal segment with caudal rami, dorsal; h, anal segment with caudal rami, ventral.

illules absent, and maxillae vestigial. Dorsal cephalic sclerite (Figs. 4a, 5a) inverted V-shaped, with approximately 70 small unsclerotized areas. Rostrum (Fig. 5b, c) widened proximally. Rounded mid-distal margin unsclerotized, but lateral and basal margins sclerotized. Distal part of each sclerotized lateral margin with a transverse row of 4 small conical spinules and 1 small hairlike sensillum posterior to spinules; each more proximal margin with 1 hairlike sensillum, and 2 similar sensilla at base. Central portion unsclerotized, and upper surface expanded (Fig. 7b).

In metasome (Fig. 4a–c), fourth and fifth segments fused dorsally, forming fourth metasomal section. Each of first to fourth segments distinctly longer than wide, resulting in elongation of body: 1.4 times as long as wide (mid-portion) on third and fourth segments. Fourth metasomal section with posterolateral lobes of fifth segment 0.38 mm wide, slightly wider than anterior 2 segments (0.34 mm wide); posterolateral lobes constricted proximally. Ventrally, long fourth segment distinguished from short fifth segment by small midventral sclerite (= location of tendon); in contracted specimens, both segments distinctly distinguished by constriction.

Urosome (Fig. 4a–c) dorsally subequally 4-segmented (genital, 2 abdominal, anal). Anal segment not constricted proximally; anus terminal on dorsal side.

Antennule (Figs. 4e, 5d) lobate, unsegmented. Armature consisting of 15 small simple setae; 2 (short) on midventral surface and 13 (8 short, 5 long) on narrowed and rounded distal margin.

Antenna (Figs. 4e, f, 5e, f) 3-segmented, as in *H. bispinosum*. Medial margin of small third segment with 4 bifurcate spines: 2 extremely small lateral, subterminal, largest terminal.

In labrum (Fig. 4e, f), broad distal margin slightly protruded posteroven-trally.

Mandible (Figs. 4e, f, 5g) small subconical lobe with 1 simple apical seta.

Vestigial maxilla (Fig. 4e, f) anterolateral to maxilliped.

Maxilliped (Figs. 4e, f, 5h) consisting of large coxa, smaller basis (no setae on medial margin), and small endopod. Endopod directed medially, including 2 short basal segments and 1 bifurcate terminal spine.

Legs 1–4 (Fig. 5i–m) alike in shape and size. Sclerotized basis with 1 simple lateral seta. Width of basis 1.2 times as long as exopod. Distal margin of endopod sloping from lateral to medial. Distal onethird of sclerotized lateral margin of exopod armed with bifurcate spines, lacking seta posterior to spines. Leg 1

exopod with 5 spines (3 lateral, subterminal, terminal); exopods of legs 2–4 with 4 spines (2 lateral, subterminal, terminal). Terminal spine largest, subterminal and lateral spines smaller and subequal in size. Armature formula for legs 1–4 as follows:

	Basis (T)	Exopod (T)
Leg 1	0-1 (1)	V-0 (5)
Leg 2	0-1 (1)	IV-0 (4)
Leg 3	0-1 (1)	IV-0 (4)
Leg 4	0-1 (1)	IV-0 (4)

Leg 5 (Figs. 4a, b, 6a) represented by 2 subequal simple setae (proximal, distal) on dorsal side of subconical lobe of fifth thoracic segment.

In dorsal genital segment (Figs. 4a, 6b), sclerotized cuticle between gonopores with 2 hairlike sensilla medially and slightly anteriorly. Medial margin of gonopore (Figs. 6c, 7c) armed with 2 rows (external, internal) of spines. External row with 2 unequal sharp conical spines; unarticulated large distal spine 1.4 times as long as articulated small proximal spine. Internal row with 5 merely conical spines. Sclerotized dorsal cuticle, lateral to medial margin of gonopore, with 1 small conical spine anteriorly.

In ventral genital segment (Fig. 6d, e), wide copulatory pore located somewhat posteriorly, not close to posterior margin of segment, and opening internally into wide seminal receptacle. Seminal receptacle (Figs. 6f, 7d) 1.5 times as wide as long (on central axis); anterior margin slightly depressed between 2 small pointed protrusions (in ventral view). Narrow receptacle ducts extending from lateral margins of seminal receptacle toward lateral antra.

Anal segment (Fig. 6g, h) wider than long, approximately 1.3 times as wide as long. Small hairlike sensilla scattered: 4 on dorsal side and 9 on slightly expanded ventral side.



Fig. 7. *Haplostoma elongatum*, female, photomicrographs. a, body form, dorsal; b, rostrum, ventral, showing unsclerotized central portion expanded; c, external row of spines on medial margin of left gonopore, dorsal, showing 2 unequal sharp conical spines (unarticulated large distal; articulated small proximal); d, copulatory organs (copulatory pore, seminal receptacle, receptacle ducts), ventral.

Caudal ramus (Fig. 6g, h) subconical lobe, as long as wide (at base), and distal half narrowed toward apex; 2 unequal slender simple setae (short dorsal, long lateral) on mid-portion of ramus, and 1 articulated conical spine on pointed apex.

Male.—Unknown.

Etymology.—The species name *elongatum* refers to the elongated body form.

Remarks.—Haplostoma elongatum is distinguished from six congeners of subgroup 2 by the elongated body form and subconical caudal ramus with 2 setae (mid-portion) and 1 spine (terminal).

Haplostoma madagascarensis, new species Figs. 8–10

Material examined.—Humes collection no. 751: ascidian host *Polyclinum ?insulsum* Sluiter, flat orange yellow, encrusting compound tunicate, attached under surface of dead coral, exposed at low tide, Nosy Bé (Navetsy), 3 November 1963. Holotype Q (USNM 1127146) and paratypes 7 QQ (USNM 1127147) deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Description of female.—Body (Fig. 8a– c) vermiform, with slight dorsal curva-



Fig. 8. *Haplostoma madagascarensis*, female, a, body form, dorsal; b, body form, left side (arrow indicates location of copulatory pore); c, body form, ventral, showing arrangement of muscles; d, left egg sac, dorsal; e, cephalosome, ventral; f, cephalosome, left side.

ture. Body length, measured along body axis (dorsal side), 1.8 mm. Proportional lengths of cephalosome, metasome, and urosome 1:5.6:1. Ratio of length of prosome to that of urosome 6.6:1. Range of lengths, based on 5 females, 1.5 to 1.84 mm. Egg sac (left, Fig. 8d) 1.2 mm long; eggs (embryos) arranged mostly in 2 rows and partly multiserially.

Cephalosome (Fig. 8a-c) approximately as long as wide (at base), and as long as first metasomal segment. Appendages (Fig. 8e, f) consisting of antennules, antennae, mandibles, and maxillipeds; maxillules absent, and maxillae vestigial. Dorsal cephalic sclerite (Figs. 8a, 9a) inverted V-shaped, with more than 100 unsclerotized small areas. Rostrum (Fig. 9b) as long as wide; proximal portion slightly widened and narrowed toward rounded distal margin. Mid-distal margin unsclerotized, and lateral and proximal margins sclerotized. Distal part of sclerotized lateral margin with 2 small conical spinules arranged side by side; 7 minute hairlike sensilla arranged along sclerotized proximal margin.

In metasome (Fig. 8a-c), first segment short, wider than long; each of second to fourth segments longer than wide; long fourth and short fifth segments fused dorsally, forming fourth metasomal section. Each of second to fourth segments 0.30 mm wide. Posterior fourth metasomal section with subconical lobes of fifth segment 0.4 mm wide, much wider than anterior segments. Ventrally, first to fifth segments distinguished by arrangement of muscles. In first to fourth segments, each side of segment with longitudinal muscles medially, and oblique muscles anteriorly and posteriorly between medial longitudinal muscles and anterior and posterior bases of leg; these muscles connected by medial tendon; short fifth segment anteriorly distinguished from fourth segment by medial tendon as illustrated (Fig. 8c).

Urosome (Figs. 8a–c, 10a) subequally 4-segmented (genital, 2 abdominal, anal).

Anal segment not constricted proximally; anus terminal on dorsal side.

Antennule (Figs. 8e, 9b) unsegmented, lobate; ventral surface slightly protruded at distal one-fourth. Armature consisting of 7 small simple setae: 1 (long) on ventral protrusion and 6 (4 long, 2 short) on rounded distal margin. In addition, 6 min elements (apparently reduced setae) present on ventral surface near distal margin.

Antenna (Figs. 8e, f, 9c, d) 3-segmented, as in previous 2 new species. Medial margin of small third segment with 4 graduated bifurcate spines; terminal spine approximately 3 times as large as smallest proximalmost spine.

In labrum (Figs. 8e, f, 9e), broad distal margin slightly protruded posteroventrally.

Mandible (Figs. 8e, f, 9e) small subconical lobe with 1 long simple seta at apex.

Vestigial maxilla (Fig. 8e, f) anterolateral to maxilliped.

Maxilliped (Figs. 8e, f, 9f) consisting of large coxa, smaller basis (no setae on medial margin), and small endopod. Endopod consisting of 2 short segments proximally and claw-shaped spine terminally.

Legs 1–4 (Fig. 9g–k) alike in shape and size. Sclerotized basis with 1 simple lateral seta. Width of basis 1.5 times as long as exopod. Distal margin of unsclerotized endopod sloping almost evenly from lateral to medial. Distal two-fifths of sclerotized lateral margin of exopod with bifurcate spines, lacking seta posterior to spines. Armature formula for legs 1–4 comparable to that (5,4,4,4) of *H. elongatum.* In legs 1–4, subterminal and lateral spines subequal in size and much smaller than largest terminal spine.

Leg 5 (Figs. 8a, 9l) represented by 2 simple setae (proximal, distal) on dorsal side of subconical lobe of fifth thoracic segment.

Dorsal genital segment (Fig. 10a) between gonopores sclerotized and with 2 hairlike sensilla medially and anteriorly.



Fig. 9. *Haplostoma madagascarensis*, female. a, inverted V-shaped cephalic sclerite, dorsal; b, rostrum and right antennule, anteroventral; c, right antenna, medial, showing third segment with 4 graduated bifurcate spines; d, right antenna, lateral; e, labrum and mandibles (each with long apical seta), ventral; f, left maxilliped, lateral; g, left leg 1, anterior; h, left leg 1, anterolateral; i, left leg 2, anterolateral; j, left leg 3, anterolateral; k, left leg 4, anterolateral; l, left leg 5, dorsal.



Fig. 10. *Haplostoma madagascarensis*, female. a, urosome with caudal rami, dorsal, showing sclerotized genital segment with 2 hairlike sensilla anteriorly between gonopores; b, right gonoporal area, dorsal, showing medial margin of gonopore with spines (external row with 2 unequal sharp conical spines, internal row with 5 conical spines); c, posterior fourth metasomal section with fifth leg and urosome with caudal ramus, left side (arrow indicates location of copulatory pore); d, urosome with caudal rami, ventral, showing copulatory organs located somewhat posteriorly in genital segment; e, copulatory organs, ventral; f, anal segment with caudal rami, dorsal; g, anal segment with caudal ramus, left side; h, anal segment with caudal rami, ventral.

Medial margin of gonopore (Fig. 10b) with 2 rows (external, internal) of spines. External row with 2 unequal sharp conical spines; unarticulated large distal spine twice as large as articulated small proximal spine. Internal row with 5 merely conical spines.

In ventral genital segment (Fig. 10c, d), wide copulatory pore located somewhat posteriorly, not close to posterior margin of segment, and opening internally into seminal receptacle. Seminal receptacle (Fig. 10d, e) widened anteriorly, and enlarged receptacle ducts diverging from anterolateral margins of seminal receptacle.

Anal segment (Fig. 10f-h) approximately 1.3 times as wide (at base) as long (central axis). Ten large mammiform sensilla present; 2 pairs (posterior pair smaller) on posterior half of dorsal surface, 2 pairs on ventral surface, and 1 midway on each lateral surface.

Caudal ramus (Fig. 10f–h) slightly longer than wide (at base), approximately subconical; posterior half narrowed toward rounded terminal margin. Proximal half of dorsal surface without sclerotization. Lateral margin with 1 simple slender seta, and rounded terminal margin with 1 reduced conical spine from dorsal side, this often not visible in ventral view.

Male.—Unknown.

Etymology.—The species name *mada-gascarensis* is given for the general region (Madagascar) where the new species was collected.

Remarks.—Haplostoma madagascarensis resembles H. canui (= H. c., based on Ooishi 1994) in having a similar body form (posterior fourth metasomal section with posterolateral lobes distinctly wider than anterior segments) and the same armature formula (5,4,4,4) for legs 1-4 exopods. However, the following small morphological differences are recognized: 1) rostrum with 2 simple spinules on each sclerotized lateral margin (2 bifurcate spinules, and pair of hairlike sensilla on unsclerotized central portion, in H. c.); 2) antennule with 8 setae and 6 minute elements (17 setae, in H. c.); 3) mandible with 1 long apical seta (short apical seta, in H. c.); 4) copulatory pore not located close to posterior margin of genital segment (close to posterior margin, in H. c); 5) anal segment with 10 large mammiform sensilla (6 small hairlike sensilla, in H. c.); 6) caudal ramus rounded at apex, with 1 reduced conical spine from dorsal side, and dorsal surface without sclerotizaton (apical margin pointed, and dorsal surface with sclerotizaton, in H. c.).

Haplostoma junctum, new species Figs. 11–14

Material examined.—Humes collection no. 921: ascidian host *Eudistoma* sp., reddish brown, attached under surface of rock, intertidal, at Nosy Bé (Antafianambitry), Madagascar, 8 September 1964. Holotype Q (USNM 1127148) and paratypes 9 QQ (USNM 1127149) deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Description of female.—Body (Fig. 11a– c) vermiform, with slight dorsal curvature. Body length, measured along body axis (dorsal side), 2.0 mm. Five specimens examined similar in length. Proportional lengths of cephalosome, metasome, and urosome 1:6:1. Ratio of length of prosome to that of urosome 7:1. Body in general ornamented with many small hairlike sensilla, as illustrated on several structures (Figs. 11d–f, 12a, d).

Cephalosome (Fig. 11a–c) as long as wide. Antennules, antennae, mandibles, and maxillipeds present (Fig. 11d, e); maxillules absent, and maxillae vestigial. Dorsal cephalic sclerite reduced, represented by 2 pairs of narrow short sclerites (Fig. 11f). Rostrum also reduced to small sclerotized structure (Fig. 12a) between proximal antennules.

In metasome (Fig. 11a–c), each of first to fourth segments slightly longer than wide; fourth and fifth segments fused dorsally, forming fourth metasomal section. Greatest width 0.28 mm on third and fourth segments. Posterior fourth metasomal section, with posterolateral lobes (slightly constricted proximally) of fifth segment 0.25 mm wide. Ventrally, first to fifth segments distinguished by arrangement of muscles (Fig. 11c), as in *H. madagascarensis* (Fig. 8c).

Urosome (Figs. 11a–c) subequally divided into 4 segments (genital, 2 abdominal, anal) dorsally. Anal segment not constricted proximally. Caudal rami fused medially. Anus posterodorsal.

Antennule (Figs. 11d, 12a) lobate, unequally 2-segmented; segmentation indistinct. Proportional lengths 3:1. First segment expanded posteriorly, and lateral anterior half articulated with small sec-



Fig. 11. *Haplostoma junctum*, female. a, body form, dorsal; b, body form, left side (arrow indicates location of copulatory pore); c, body form, ventral, showing arrangement of muscles; d, cephalosome, ventral, showing reduced rostrum between antennules, oral area, appendages, and ornamentation of hairlike sensilla in general; e, cephalosome, left side; f, cephalosome, dorsal, showing reduced cephalic sclerites and ornamentation of hairlike sensilla in general.



Fig. 12. *Haplostoma junctum*, female. a, right antennule and reduced rostrum, ventral; b, second segment of right antennule, showing only arrangement of 12 setae on distal margin (1 seta from first segment close to second segment); c, right antenna, medial; d, labrum, mandibles (each with 2 setae), and ornamentation of hairlike sensilla in general, ventral; e, left maxilliped, lateral; f, left leg 1, anterior; g, left leg 1, anterolateral, showing proximalmost spine displaced to anterolateral surface of exopod; h, left leg 2, anterolateral; i, left leg 3, anterolateral; j, left leg 4, anterolateral.

ond segment. Armature (Fig. 12a, b) consisting of 14 simple setae: first segment with 2 setae (larger) on ventral surface near second segment. Second segment with 12 setae (8 short, 4 slender) on apical margin.

Antenna (Figs. 11d, e, 12c) 3-segmented, as in previous 3 new species. Medial margin of small third segment with 4 bifurcate spines; terminal spine largest, subterminal and 2 lateral spines smaller and subequal in size.

In labrum (Figs. 11d, e, 12d), broad distal margin slightly protruded postero-ventrally.

Mandible (Figs. 11d, e, 12d) small subconical lobe with 2 short simple setae terminally.

Vestigial maxilla (Fig. 11d, e) anterolateral to maxilliped.

Maxilliped (Figs. 11d, e, 12e) consisting of large coxa, smaller basis (no setae on medial margin), and small endopod. Endopod directed medially, consisting of 2 short basal segments and 1 bifurcate terminal spine.

Legs 1–4 (Fig. 12f–j) alike in shape and size. Sclerotized basis lacking seta on lateral margin. Width of basis slightly longer than exopod. Distal margin of unsclerotized endopod sloping from lateral to medial. In exopod, distal half of sclerotized lateral margin with bifurcate spines, lacking seta posterior to spines. Armature formulas for legs 1-4 exopods 5,4,4,4, as in H. elongatum and H. madagascarensis. In these exopods, lateral and subterminal spines subequal in size, much smaller than largest terminal spine, and proximalmost lateral spine displaced to anterolateral sclerotized surface of exopod.

Anterolateral surface of exopod close to spines ornamented with patches of many conical spinules (directed laterally). In leg 1 (Fig. 12g), each of 3 lateral spines associated with patch of 10 or more spinules; subterminal and terminal spines with common patch of fewer than 10 spinules. In legs 2–4 (Fig. 12h–j), proximalmost lateral spine with respective patch of 13–20 spinules, but remaining 3 spines (lateral, subterminal, terminal) with common patch of more than 20 spinules.

Leg 5 (Fig. 13a, b, c) represented by 3 simple setae (1 short slender proximal, 2 long large terminal) on dorsal side of subconical lobe of fifth thoracic segment.

In dorsal genital segment (Fig. 13a), sclerotized cuticle between gonopores with 2 hairlike sensilla medially and somewhat anteriorly. Medial margin of gonopore (Fig. 13e) with 2 rows (external, internal) of spines. External row (Figs. 13e, 14a) with 2 remarkably unequal sharp conical spines; unarticulated large distal spine 3 times as large as articulated small proximal spine. Internal row (Figs. 13f, 14b) with 4 merely conical spines.

In ventral genital segment, wide copulatory pore (Fig. 13b, d) located close to posterior margin of segment, opening internally into seminal receptacle. Seminal receptacle (Fig. 13g) wider than long, constricted anteriorly. Somewhat enlarged receptacle ducts diverging from anterior portion of seminal receptacle, becoming slender, and extending toward lateral antra. Cuticle of anterior first abdominal segment (Fig. 13d, g), close to copulatory pore of genital segment, with 2 small sclerotizations on each side.

Anal segment (Fig. 13h–j) wider than long. Ventral anal segment (Fig. 13j) approximately 1.4 times as long as fused caudal rami, with several small hairlike sensilla scattered on surface.

Caudal rami (Fig. 13h–j) fused medially, incompletely on dorsal side, and completely on ventral side. Fused caudal rami indistinctly articulated with anal segment proximally. On dorsal side, each ramus represented by ventrally directed terminal spine on endite. In ventral view, terminal portion of each spine visible posterior to distal margin of segment-like fused caudal rami.



Fig. 13. *Haplostoma junctum*, female. a, posterior fourth metasomal section with fifth legs and urosome, dorsal; b, same specimen, left side (arrow indicates location of copulatory pore); c, left leg 5 (distal portion), lateral; d, 4-segmented urosome with fused caudal rami terminally, ventral, showing location of copulatory organs in genital segment; e, left gonoporal area, dorsal, showing medial margin of gonopore with 2 rows of spines (external row with 2 remarkably unequal sharp conical spines, internal row with 4 conical spines); f, same specimen, ventral, showing internal row with 4 conical spines (with black line); g, copulatory organs and 2 small sclerites on each side, ventral; h, anal segment and fused caudal rami, dorsal, showing caudal rami represented by terminal curved spines; i, same specimen, left side; j, same specimen, ventral, showing caudal rami completely fused on ventral side.



Fig. 14. *Haplostoma junctum*, female, photomicrographs. a, medial margin of left gonopore, dorsal, showing external row with 2 remarkably unequal sharp conical spines; b, same specimen, ventral, showing internal row with only 4 merely conical spines.

Male.—Unknown.

Etymology.—The species name *junctum* is given for the caudal rami, which are fused medially.

Remarks.—Haplostoma junctum resembles *H. dudleyae* (see Ooishi 1998), because the dorsal cephalic sclerite and rostrum are reduced and a lateral seta on the basis of legs 1–4 is lacking (*H. junctum*) or reduced (*H. dudleyae*). However, *H. junctum* is easily distinguished from *H. dudleyae* as well as all other species of *Haplostoma* in having the fused caudal rami.

Discussion

Further common morphological features for seven species of subgroup 2 (*Haplostoma*) were obtained from the following studies: redescription of *H*. *canui* by Ooishi (1994); original descriptions of *H. humesi* and *H. dudleyae* by Ooishi (1995, 1998); and the present descriptions of four new species. Based on a comparative study of the seven species, the primary diagnosis of subgroup 2 is revised. The revised diagnosis is given below as characteristics of subgroup 2. In order to distinguish subgroup 2 from subgroup 1, corresponding characters of subgroup 1 are noted in parentheses after the characters of subgroup 2.

The characters of subgroup 1 (11 species) were obtained from the following studies: description of *H. gibberum* by Schellenberg (1922, partly used); descriptions of *H. albicatum*, *H. minutum*, *H. dentatum*, *H. elegans*, *H. setiferum*, and *H. ambiguum* by Ooishi & Illg (1977); description of *H. kimi* by Seo & Lee (2001); redescriptions of *H. banyulensis* (Brément, 1909) and *H. brevicauda* (Canu, 1886), respectively, by Ooishi (2004a, 2004b); and redescription of *H. eruca* (Norman, 1886) by Ooishi & O'Reilly (2004).

Characteristics of subgroup 2.-1) in antenna, third segment small, and lateral margin close to distal margin of second segment and medial margin with 4 bifurcate spines (third segment free, not especially small, medial margin with simple spines, or spines and setae, in subgroup 1); 2) mandible a small lobe with 1 (in general) or 2 (rarely) apical setae, rarely vestigial (mandible with 2 setae, in subgroup 1); 3) in maxilliped, medial margin of basis lacking setae (with 2 setae, in subgroup 1); 4) in legs 1-4, distal margin of endopods sloping from lateral to medial (protruded distally, in subgroup 1); 5) leg 1–4 exopods with bifurcate spines, lacking seta posterior to spines (simple spines, with 1 seta posterior to spines, in subgroup 1); 6) leg 5 with 2 (proximal, distal) or rarely 3 (proximal, 2 distal) setae (1 proximal and 2 distal, in subgroup 1); 7) caudal ramus subconical, shortened, or both rami fused medially

(subconical, neither shortened nor fused, in subgroup 1). It is obvious that the appendages of subgroup 2 are morphologically more reduced than those of subgroup 1.

Key to species (females) of *Haplostoma* (subgroup 2)

1a. In legs 1–4, basis with 1 lateral seta; armature formula (bifurcate spines) for legs 1–4 exopods 5,4,5,5 or 5,4,4,4; dorsal cephalic sclerite and rostrum developed; mandible present

2

6

3

4

- 1b. In legs 1–4, lateral seta on basis lacking or reduced; armature formula (bifurcate spines) for legs 1–4 exopods 5,4,4,4; dorsal cephalic sclerite and rostrum reduced; mandible present or vestigial
- 2a. Armature formula for legs 1–4 exopods 5,4,5,5; caudal ramus subconical, with 1 lateral seta and 2 blunt unequal terminal spines *H. bispinosum*
- 2b. Armature formula for legs 1–4 exopods 5,4,4,4; caudal ramus subconical or shortened, with various armature of elements
- 3a. Caudal ramus subconical, with various armature of elements
- 3b. Caudal ramus shortened, with 1 lateral seta and 1 curved pointed terminal spine *H. humesi* Ooishi, 1995
- 4a.Caudal ramus with 2 setae (dorsal, lateral) on mid-portion, and terminal margin pointed, with 1 articulated conical spine H. elongatum
- 5a.Caudal ramus pointed at apex, and pointed tip not developed as claw or spine; anal segment ornamented with small hairlike sensilla; mandible with 1 short apical seta

- 6a. Mandible present, with 2 terminal setae; in legs 1–4, lateral seta on basis lacking; caudal rami medially fused, and each represented by 1 curved terminal spine from dorsal side *H. junctum*
- 6b.Mandible vestigial; in legs 1–4, lateral seta on basis reduced; caudal ramus shortened, with 1 seta on lateral margin, and rounded terminal margin lacking armature

. H. dudleyae Ooishi, 1998 Relationship of ascidian hosts to copepod associates of subgroup 2.-Seven species of subgroup 2 are associated with three genera of compound ascidians: 1) H. canui, *H. bispinosum, *H. elongatum, and *H. madagascarensis, with Polyclinum; 2) H. dudleyae and *H. junctum, with Eudistoma; and 3) *H. humesi, with Aplidium. Except for H. canui (Channel coast of France) and H. dudleyae (Atlantic coast of Florida), the remaining five species (each denoted with an asterisk) occur in the Indian Ocean (Madagascar). Four of the 10 known species of Haplostomides live in Polyclinum (see Ooishi 2008), but no Haplostoma species (11) of subgroup 1 have been found in Polyclinum to date.

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