Species of Taeniacanthus Sumpf, 1871 (Crustacea: Copepoda: Taeniacanthidae) parasitic on boxfishes (Tetraodontiformes: Aracanidae and Ostraciidae) from the Indo-West Pacific region...

Article *in* Systematic Parasitology · October 2011

DOI: 10.1007/s11230-011-9318-7 · Source: PubMed

3 authors, including:

Danny Tang
Orange County Sanitation District
42 PUBLICATIONS **187** CITATIONS
SEE PROFILE

Daisuke Uyeno
Florida Museum of Natural History
77 PUBLICATIONS **217** CITATIONS
SEE PROFILE

Syst Parasitol (2011) 80:141–157
DOI 10.1007/s11230-011-9318-7

Species of *Taeniacanthus* Sumpf, 1871 (Crustacea: Copepoda: Taeniacanthidae) parasitic on boxfishes (Tetraodontiformes: Aracanidae and Ostraciidae) from the Indo-West Pacific region, with descriptions of two new species

Danny Tang · Daisuke Uyeno · Kazuya Nagasawa

Received: 16 May 2011 / Accepted: 23 June 2011

Abstract Two new copepod species of the genus *Taeniacanthus* Sumpf, 1871 (Cyclopoida: Taeniacanthidae) are described from boxfishes (Aracanidae and Ostraciidae) caught in the Indo-West Pacific region: *T. larsonae* n. sp. from *Ostracion nasus* Bloch in the Arafura Sea and off Australia and *Tetrosomus concatenatus* (Bloch) off Japan; and *T. thackerae* n. sp. from *O. immaculatus* Temminck & Schlegel off Palau, *O. rhinorhynchos* Bleeker off Australia, *Lactoria cornuta* (Linnaeus) and *Ostracion* sp. off Japan, and *Kentrocapros aculeatus* (Houttuyn) in the East China Sea. *T. larsonae* n. sp. differs from its congeners by having several rows of spinules on the large pectinate process of the antenna and by differences in the shape of the sclerotised plates on the rostral area and structure of the maxilliped. *T. thackerae* n. sp. can be distinguished from its congeners by differences in the shape of the sclerotised plates on the rostral area, the structure of the maxilliped and ornamentation pattern of legs 1–4. Supplemental information for the female of *Taeniacanthus ostracionis* (Richiardi, 1870) and *T. moa* (Lewis, 1967), as well as the first description of the male of *T. moa*, are also provided based on new material collected from ostraciid hosts caught in the Arafura Sea and off Australia, Indonesia and Japan. The four taeniacanthid species reported from boxfishes exhibit variable levels of host-specificity and have broad geographical ranges within the Indo-West Pacific region.

D. Tang (✉)
Department of Zoology (M092), The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia
e-mail: copepods@gmail.com

D. Tang · D. Uyeno · K. Nagasawa
Laboratory of Aquaculture, Department of Bioresource Science, Graduate School of Biosphere Science, Hiroshima University, 1-4-4 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8528, Japan

D. Uyeno
Department of Chemistry, Biology and Marine Science, Faculty of Science, University of the Ryukyus, 1 Senbaru, Nishihara, Okinawa 903-0213, Japan

Introduction

The Taeniacanthidae C. B. Wilson, 1911 is a unique family in the copepod order Cyclopoida Rafinesque, 1815, as this group includes members that are parasites of sea urchins and fishes (Boxshall & Halsey, 2004). In their revision of Taeniacanthidae, Dojiri & Cressey (1987) recognised 14 genera, which together contained 91 species. Since then, three new genera (*Biacanthus* Tang & Izawa, 2005, *Caudacanthus* Tang & Johnston, 2005 and *Makrostrotos* Ho & Lin, 2006) and the following 12 new species of taeniacanthids from elasmobranch and teleost hosts have been established: *Pseudotaeniacanthus margolisi* Johnson & Kabata, 1995 and *P. septemsetigerus*

Johnson & Kabata, 1995, each from an unidentified moray eel (Muraenidae) in the Gulf of Aqaba, Red Sea (Johnson & Kabata, 1995); *Taeniastrotos braziliensis* Montú & Boxshall, 1997 from *Cathorops spixii* (Agassiz) (as *Cathrops* [sic] *spixii*) in the Baia Paranagua, Santa Catarina, Brazil (Montú & Boxshall, 1997); *Irodes kuwaitensis* Ho, Kim & Sey, 1999 from *Upeneus sulphureus* Cuvier in Kuwait Bay, Arabian Gulf (Ho et al., 1999); *Taeniacanthodes dojirii* Braswell, Benz & Deets, 2002 from *Narcine entemedor* Jordan & Starks in the Gulf of California (Braswell et al., 2002); *Makrostrotos acuminatus* Ho & Lin, 2006 and *M. hamus* Ho & Lin, 2006 from *Gymnothorax favagineus* Bloch & Schneider from off Taiwan (Ho & Lin, 2006); *Irodes parupenei* Ho & Lin, 2007 from *Parupeneus spilurus* (Bleeker) and *Taeniacanthus spinifer* Ho & Lin, 2007 from *Acanthocepola limbata* (Valenciennes) both off Taiwan (Ho & Lin, 2007); and *Pseudotaeniacanthus dentiferus* Lin & Ho, 2008, *P. similis* Lin & Ho, 2008 and *P. conspicuus* Lin & Ho, 2008 from *G. favagineus* off Taiwan (Lin & Ho, 2008). In this paper we describe two new copepod species of *Taeniacanthus* Sumpf, 1871 collected from boxfishes (Aracanidae and Ostraciidae) caught in the Indo-West Pacific region, include supplemental information for the female of *T. ostracionis* (Richiardi, 1870) and *T. moa* (Lewis, 1967), and provide the first description of the male of *T. moa*.

Materials and methods

Freshly caught boxfish samples from off the central Ryukyu Islands, Okinawa Prefecture, Japan, were obtained by spear fishing and were purchased at fishing ports, and one freshly caught host from the western North Pacific Ocean, off Tosasaga, Japan, was purchased at a fishing port. Preserved boxfish specimens accessioned at the Museum and Art Gallery of the Northern Territory (MAGNT), Darwin, Australia, and the Faculty of Science of the University of the Ryukyus (URM), Nishihara, Japan, were also inspected for parasitic copepods. Copepods were removed from the hosts with fine forceps and preserved in 70% ethanol. Additional copepod material was obtained as follows: (a) specimens collected in Australian waters were generously placed at our disposal by Dr Brian Jones (Department of Fisheries, Western Australia); (b) Dojiri & Cressey's (1987) voucher specimens of *Taeniacanthus ostracionis* were borrowed from the National Museum of Natural History (USNM), Smithsonian Institution, USA, for comparative purposes; and (c) copepod specimens collected from *Ostracion immaculatus* Temminck & Schlegel captured off Palau by Dr Masaaki Machida were borrowed from the National Museum of Nature and Science (NSMT), Tokyo, Japan.

Preserved copepod specimens were soaked in lactic acid for a minimum of 24 h prior to examination using an Olympus SZ60 dissection microscope and an Olympus BX50 compound microscope. Selected specimens were measured intact using an ocular micrometer and/or dissected and examined according to the wooden slide procedure of Humes & Gooding (1964). Measurements given are the mean followed by the standard deviation. Selected intact specimens and dissected appendages were also drawn with the aid of a drawing tube. Morphological terminology follows Dojiri & Cressey (1987) and Huys & Boxshall (1991) and fish names conform to FishBase (Froese & Pauly, 2011).

Type and/or voucher material is deposited at MAGNT, NSMT and the Western Australian Museum (WAM), Perth, Australia.

Taeniacanthus larsonae n. sp.

Type-host: *Ostracion nasus* Bloch.
Additional host: *Tetrosomus concatenatus* (Bloch).
Type-locality: Off Cobourg Peninsula, Northern Territory, Australia.
Material examined: 5 adult females (1 damaged), ex 1 *Ostracion nasus* Bloch (MAGNT S.10031-066), Cobourg Peninsula, Northern Territory, Australia, 20 October 1981; 3 adult females, ex 1 *O. nasus* (MAGNT S.13284-001), Beagle Gulf, Northern Territory, Australia, 2 September 1992; 7 adult females (1 damaged), ex 2 *O. nasus* (MAGNT S.12942-008), Arafura Sea, 22 October 1990; 9 adult females, ex 1 *O. nasus* (MAGNT S.12938-003), Arafura Sea, 21 October 1990; 10 adult females, ex unknown number of *O. nasus*, Shark Bay, Western Australia, 1 July 1962, donated by Dr Brian Jones; 1 adult female, ex *Tetrosomus concatenatus* (Bloch), western North Pacific Ocean, Tosasaga, Kochi Prefecture, Japan, 11 May 2006.

Type-material: Holotype female (MAGNT Cr015022) and 4 female paratypes (1 damaged) (MAGNT Cr015023–Cr015025).
Additional material deposited: MAGNT Cr015027–Cr015030 and Cr015032 (19 adult females) and WAM C38717 (10 adult females) from *O. nasus*; and NSMT-Cr 21641 (1 female) from *T. concatenatus*.
Attachment site: Branchial cavity wall.
Etymology: This species is named for Dr Helen K. Larson, Curator of Fishes at the Museum and Art Gallery of the Northern Territory, Australia.

Description (Figs. 1–3)

Adult female
Body 1.06 ± 0.07 mm long (excluding caudal rami setae) and 0.43 ± 0.02 mm wide (n = 8) (Fig. 1A). Prosome 0.72 ± 0.06 mm long, composed of broad cephalothorax (1st pedigerous somite fused with cephalosome) and 3 narrower pedigerous somites. Cephalothorax bears highly sclerotised transverse bar and marginal hyaline membrane. Urosome comprised of 5th pedigerous somite, genital double-somite and 3 free abdominal somites. Genital double-somite wider (141 ± 4 μm) than long (97 ± 9 μm), ornamented with rows of minute spinules and pair of sensilla and pores on ventral surface (Fig. 1B). Abdomen (Fig. 1B) 167 ± 5 μm long and 105 ± 6 μm wide; first abdominal somite naked; second abdominal somite bears pair of sensilla and pores on ventral surface; ventral surface of anal somite with 3 interrupted rows of spinules anteriorly and row of spinules on each posterolateral corner. Caudal ramus (Fig. 1C,D) longer (39 ± 2 μm) than wide (25 ± 0 μm), bears 7 setae (seta I minute); setae II and III with row of minute spinules at base; setae IV and V ornamented with medial row of bristles and lateral row of spinules; seta VII about 0.50 times as long as seta VI; seta V longest, at least twice length of seta IV.

Rostral area (Fig. 1E) with 2 sclerotised structures on each side of T-shaped sclerotised plate. Antennule (Fig. 1F) 6-segmented (articulation between ancestral segments XIV–XVII and XVIII–XX not expressed); armature formula: 5, 15, 8, 4, 2 + 1 aesthetasc and 7 + 1 aesthetasc. Antenna (Fig. 1G) composed of coxobasis and 2 endopodal segments; coxobasis with distal seta; 1st endopodal segment with inner seta; 2nd endopodal segment bears 2 unequal pectinate processes, 3 claw-like spines and 4 unequal setae; large pectinate process with seta and several rows of spinules; short pectinate process with minute blunt seta and row of spinules. Postantennal process (Fig. 1H) relatively elongate, curved distally.

Labrum (Fig. 2A) with row of spinules on ventromedian surface and along posterior margin. Mandible (Fig. 2B) armed with 2 apical blades and bristled accessory seta; both blades spinulate along inner margin. Paragnath (Fig. 2C) ornamented with apical row of minute spinules and 2 patches of minute spinules on ventral surface. Maxillule (Fig. 2D) lobate, bears semi-pinnate seta, anterior knob-like process and 2 long and 2 short naked setae. Maxilla (Fig. 2E) 2-segmented; syncoxa unarmed; basis armed with spinulate terminal process, long spinulate spine and short naked seta. Maxilliped (Fig. 2F,G) 3-segmented; syncoxa large, irregularly-shaped, bears naked seta; basis with 2 proximal naked setae and distomedial protrusion; endopod elongate, curved distally, bears 2 unequal naked setae, minute spinules apically and well-developed inner basal protrusion ornamented with hyaline membrane.

Legs 1–4 biramous (Figs. 2H, 3A–G); leg 1 with bimerous rami; other legs with trimerous rami. Armature on rami of legs 1–4 as follows (Roman numerals = spines; Arabic numerals = setae; int. = intermediate spine):

	Coxa	Basis	Exopod	Endopod
Leg 1	0-1	1-1	1-0; 9	0-1; 7
Leg 2	0-0	1-0	I-0; I-1; II, I, 4	0-1; 0-1; II, I, 3
Leg 3	0-0	1-0	I-0; I-1; II, I, 5	0-1; 0-1; II, I, 2
Leg 4	0-0	1-0	I-0; I-1; II, I, 4	0-1; 0-1; I, I, int.

Leg 1 (Fig. 2H) coxa, basis and rami flattened. Intercoxal sclerite subtriangular, ornamented with fine spinules on anterodistal surface. Coxa with patch of setules on outer border; coxa and basis ornamented with rows of minute spinules. Outer margin of second endopodal segment with patch of setules. Leg 2 intercoxal sclerite (Fig. 3A) triangular, ornamented with rows of spinules along posterior margin. Coxa with large spinules along distolateral margin and rows of minute spinules scattered on anterior surface. Basis ornamented with patch of minute spinules on anterior surface, rows of spinules along inner margin and row of spinules along posterior margin. Leg 2

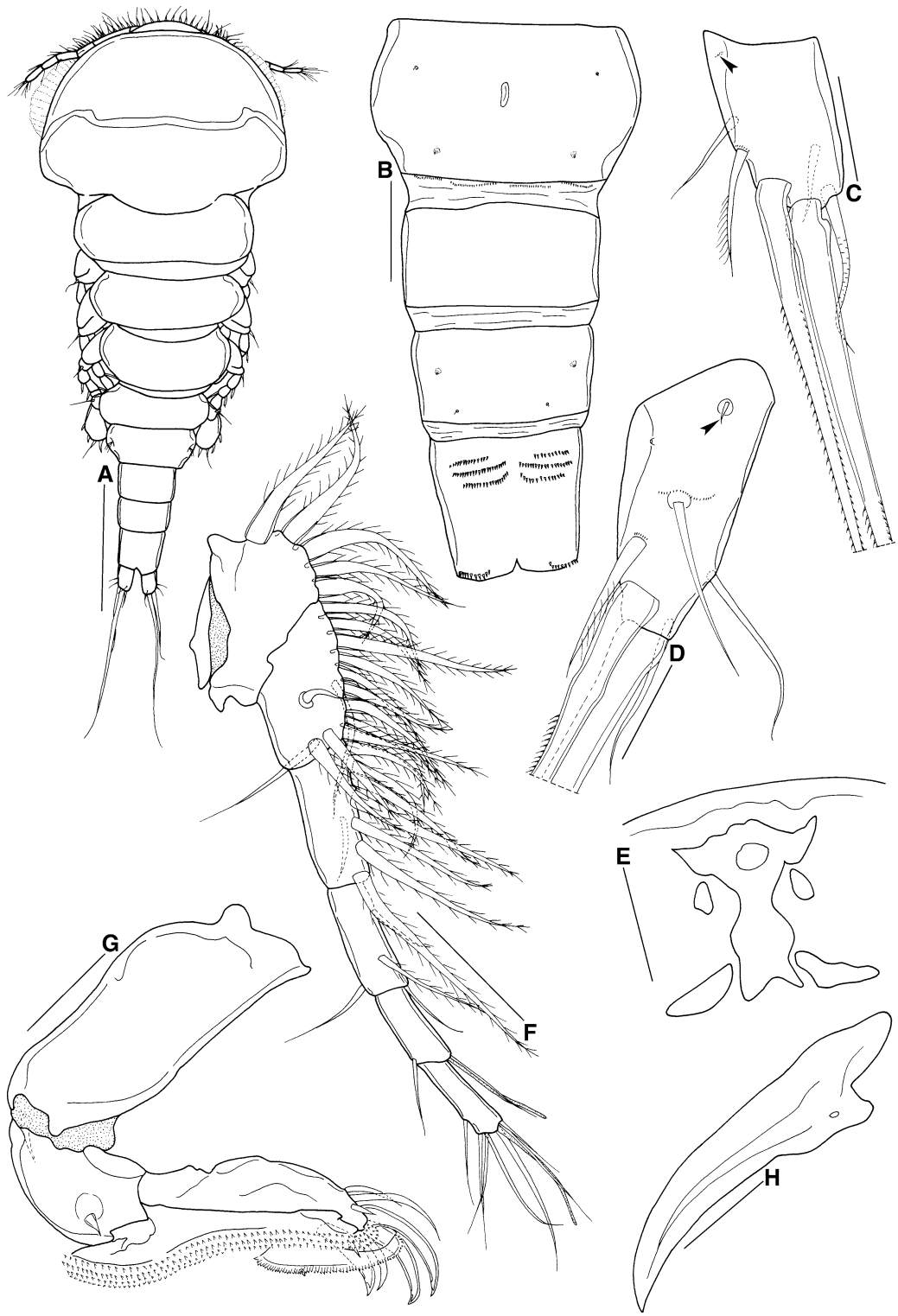


Fig. 1 *Taeniacanthus larsonae* n. sp., adult female. A, habitus, dorsal; B, genital double-somite and abdominal somites, ventral; C, caudal ramus (seta I indicated by arrowhead), ventral; D, same (seta I indicated by arrowhead), lateral; E, rostral area, ventral; F, antennule, ventral; G, antenna, anterior; H, postantennal process, medial. *Scale-bars*: A, 0.2 mm; B,F, 50 μm; C–E,G–H, 25 μm

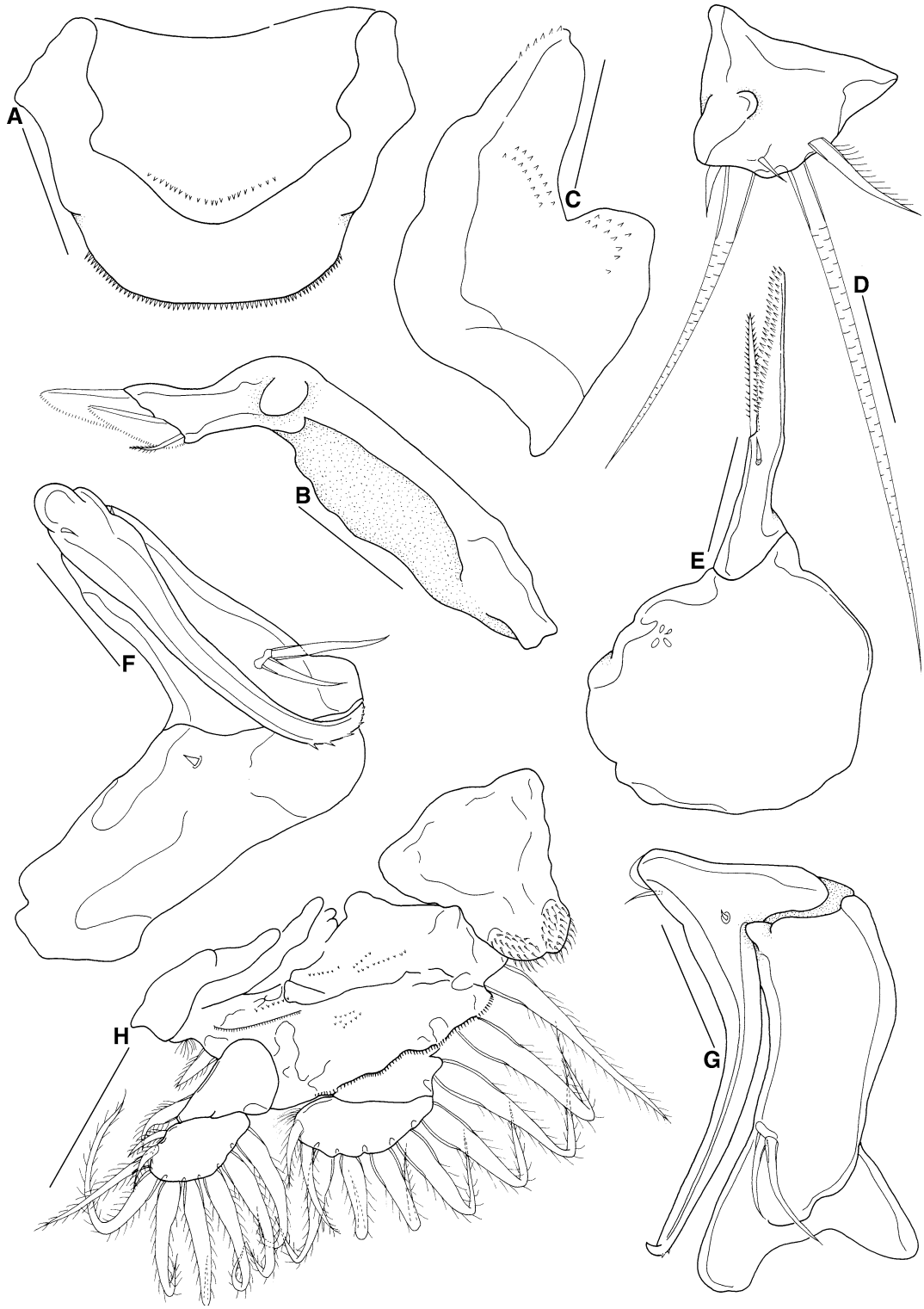


Fig. 2 *Taeniacanthus larsonae* n. sp., adult female. A, labrum, ventral; B, mandible, dorsal; C, paragnath, ventral; D, maxillule, anterior; E, maxilla, ventral; F, maxilliped, medial; G, same, posterior; H, leg 1, ventral. *Scale-bars*: A,B,D–F,G, 25 μm; C, 12.5 μm; H, 50 μm

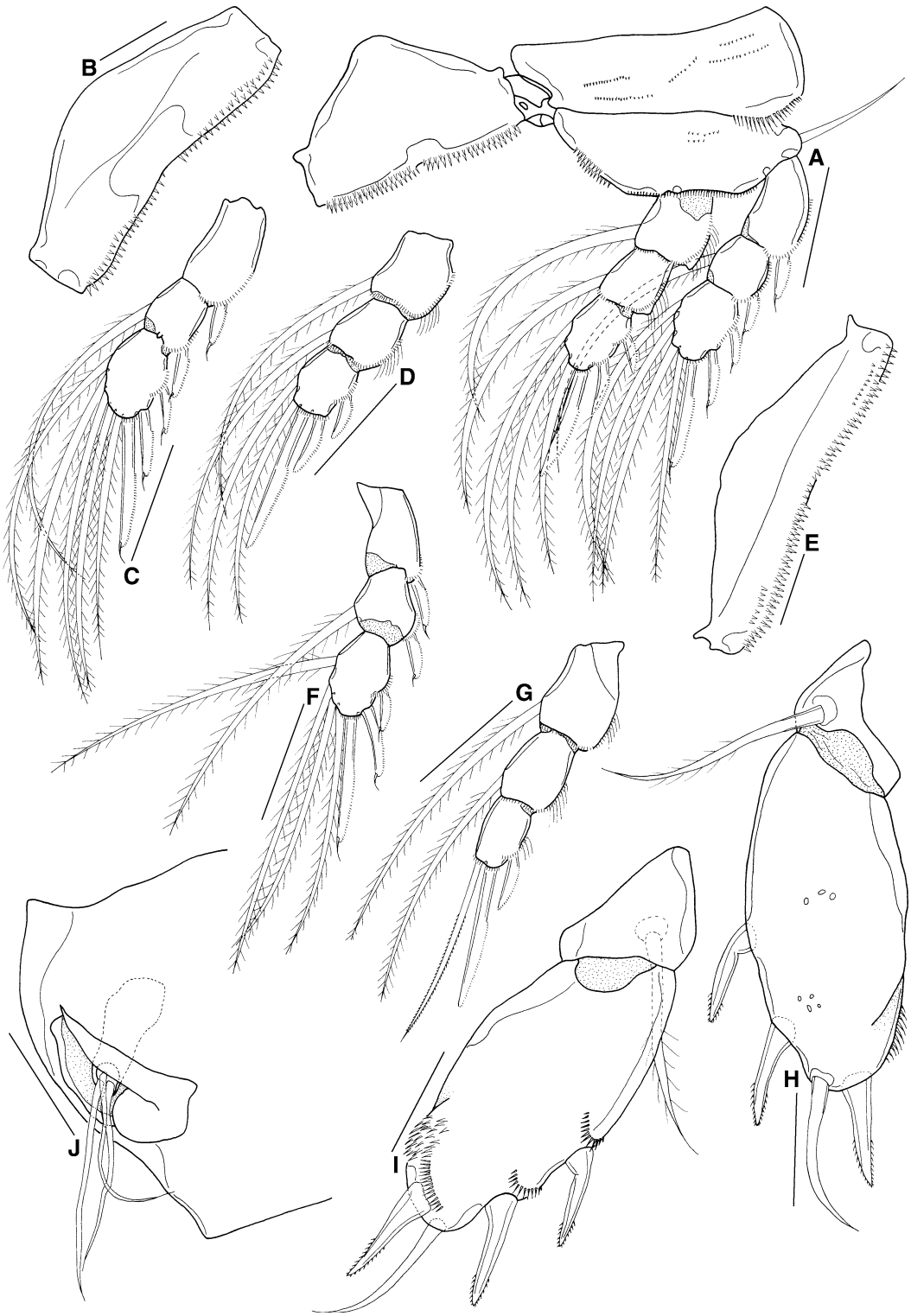


Fig. 3 *Taeniacanthus larsonae* n. sp., adult female. A, leg 2, anterior; B, leg 3 intercoxal sclerite, anterior; C, leg 3 exopod, anterior; D, leg 3 endopod, anterior; E, leg 4 intercoxal sclerite, anterior; F, leg 4 exopod, anterior; G, leg 4 endopod, anterior; H, leg 5, dorsomedial; I, same, ventrolateral; J, leg 6, dorsal. *Scale-bars*: A,C–D,F–G, 50 μm; B,E,H–J, 25 μm

exopodal spines (Fig. 3A) spinulate along outer margin, each with accessory terminal flagellum; outer margin of exopod segments ornamented with row of spinules. Leg 2 endopodal segments (Fig. 3A) with row of spinules along lateral margin; first 2 segments also slightly protruded distolaterally and with row of setules along outer border; spines on terminal segment spinulate along outer margin.

Intercoxal sclerite of legs 3 and 4 (Fig. 3B,E) wider than long, spinulate along posterior margin. Coxa and basis of legs 3 and 4 similar to those of leg 2, except without inner row of spinules on basis. Structure of spines and ornamentation of rami of legs 3 (Fig. 3C,D) and 4 (Fig. 3F,G) as in leg 2, except terminal segment of leg 4 endopod with additional outer row of setules. First 2 endopodal segments of legs 3 and 4 without distolateral protrusion.

Leg 5 (Fig. 3H,I) well developed, 2-segmented. Protopodal segment unornamented, armed with dorsolateral pinnate seta. Free exopodal segment ornamented with patch of spinules on distomedial surface and row of spinules at base of each spine and armed with 3 spinulate spines and naked seta. Leg 6 (Fig. 3J) vestigial, represented by opercular plate armed with 3 naked setae at egg sac attachment area.

Adult male: Unknown.

Remarks

T. larsonae n. sp. resembles *T. ostracionis* (Richiardi, 1870) and the new species described immediately below. For the distinguishing features of *T. larsonae* n. sp., see the 'Remarks' section of the following taxon.

Taeniacanthus thackerae n. sp.

Type-host: *Ostracion rhinorhynchos* Bleeker.
Additional hosts: *Lactoria cornuta* (Linnaeus), *Kentrocapros aculeatus* (Houttuyn) and *Ostracion* sp.
Type-locality: Off Port Essington, Northern Territory, Australia.
Material examined: 4 adult females, 1 adult male and 1 copepodid, ex 1 *Ostracion rhinorhynchos* Bleeker (MAGNT S.10432-010), Port Essington, Northern Territory, Australia, 3 March 1982; 4 adult females, ex 1 *Lactoria cornuta* (Linnaeus) (URMP0522), East China Sea, Sesoko-jima Island, Okinawa Islands, Okinawa Prefecture, Japan, July 1978; 36 adult females and 2 adult males, ex 1 *L. cornuta* (URMP6621), East China Sea, Chinen, Okinawa-jima Island, Okinawa Prefecture, Japan, 28 January 1983; 1 adult female, ex *Kentrocapros aculeatus* (Houttuyn) (URMP30740), East China Sea, 13 November 1993; 5 adult females, ex unknown number of *O. immaculatus* Temminck & Schlegel, Ngeremlengui, Palau, 24 June 1980, leg. M. Machida; 8 adult females, ex 1 *Ostracion* sp., western North Pacific Ocean, Tohbaru, Henza-jima Island, Okinawa Islands, Okinawa Prefecture, Japan, October 2008; 22 adult females and 6 adult males, ex 1 *Ostracion* sp., Tohbaru, Henza-jima Island, Okinawa Islands, Okinawa Prefecture, Japan, 18 October 2008.
Type-material: Holotype female (MAGNT Cr015033), allotype male (MAGNT Cr015034) and 4 paratypes (3 adult females and 1 copepodid) (MAGNT Cr015035–Cr015037).
Additional material deposited: NSMT-Cr 21634 and 21636 (40 females and 2 males) from *L. cornuta*; NSMT-Cr 21639 (1 female) from *K. aculeatus*; NSMT-Cr 21645 (5 females) from *O. immaculatus*; and NSMT-Cr 21642 and 21644 (30 females and 6 males) from *Ostracion* sp.
Attachment sites: Branchial cavity wall and gill filaments.
Etymology: The species epithet is dedicated to Dr Christine Thacker, Associate Curator of Ichthyology at the Natural History Museum of Los Angeles County, USA.

Description (Figs. 4–5)

Adult female
Body 1.18 ± 0.15 mm long (excluding caudal rami setae) and 0.45 ± 0.02 mm wide (n = 3) (Fig. 4A). Prosome composed of broad cephalothorax (1st pedigerous somite fused with cephalosome) and 3 progressively narrower pedigerous somites. Cephalothorax with highly sclerotised transverse bar on dorsal surface. Urosome composed of 5th pedigerous somite, genital double-somite and 3 free abdominal somites. Genital double-somite wider (153 ± 8 μm) than long (107 ± 11 μm). Abdomen 153 ± 20 μm long and 120 ± 10 μm wide; ventral surface of anal somite (Fig. 4B) with 3 transverse rows of stout

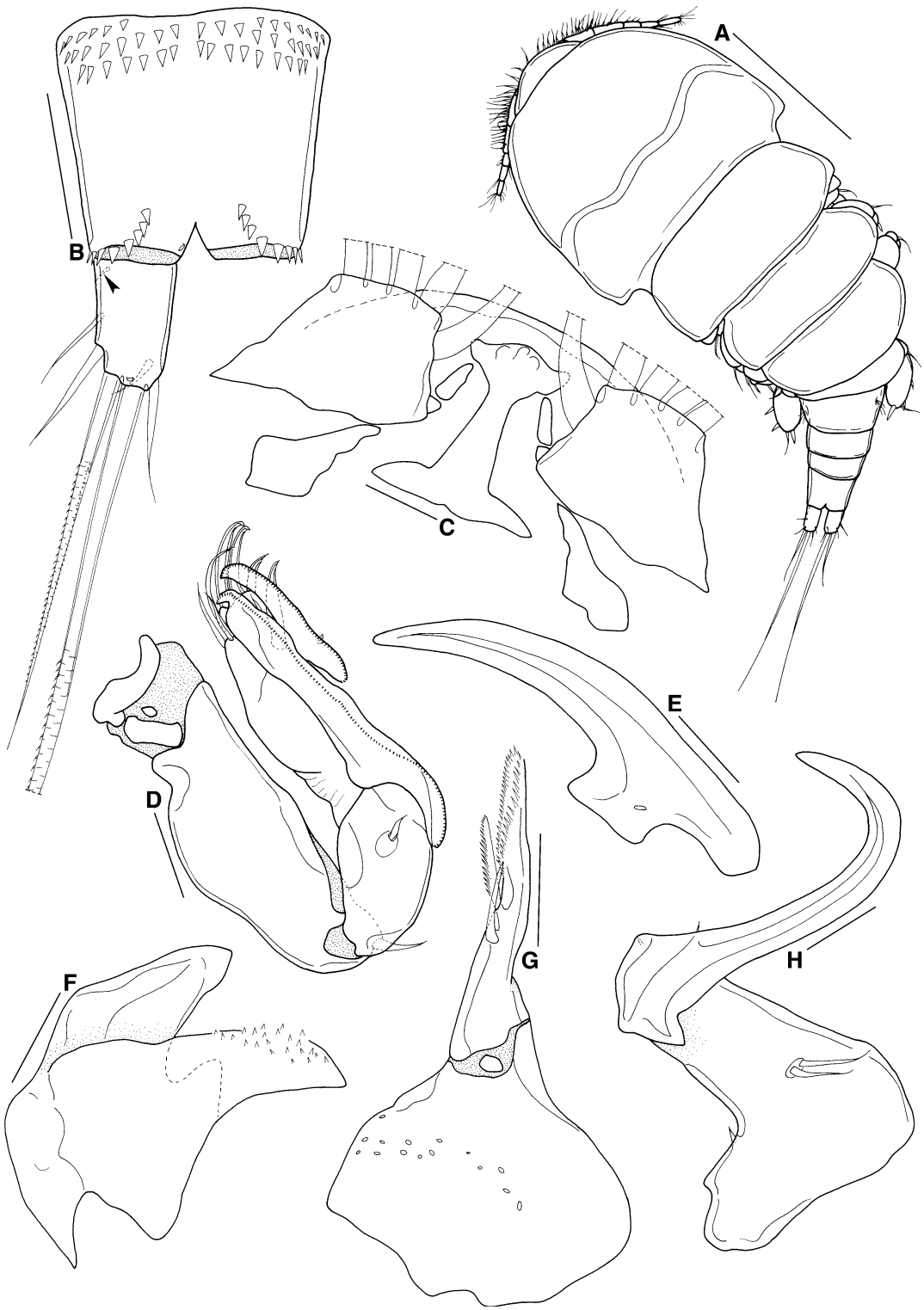


Fig. 4 *Taeniacanthus thackerae* n. sp., adult female. A, habitus, dorsal; B, anal somite and right caudal ramus (seta I indicated by arrowhead), ventral; C, rostral area, ventral; D, antenna, anterior; E, postantennal process, medial; F, paragnath, ventrolateral; G, maxilla, ventral; H, maxilliped, anterior. *Scale-bars*: A, 0.3 mm; B, 50 μm; C–E,G–H, 25 μm; F, 12.5 μm

spinules anteriorly and curved row of stout spinules near insertion of each caudal ramus. Caudal ramus (Fig. 4B) longer (38 ± 3 μm) than wide (25 ± 0 μm), bears 7 setae (seta I smallest); seta IV with inner row of barbules and outer row of spinules; seta V with outer row of spinules only; all other setae naked.

Rostral area (Fig. 4C) slightly protuberant, bears inverted T-shaped structure flanked anteriorly by 2 small sclerotised plates and posteriorly by 2 large plates. Antennule, labrum, mandible and maxillule similar to those in *T. larsonae* n. sp. Antenna (Fig. 4D) 3-segmented (2nd and 3rd endopodal segments fused); coxobasis bears usual distal seta; 1st endopodal segment with inner seta; 2nd endopodal segment bears 2 unequal pectinate processes, 4 claw-like spines and 3 unequal setae; large pectinate process with seta and row of minute spinules; short pectinate process with minute seta and row of minute spinules. Postantennal process (Fig. 4E) slender and slightly curved. Paragnath (Fig. 4F) with basal patch of minute spinules. Maxilla (Fig. 4G) 2-segmented; syncoxa bears numerous pores; basis armed with spinulate terminal process and 2 subequal elements (spine with unilateral row of spinules; seta naked). Maxilliped (Figs. 4H, 5A) 2-segmented (syncoxa and basis fused); basal segment armed with minute seta and 2 longer naked setae; endopod elongate, claw-like and strongly curved, bears large thorn-like process on proximal anterior surface, minute basal seta and small spiniform process on posterior surface.

Armature and structure of legs 1–4 similar to those of *T. larsonae* n. sp., except for the following features. Leg 1 intercoxal sclerite (Fig. 5B) with stout spinules along distal margin; coxa with short row of setules along outer border and several rows of spinules on anterior surface; basis bears distal row of spinules. Leg 2 intercoxal sclerite (Fig. 5C) with cluster of long spinules posterolaterally and continuous row of unequal spinules along distal margin; coxa with row of spinules along distolateral margin; basis with patch of long spinules along inner border and distal row of spinules. Intercoxal sclerite of legs 3 (Fig. 5D) and 4 (Fig. 5E) with cluster of spinules on each posterior corner and discontinuous row of spinules along distal margin. Leg 5 (Fig. 5F) protopod bears dorsolateral unipinnate seta and ventrolateral row of short spinules; free exopodal segment with 3 stout spinulate spines, naked seta, several rows of spinules on distomedial corner and row of spinules at base of each spine. Leg 6 (not figured) as in *T. larsonae* n. sp.

Adult male

Body 0.79 ± 0.05 mm long (excluding caudal rami setae) and 0.29 ± 0.02 mm wide (n = 2) (Fig. 5G). Posterodorsal surface of cephalothorax with pair of bifurcate, sclerotised structures. Second pedigerous somite 220 ± 14 μm wide; remaining prosomites narrower than 2nd prosomite. Genital somite length and width almost equal (105 ± 7 × 111 ± 6 μm). Abdomen 136 ± 20 μm long and 79 ± 5 μm wide, composed of 3 free somites. Caudal ramus longer (31 ± 2 μm) than wide (20 ± 0 μm).

Postantennal process (Fig. 5H) strongly curved. Maxilliped (Fig. 5I) 4-segmented; syncoxa (not figured) with usual distal seta; basis well developed, with 2 medial setae, longitudinal row of squarish denticles posteromedially and longitudinal row of minute spinules anteromedially; 1st endopodal segment small, naked and unarmed; 2nd endopodal segment a curved claw, bears posterior seta, 2 anterior setae, basal tooth and 2 rows of blunt denticles along concave margin.

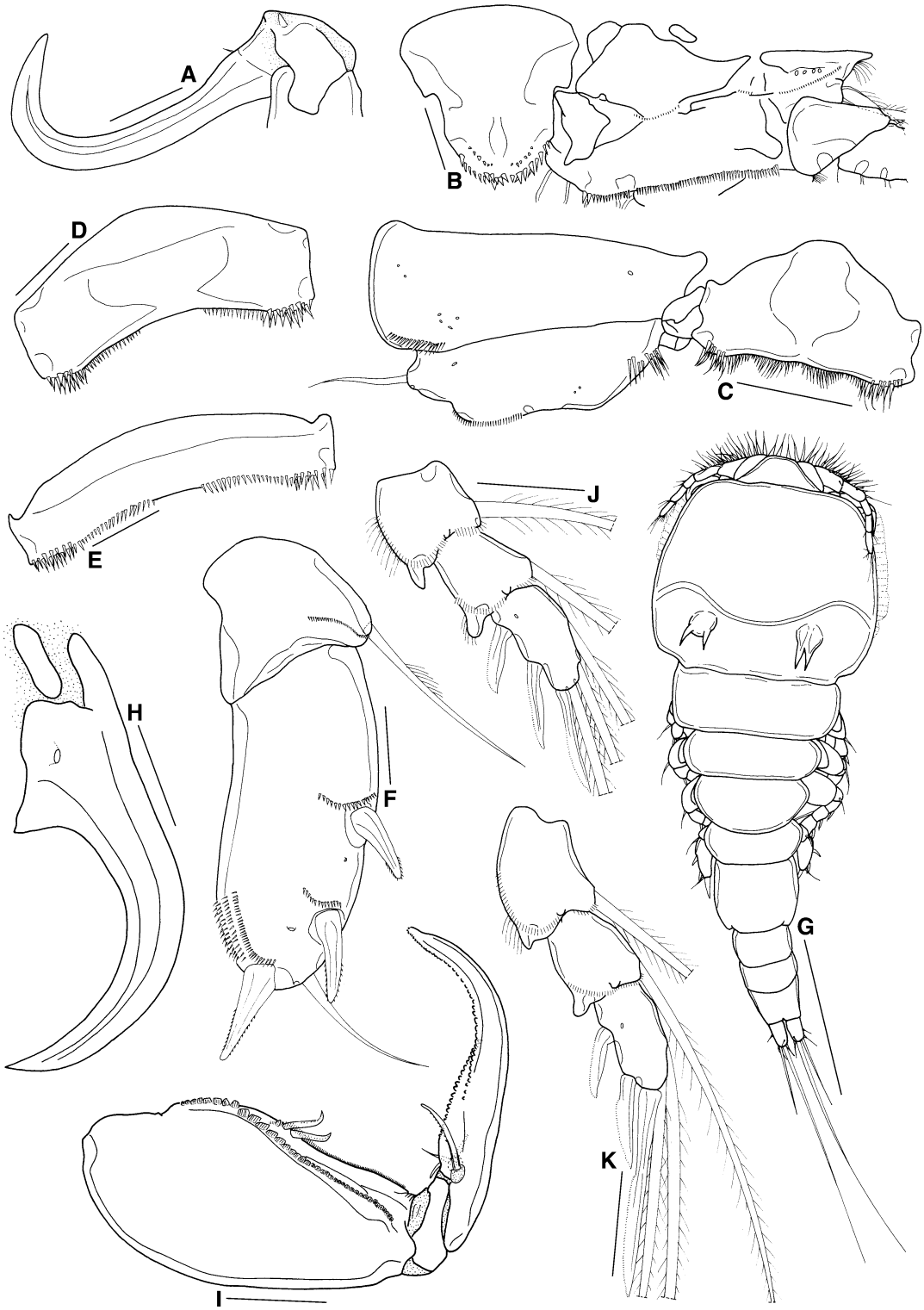
First and 2nd endopodal segments of legs 2 (Fig. 5J) and 3 (Fig. 5K) with well-developed distolateral protrusion; apical spine on 3rd endopodal segment of leg 2 considerably shorter than that of leg 3. Leg 6 (not figured) vestigial, represented by unarmed opercular plate on posteroventral surface of genital somite.

Variability

One female with armature II, I, 4 on 3rd exopodal segment of right leg 3 (not figured).

Remarks

T. thackerae n. sp. resembles *T. larsonae* n. sp. and *T. ostracionis* based on the following features: (1) a transverse sclerotised bar on the cephalothorax; (2) three free abdominal somites; (3) a 6-segmented antennule; (4) an armature formula of II, I, 5 on the third exopodal segment of leg 3; and (5) a terminal flagellum on each exopodal spine of legs 2–4. *T. thackerae* can be differentiated from the other two species by the structure of the maxilliped [2-segmented, with a large thorn-like process on the


A
B
D
C
E
J
H
F
G
K
I

◀ **Fig. 5** *Taeniacanthus thackerae* n. sp., adult female (A–F) and adult male (G–K). A, distal end of maxilliped, posterior; B, leg 1 intercoxal sclerite, coxa and basis, ventral; C, leg 2 intercoxal sclerite, coxa and basis, anterior; D, leg 3 intercoxal sclerite, anterior; E, leg 4 intercoxal sclerite, anterior; F, leg 5, lateral; G, habitus, dorsal; H, postantennal process, medial; I, maxilliped (syncoxa omitted), posterior; J, leg 2 endopod, anterior; K, leg 3 endopod, anterior. *Scale-bars*: A–B,D–F,J–K, 25 μm; C, 50 μm; G, 0.2 mm; H, 20 μm; I, 30 μm

anterior surface of the claw (endopod) and lacking any inner basal protrusion on the claw], and differences in the shape of the sclerotised plates on the rostral area and ornamentation pattern of the intercoxal sclerite, coxa and basis of legs 1–4 in the female. *T. larsonae* can be distinguished from *T. ostracionis* and *T. thackerae* by the shape of the sclerotised plates on the rostral area and having a naked protopod on leg 5, several rows of spinules on the large pectinate process of the antenna, a short naked seta on the terminal segment of the maxilla, a distomedial protrusion on the posterior surface of the maxilliped basis and a prominent basal protrusion ornamented with a hyaline membrane on the maxilliped claw (endopod) in the female.

Taeniacanthus ostracionis (Richiardi, 1870)

Material examined: 2 adult females, ex 1 *Tetrosomus gibbosus* (Linnaeus) (MAGNT S.13354-001), Arafura Sea, 12 November 1990; 9 adult females, ex 3 *T. gibbosus* (MAGNT S.11672-035), Northwest Shelf, Australia, 2 June 1985; 2 adult females, ex 1 *T. gibbosus* (MAGNT S.12978-003), Arafura Sea, 31 October 1990; 9 adult females (USNM 229423), ex *Lactoria cornuta* (Linnaeus) (USNM 176885), Great Barrier Reef, Queensland, Australia, leg. M. Dojiri & R. F. Cressey.
Voucher specimens: MAGNT Cr015038–Cr015043 (13 adult females).
Attachment sites: Branchial cavity wall and gill filaments.

Description (Fig. 6)

Adult female
Body 1.08 ± 0.04 mm long (excluding caudal rami setae) and 0.51 ± 0.03 mm wide (n = 5) (Fig. 6A). Genital double-somite (Fig. 6B) with several patches of minute spinules on ventromedian surface. Caudal ramus (Fig. 6C) with 7 setae (seta I minute).

Remarks

This species was originally described as *Bomolochus ostracionis* by Richiardi (1870), but was later transferred to *Taeniacanthus* by Dojiri & Cressey (1987). The specimens examined in this study conform to the description and illustrations provided by Dojiri & Cressey (1987), except for the presence of spinules on the ventral surface of the genital double-somite and seta I on the caudal rami of our specimens. Examination of Dojiri & Cressey's (1987) *T. ostracionis* specimens revealed that these authors simply overlooked those two features. *T. ostracionis* resembles *T. thackerae* n. sp., but it can be distinguished from the latter species by the unique configuration of the rostral plates and having a conspicuous inner basal protrusion on the maxilliped claw in the female.

Taeniacanthus moa (Lewis, 1967)

Material examined: 31 adult females (2 damaged), ex 5 *Ostracion cubicus* Linnaeus (MAGNT S.14982-007), off Indonesia, December 1995; 1 adult female and 6 adult males, ex 1 *O. cubicus*, East China Sea, Seragaki, Okinawa-jima Island, Okinawa Prefecture, Japan, 1 July 2007; 21 adult females, ex 1 *Ostracion meleagris* Shaw, East China Sea, Mizugama, Okinawa-jima Island, Okinawa Prefecture, Japan, 22 July 2007; 7 adult females and 1 copepodid V female, ex 1 *O. meleagris*, East China Sea, Maeda Cape, Okinawa-jima Island, Okinawa Prefecture, Japan, August 2005; 6 adult females and 2 adult males, ex 1 *O. meleagris*, East China Sea, Gahi-jima Island, Okinawa Islands, Okinawa Prefecture, Japan, 27 May 2006; 1 adult female, ex 1 *Ostracion* sp., western North Pacific Ocean, Tohbaru, Henza-jima Island, Okinawa Islands, Okinawa Prefecture, Japan, 18 October 2008.
Voucher specimens: MAGNT Cr015016–Cr015021 (31 adult females) and NSMT-Cr 21640 (1 female and 6 males) from *O. nasus*; NSMT-Cr 21635 and 21637–21638 (34 females, 2 males and 1 copepodid V female) from *O. meleagris*; and NSMT-Cr 21643 (1 female) from *Ostracion* sp.

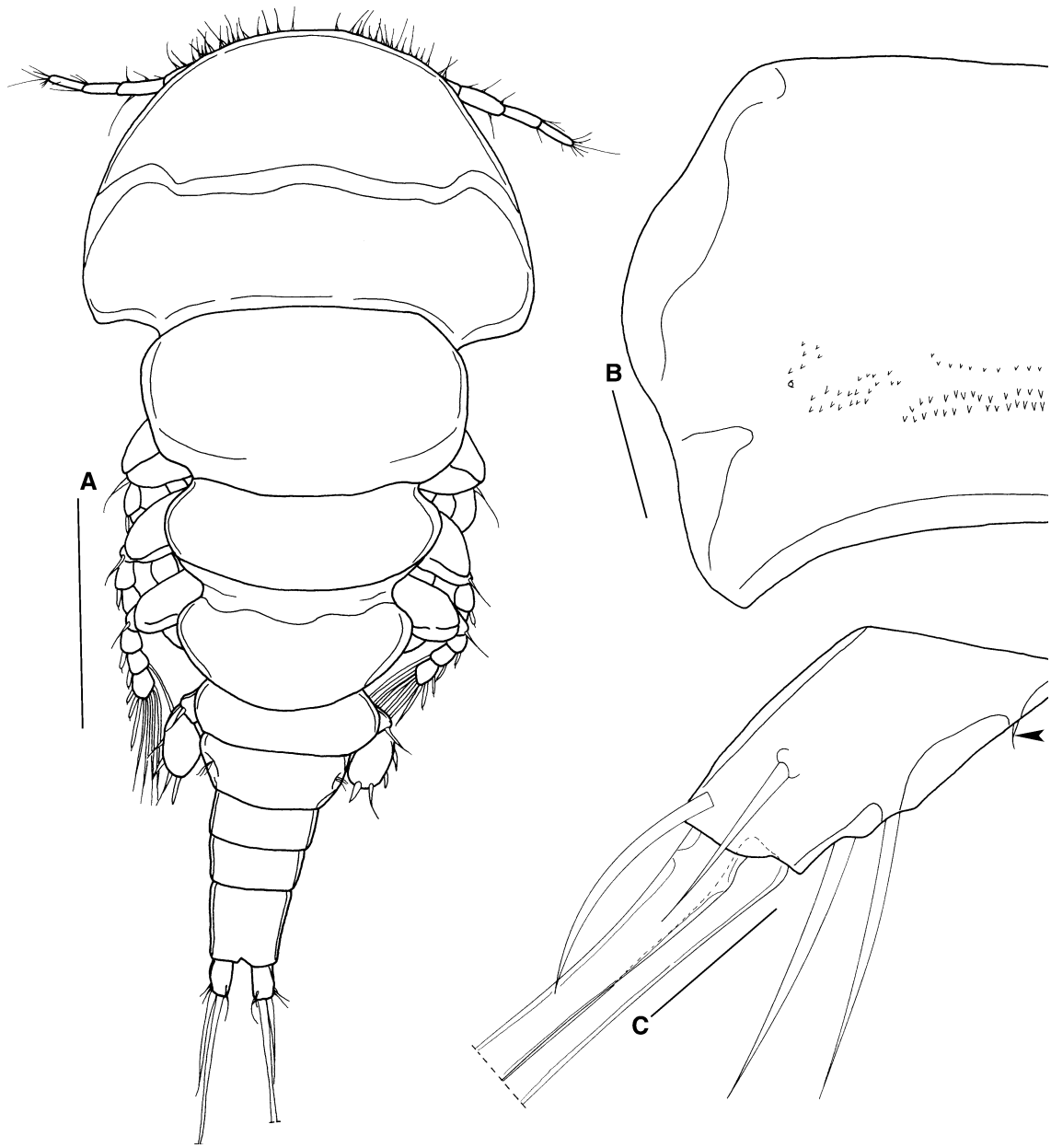


Fig. 6 *Taeniacanthus ostracionis* (Richiardi, 1870), adult female. A, habitus, dorsal; B, genital double-somite, ventral; C, caudal ramus (seta I indicated by arrowhead), dorsal. *Scale-bars*: A, 0.25 mm; B–C, 25 μm

Attachment sites: Branchial cavity wall and gill filaments.

Description (Figs. 7–8)

Adult female

Body 1.01 ± 0.03 mm long (excluding caudal rami setae) and 0.57 ± 0.03 mm wide (n = 4) (Fig. 7A). Caudal ramus (Fig. 7B) with 7 setae (seta I minute). Distomedial corner of maxilliped basis (Fig. 7C) with bilobed protrusion.

Adult male

Body 0.57 ± 0.03 mm long (excluding caudal rami setae) and 0.25 ± 0.02 mm wide (n = 2) (Fig. 7E). Posterior margin of cephalothorax with 2 pairs of tines (inner pair larger than outer pair). Second pedigerous

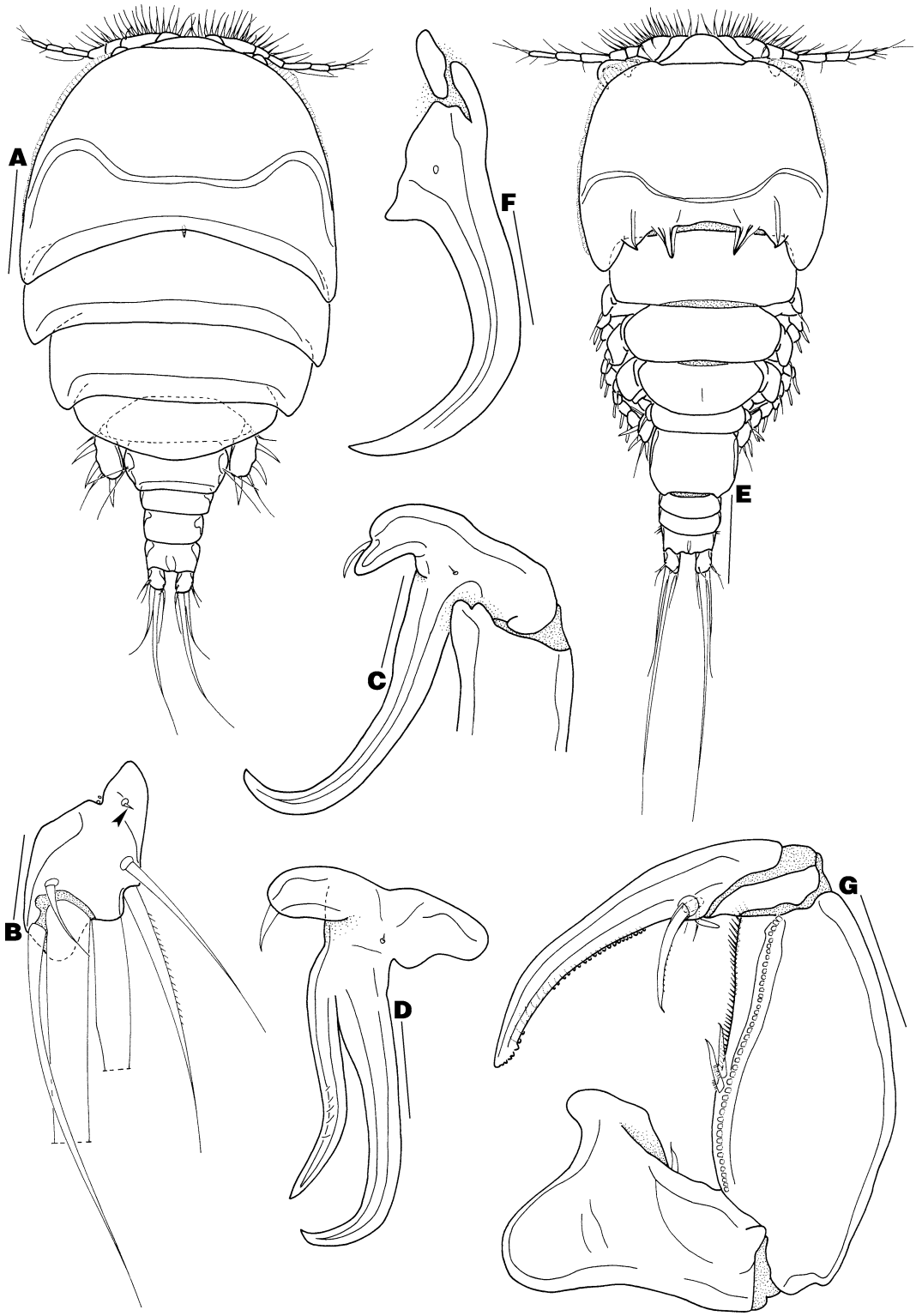


Fig. 7 *Taeniacanthus moa* (Lewis, 1967), adult female (A–D) and adult male (E–G). A, habitus, dorsal; B, caudal ramus (seta I indicated by arrowhead), dorsal; C, distal end of maxilliped, posterior; D, maxilliped claw, posterior; E, habitus, dorsal; F, postantennal process, medial; G, maxilliped, posterior. *Scale-bars*: A, 0.2 mm; B–D, 25 μm; E, 0.1 mm; F, 20 μm; G, 30 μm

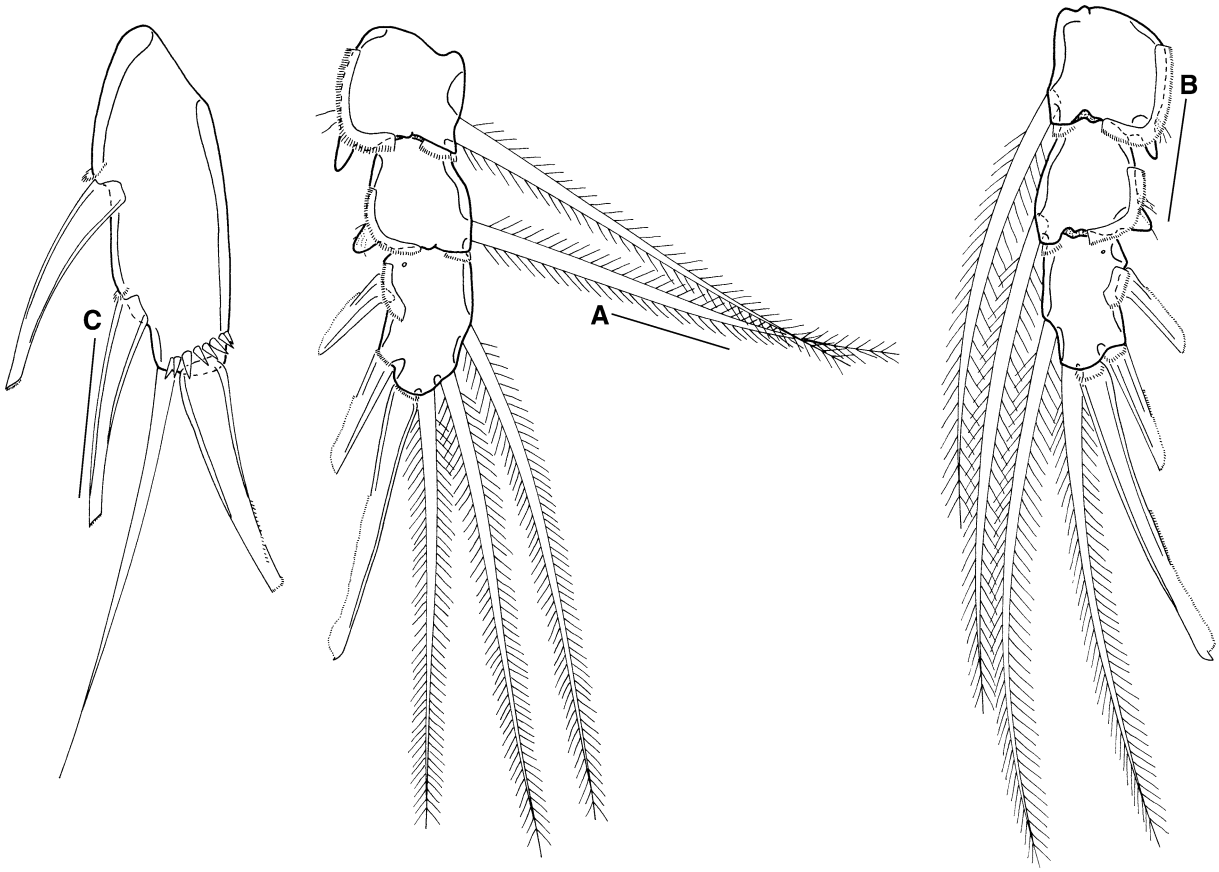


Fig. 8 *Taeniacanthus moa* (Lewis, 1967), adult male. A, leg 2 endopod, anterior; B, leg 3 endopod, anterior; C, free exopodal segment of leg 5, ventral. *Scale-bars*: A–C, 20 μm

somite 197 ± 11 μm wide; remaining prosomites narrower than 2nd prosomite. Genital somite wider than long (69 ± 2 × 95 ± 0 μm). Abdomen 61 ± 2 μm long and 66 ± 2 μm wide, composed of 3 free somites. Caudal ramus longer (20 ± 0 μm) than wide (17.5 ± 0 μm).

Postantennal process (Fig. 7F) strongly curved. Maxilliped (Fig. 7G) 4-segmented; syncoxa with middle inner seta; basis well developed, with 2 medial setae, longitudinal row of squarish denticles posteromedially and longitudinal row of spinules anteromedially; 1st endopodal segment small, naked and unarmed; 2nd endopodal segment a curved claw, bearing posterior seta, 2 anterior setae, basal tooth and row of blunt denticles along concave margin.

First and 2nd endopodal segments of legs 2 (Fig. 8A) and 3 (Fig. 8B) with well-developed distolateral protrusion. Free exopodal segment of leg 5 (Fig. 8C) narrow, with fringe of minute spinules at base of outer spines and large spinules at base of innermost spine. Leg 6 (not figured) vestigial, represented by unarmed opercular plate on posteroventral surface of genital somite.

Variability

One female with bifurcate claw on left maxilliped (Fig. 7D).

Remarks

This species was originally described as a member of *Anchistrotos* Brian, 1906 by Lewis (1967), but was subsequently transferred to *Taeniacanthus* by Dojiri & Cressey (1987). Our specimens, apart from the presence of seta I on the caudal rami, conform to the excellent redescription provided by Dojiri & Cressey (1987). Although a distomedial protrusion on the female maxilliped basis of *T. moa* was observed in

Table 1 Boxfish (Aracanidae and Ostraciidae) hosts and marine localities of *Taeniacanthus* spp.

Copepod	Host	Locality	Reference
T. larsonae n. sp.	*Ostracion nasus* Bloch[a]	Arafura Sea	Present study
		Australia	Present study
	Tetrosomus concatenatus (Bloch)[a]	Japan	Present study
T. moa (Lewis, 1967)	*Ostracion cubicus* Linnaeus[a] (as *O. tuberculatus* Linnaeus)	Australia	Ho & Dojiri (1976)
	Ostracion cubicus Linnaeus[a]	Indonesia[d]	Present study
		Japan[d]	Present study
	Ostracion meleagris Shaw[a] (as *O. lentiginosum* Bloch & Schneider)	Hawaiian Islands (USA)	Lewis (1967);
		Fijian Islands	Dojiri & Cressey (1987)
			Dojiri & Cressey (1987)
	Ostracion meleagris Shaw[a]	Japan[d]	Present study
	Ostracion sp.[a]	Japan[d]	Present study
T. ostracionis (Richiardi, 1870)	*Lactoria cornuta* (Linnaeus)[a] (as *Ostracion cornutus* Linnaeus)	Africa	Richiardi (1870)
	Lactoria cornuta (Linnaeus)[a]	Australia	Dojiri & Cressey (1987)
	Tetrosomus gibbosus (Linnaeus)[a,c]	Arafura Sea[d]	Present study
		Australia	Present study
T. thackerae n. sp.	*Kentrocapros aculeatus* (Houttuyn)[b]	East China Sea	Present study
	Lactoria cornuta (Linnaeus)[a]	Japan	Present study
	Ostracion immaculatus Temminck & Schlegel[a]	Palau	Present study
	Ostracion rhinorhynchos Bleeker[a]	Australia	Present study
	Ostracion sp.[a]	Japan	Present study

[a] Species of the Ostraciidae

[b] Species of the Aracanidae

[c] New host record

[d] New locality record

this study, we note here that Dojiri & Cressey (1987) illustrated, but did not describe, a similar structure in their material [cf. Fig. 7C herein and fig. 48B in Dojiri & Cressey (1987)]. *T. moa* shares a highly sclerotised transverse bar on the cephalothorax, three free abdominal somites, an elongate maxilliped claw and a terminal flagellum on each exopodal spine of legs 2–4 with *T. ostracionis*, *T. larsonae* n. sp. and *T. thackerae* n. sp. *T. moa* can be readily distinguished from those three species by having an ovoid prosome, a short anal somite furnished on the ventral surface with three anterior rows of large spinules and a posterior row of numerous short spinules, seven antennulary segments, an armature of II, I, 4 on the third exopodal segment of leg 3, the seta on the free exopodal segment of leg 5 longer than the segment itself and two (of three) setae on leg 6 extending to the second abdominal somite in the female.

Discussion

Morphology

The caudal ramus of copepods may bear a maximum of seven setae: one proximolateral (seta I), one midlateral (seta II), one posterolateral (seta III), two apical (setae IV and V), one posteromedial (seta VI) and one posterodorsal (seta VII) (Huys & Boxshall, 1991). Seta I in taeniacanthid species may be minute and spiniform, as exemplified by *Phagus muraenae* (Brian, 1906) [see fig. 133D in Dojiri & Cressey (1987)] and the four taeniacanthid species reported in this study (see Fig. 1D herein), well developed as in *P. septemsetigerus* Johnson & Kabata, 1995 [see fig. 34 in Johnson & Kabata (1995)] and *P. dentiferus* Lin & Ho, 2008 [see fig. 1B in Lin & Ho (2008)], or, in most cases, apparently absent. Although seta I may

be secondarily lost in many taeniacanthids, there is a distinct possibility that this setal element may have been overlooked by previous workers due predominantly to its miniscule size or, more likely considering its extreme fragility, may have broken off from the caudal ramus of their specimens. Moreover, based on our experience seta I is more easily observed when the caudal ramus is viewed from a lateral or dorsal angle rather than in ventral view, as is typically depicted in descriptions of taeniacanthid species presumably without seta I.

A remarkable feature of the male of *T. moa* and *T. thackerae* n. sp. is, respectively, the double set of tines and the single pair of bifurcate tines on the cephalothorax. The presence of cephalothoracic tines may be a synapomorphy of this group of taeniacanthid species parasitic on boxfishes, but descriptions of the male of *T. larsonae* n. sp. and *T. ostracionis* are needed to bolster this hypothesis. Similar, but non-homologous, cephalothoracic structures are found in five genera (*Vaigamus* Thatcher & Robertson, 1984, *Gamidactylus* Thatcher & Boeger, 1984, *Gamispatulus* Thatcher & Boeger, 1984, *Gamispinus* Thatcher & Boeger, 1984 and *Pseudovaigamus* Amado, Ho & Rocha, 1995) of the Ergasilidae von Nordmann, 1832 (Cyclopoida Rafinesque, 1815) and in some representatives of the Siphonostomatoida Thorell, 1859, such as the paired dorsal styliform processes of *Jusheyus shogunus* Deets & Benz, 1987 (Eudactylinidae C. B. Wilson, 1922) and the paired dorsal stylets of species of *Kroyeria* van Beneden, 1853 (Kroyeriidae Kabata, 1979). Those siphonostome copepods use their cephalothoracic dorsal processes/stylets as secondary attachment structures by inserting them into the gill filament lamellae of their hosts (Deets, 1994; Benz et al., 1999). The cephalothoracic tines of the male of *T. moa* and *T. thackerae* n. sp. probably function in a similar manner.

Host-specificity and geographical distribution

The four taeniacanthid species reported from boxfishes exhibit variable levels of host-specificity and have broad and overlapping geographical ranges within the Indo-West Pacific region (Table 1). *T. larsonae* n. sp. and *T. ostracionis* each have been reported from two host species belonging to two ostraciid genera, whereas *T. moa* has been reported from three host species belonging to one genus (*Ostracion*) of the Ostraciidae. *T. thackerae* n. sp. exhibits the lowest host-specificity, as it was reported from four species of ostraciids and one species of the Aracanidae. It should be noted, however, that additional sampling of *Tetrosomus concatenatus* (Bloch) and *Kentrocapros aculeatus* (Houttuyn) is needed to determine whether they are commonly or rarely infected with *T. larsonae* and *T. thackerae*, respectively, as only one copepod individual was collected from each host during this study. Among the boxfish hosts, *Lactoria cornuta* (Linnaeus) and *Ostracion* sp. are the only two species known to host more than one taeniacanthid species. *T. larsonae* was discovered off the coasts of Australia and Japan and in the Arafura Sea. *T. moa* was previously reported from off the Hawaiian Islands, the Fijian Islands and Australia, and found in this study from two new localities, Japan and Indonesia. *T. ostracionis* was previously collected from off the African and Australian coasts and newly recorded from the Arafura Sea. *T. thackerae* was found off the coasts of Palau, Australia and Japan and in the East China Sea.

Acknowledgements We thank Chad Walter (Smithsonian Institution) and Toshiaki Kuramochi (National Museum of Nature and Science) for kindly arranging loans of copepod material, Helen Larson (Museum and Art Gallery of the Northern Territory) and Tetsuo Yoshino (University of the Ryukyus) for allowing us to collect copepods from preserved fish specimens, Brian Jones (Department of Fisheries, Western Australia) for providing copepod samples and two anonymous reviewers for their constructive comments. This research was made possible through financial support from the Department of Zoology at the University of Western Australia, the Ocean Exposition Commemorative Park Management Foundation, Okinawa, to K.N. and the Japan Society for the Promotion of Science Postdoctoral Fellowship (Grant No. 21-09117) to D.T.

References

Benz, G. W., Fennessy, C. J., & Vogelbein, W. K. (1999). New host and ocean records and remarks on the morphology and behavior of *Jusheyus shogunus* (Copepoda: Siphonostomatoida: Eudactylinidae). *Journal of Parasitology, 85*, 809–814.

Boxshall, G. A., & Halsey, S. H. (2004). *An introduction to copepod diversity*. London: The Ray Society, 966 pp.

Braswell, J. S., Benz, G. W., & Deets, G. B. (2002). *Taeniacanthodes dojirii* n. sp. (Copepoda: Poecilostomatoida: Taeniacanthidae), from Cortez electric rays (*Narcine entemedor*: Torpediniformes: Narcinidae) captured in the Gulf of California, and a phylogenetic analysis of and key to species of *Taeniacanthodes*. *Journal of Parasitology, 88*, 28–35.

Deets, G. B. (1994). *Copepod-chondrichthyan coevolution: a cladistic consideration*. PhD Thesis, The University of British Columbia, 448 pp.

Dojiri, M., & Cressey, R. F. (1987). Revision of the Taeniacanthidae (Copepoda: Poecilostomatoida) parasitic on fishes and sea urchins. *Smithsonian Contributions to Zoology, 447*, 1–250.

Froese, R., & Pauly, D. (2011). *FishBase. World Wide Web electronic publication*. http://www.fishbase.org/, version (4/2011).

Ho, J.-s., & Dojiri, M. (1976). Parasitic copepods on the fishes of the Great Barrier Reef, Australia Part I. Cyclopoida. *Publications of the Seto Marine Biological Laboratory, 23*, 257–273.

Ho, J.-s., & Lin, C. L. (2006). Two Species of *Makrostrotos* gen. nov. (Copepoda: Taeniacanthidae) parasitic on the laced moray (*Gymnothorax favagineus* Bloch and Schneider) in Taiwan. *Zoological Studies, 45*, 578–585.

Ho, J.-s., & Lin, C. L. (2007). Two new species of taeniacanthid copepods (Poecilostomatoida) parasitic on marine fishes of Taiwan. *Systematic Parasitology, 67*, 73–80.

Ho, J.-s., Kim, I. H., & Sey, O. (1999). New species of *Irodes* (Copepoda, Taeniacanthidae) parasitic on goatfish from Kuwait, with a key to the species of *Irodes*. *Pakistan Journal of Marine Sciences, 8*, 123–129.

Humes, A. G., & Gooding, R. U. (1964). A method for studying the external anatomy of copepods. *Crustaceana, 6*, 238–240.

Huys, R., & Boxshall, G. A. (1991). *Copepod evolution*. London: The Ray Society, 468 pp.

Johnson, S. C., & Kabata, Z. (1995). Two new copepod species of the genus *Pseudotaeniacanthus* Yamaguti and Yamasu, 1959 (Poecilostomatoida: Taeniacanthidae), parasitic on moray eels in the Red Sea. *Canadian Journal of Fisheries and Aquatic Sciences, 52*(Suppl. 1), 166–174.

Lewis, A. G. (1967). Copepod crustaceans parasitic on teleost fishes of the Hawaiian Islands. *Proceedings of the United States National Museum, 121*, 1–204.

Lin, C. L., & Ho, J.-s. (2008). Three species of *Pseudotaeniacanthus* Yamaguti & Yamasu, 1959 (Copepoda, Taeniacanthidae) parasitic on laced moray (*Gymnothorax favagineus*) in Taiwan. *Proceedings of the Biological Society of Washington, 121*, 177–190.

Montú, M. A., & Boxshall, G. A. (1997). A new species of *Taeniastrotos* Cressey (Copepoda: Poecilostomatoida) from southern Brazil. *Systematic Parasitology, 36*, 109–114.

Richiardi, S. (1870). Intorno ad una nuova specie del genere *Bomolochus* (*B. ostracionis*). *Archivio per la Zoologia, l'Anatomia e la Fisiologia, 2*, 47–59.