

A New Species of *Thetispelecaris* (Crustacea: Peracarida) from Submarine Cave on Grand Cayman Island

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ABSTRACT—A new species of the peracaridan order Bochsacea, *Thetispelecaris yurikago*, is described from a submarine cave on Grand Cayman Island, the Caribbean Sea. The new species is the fourth species of the order and family, and the second of the genus. Recent studies have strongly suggested a close phylogenetic affinity between cave-dwelling and deep-sea taxa in the Bochsacea as recognized in other cavernicolous/deep-sea crustaceans such as amphipods and copepods. The morphology of the gut and female reproductive system is observed for the first time in the Bochsacea: the stomach is complex with structures such as ridges, processes, spinules, and hairs in the lumen; paired gonopores are located near the base of the fifth pereopods on the sternite.

Key words: *Thetispelecaris*, Peracarida, Bochsacea, submarine cave, Grand Cayman Island

INTRODUCTION

The enigmatic peracaridan order Mictacea accommodated only three species: *Hirsutia bathyalis* Sanders, Hessler and Garner, 1985 from a muddy bottom at a depth of 1000 m off the tropical Atlantic, *H. sanderstalia* Just and Poore, 1988 from a mud and silt bottom at a depth of 1500 m off southeastern Australia, and *Mictocaris halope* Bowman and Iliffe, 1985 from a marine cave on Bermuda, each genus of which constituted its own family, the Hirsutiidae and the Mictocarididae. The Mictacea was distinguished from the other peracaridan orders by the combination of the following features (Bowman *et al.*, 1985): (1) the cephalon fused with the first thoracic somite, which is covered with the cephalothoracic shield; (2) lack of the posterior carapace fold; (3) eyestalks present or absent; (4) both rami of uropod multisegmented; (5) antennules with 3-segmented peduncle and 2 multisegmented flagella; (6) antennae with 5-segmented peduncle bearing scale; (7) mandibles with incisor widely separated from molar process; (8) maxillules lacking palp; (9) maxillipeds without an epipod; (10) pereopods I-V or II-VI with natatory exopods, without branchiae;

(11) coxa-basis articulation of pereopods monocondylic; (12) limb plane of the endopods of pereopods bending only at merus-carpus articulation; (13) oostegites originating from the coxa of pereopods I-V or II-VI, armed or unarmed; (14) pleopods I-V rudimentary, unisegmented, separate from or fused to the body; (15) male pleopod II modified; (16) the presence of manca larva. Phylogenetic relationships between peracaridan orders have been intensively debated since 1904 when Calman established the superorder Peracarida, and are as yet incompletely solved, partly because of the lack of a strict homologous comparison between peracaridan orders (Hessler and Watling, 1999; Watling, 1999).

Recently Gutu and Iliffe (1998) described a new hirsutiid, *Thetispelecaris remex* Gutu and Iliffe, 1998, from anchialine and submarine caves of Bahamas, and established a new order, Bochsacea to accommodate the family Hirsutiidae. Simultaneously Gutu (1998) erected a new order, Cosinzeneacea to contain the family Mictocarididae together with the Spelaeogriphacea. Consequently the order Mictacea proposed by Bowman *et al.* (1985) was ranked as a suborder of the Cosinzeneacea (Gutu, 1998).

During a faunal survey in 2000 of submarine caves on Grand Cayman Island in the Caribbean Sea, the third author discovered a bochsacean and a thermosbaenacean crustaceans. The present paper describes the new species of the Bochsacea and comments on phylogenetic relation-

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ships between cavernicolous and deep-sea crustaceans. The morphology of the gut and the female reproductive system are also described.

MATERIALS AND METHODS

Bochusaceans were collected in a submarine cave named by local SCUBA divers as "The Mouse Trap" (see Davis, 1999). The cave is located in a coral reef approximately 400 m offshore on the west side of the Grand Cayman Island (19° 19' 14.8" N, 81° 23' 22.8" W). The cave opens at depth of about 10 m with an entrance ca. 1 m high and ca. 2 m wide, and extends toward the island. The cave consists at least of two parts: the first part is an almost horizontal, straight tube ca. 15 m long and the second part is a crevicular tube of unknown length. The two are connected by a narrow passage that spirals down to the bottom about 34 m deep. The cave was filled with normal seawater at the time of collecting, but Davis (1999) mentioned that there is a slight outflow of green fresh water during the rainy summer months. Bochusaceans inhabited the middle to the end of the first part, where the floors were covered with a substantial amount of mud and it was totally dark. They were collected with hand-held fine-mesh nets (mouth diameter 30 cm; mesh size 0.35 mm) by brushing the under-surface of rocks on the bottom sediments. The wall and ceiling of the cave were covered densely with tube-dwelling annelids. Other animals were scarce, except for some acroid bivalves.

The bodies and appendages of the new bochusaceans were observed in lactophenol and gum-chloral media, respectively, with a differential interference/phase contrast microscope (Nikon Optiphot). Type specimens are deposited at the National Science Museum, Tokyo (NSMT-Cr). Four partly damaged adult females from the same locality were rinsed with distilled water, dehydrated by ethanol series, critical point dried, sputter-coated with gold, and then observed with a scanning electron microscope (Jeol T-20). Body lengths were measured from anterior tip of rostrum to posterior tip of telson excluding setae. Terminology follows Bowman and Iliffe (1985) and Sanders *et al.* (1985). The internal structures of the stomach are tentatively identified by reference to those of isopods (Schmitz, 1992), mysids (Nath and Pillai, 1973) and euphausiids (Suh and Nemoto, 1988). Reproductive systems are referred to those of Thermosbaenacea (Monod and Cals, 1999).

TAXONOMY

Order Bochusacea Gutu and Iliffe, 1998

Remarks.-Gutu and Iliffe (1998) have pointed out differences in the structures of pereopods and uropods between the two families, Hirsutiidae and Mictocarididae in the Mictacea. This resulted in the recognition of a new order Bochusacea to accommodate the former family. We follow Gutu and Iliffe (1998), emphasizing the following features: (1) the displacement of oostegites (= epipods) bearing plumose marginal setae, as well as the setal appearance in early stages, (2) pereopod I modified into a feeding appendage; (3) the presence of long palpiform elongations of the paragnath. However, the validity of these two orders should be rigorously reconsidered, since phylogenetic relationships among all peracaridan orders are still incompletely revealed (cf. Hessler and Watling, 1999; Watling, 1999).

Family Hirsutiidae Sanders, Hessler and Garner, 1985

Type genus.-*Hirsutia* Sanders, Hessler and Garner,

1985.

Other genus.-*Thetispelecaris* Gutu and Iliffe, 1998.

Remarks.-The familial diagnosis is provided by Gutu and Iliffe (1998), which is the same as that of the order Bochusacea.

The identity of rami originating from the posterior surface of coxae of pereopods II-VI has been disputed since the discovery of the Hirsutiidae (Sanders *et al.*, 1985; Just and Poore, 1988; Gutu and Iliffe, 1998): are these epipods or oostegites? Sanders *et al.* (1985) pointed out a unique (not medial but posterior) configuration of the rami, and tentatively regarded these as oostegites in accordance with Bowman and Iliffe (1985). Just and Poore (1988) suggested a similar configuration between "oostegites" of hirsutiids and corophiid amphipods, both of which are characterized by the cylindrical shape of the body, and supposed that the uniqueness may be due to the body shape. However their opinions were not yet conclusive, because of no observation of juvenile stages. Gutu and Iliffe (1998) first found that juveniles of *Thetispelecaris remex* also bear these rami, and considered that these could play roles both in respiration and brooding. In addition they thought that eggs/embryos might be retained at most by plumose setae of the rami without formation of a well developed marsupium as in other peracarids. Our observation strongly supports their idea, and we use epipods throughout this paper.

Genus *Thetispelecaris* Gutu and Iliffe, 1998

Type species.-*Thetispelecaris remex* Gutu and Iliffe, 1998.

Other species.-*Thetispelecaris yurikago* n. sp.

Diagnosis (emend.).-Cephalon with sharply pointed rostrum. Antennule with 3-segmented peduncle and 3- or 4-segmented flagella. Antenna bearing 2-segmented protopod, unisegmented exopodal scale, and multisegmented endopod comprising 3-segmented peduncle and 5- or 6-segmented flagellum. Palpiform extensions of paragnath covered with long hairs. Pereiopod I with exopod but lacking epipod; basis and ischium of pereopods II-VI incompletely or almost completely fused. Pleopods IV and V unisegmented, articulated with body. Uropodal protopod with single inner spine.

Remarks.-The genus *Thetispelecaris* was briefly defined by Gutu and Iliffe (1998), but the discovery of the new species described below strengthens the generic validity. *Thetispelecaris* differs from *Hirsutia* in: (1) pereiopod I with a 2-segmented exopod (absent in *Hirsutia*); (2) the numbers of exopodal segments of pereiopods II-VI are 3 (4, 3), 4 (4, ?), 4 or 5 (4, ?), 4 or 5 (4, 4), and 4 (3, ?), respectively (numbers in parenthesis in *H. bathyalis* and *H. sandersetalia*, respectively); (3) the reduced number of terminal setae/spines on carpus and propodus of pereiopod II (4 and 7 in *Thetispelecaris* vs 6 and 12 in *Hirsutia*, respectively); (4) unisegmented pleopods IV and V, distinctly articulated with the body (completely incorporated into the body in *Hirsutia*); (5) the reduced numbers of elements on the

uropodal protopod and endopod (single spine on each segment in *Thetispelecaris* vs 2 or 3 spines on protopod and 6 inner spines on the first endopodal segment in *Hirsutia*); (6) a palpiform lobe of the paragnath with numerous hairs along the entire length (only setose in the basal part in *Hirsutia*). The body size may also be diagnostic because *Thetispelecaris* (*T. remex* 1.2–1.6 mm; the new species described below 1.30–1.78 mm) is much smaller than *Hirsutia* (*H. bathyalis* 2.7 mm; *H. sandersetalia* 3.3 mm). On the other hand, there are several differences between two congeners of *Hirsutia*: (1) a rostrum is present in *H. sandersetalia* but absent in *H. bathyalis*; (2) epipods are furnished with many long plumose setae in *H. sandersetalia* where in *H. bathyalis* fewer spiniform setae. However the epipods of *H. bathyalis* may not be fully developed because the only one individual examined (holotype) of the species is a “preparatory female” (Sanders et al., 1985).

The habitats of these two genera are also different. *Hirsutia* is a deep-sea taxon, while *Thetispelecaris* is cavernicolous.

***Thetispelecaris yurikago* n. sp.**

(Figs. 1–9)

Material examined.—Twenty adult females, collected from a submarine cave named “The Mouse Trap,” the Grand Cayman Island, November 15 and 19, 2000.

Types.—Holotype: , whole specimen, NSMT-Cr 14298. Paratypes: 2 , dissected and mounted on glass slides, NSMT-Cr 14299; 13 , whole specimens, NSMT-Cr 14300.

Body length.—Range 1.30–1.78 mm (mean±standard deviation=1.50±0.13 mm, N=16); Holotype 1.50 mm.

Description based on holotype and paratypes dissected. Female. Body (Figs. 1A, 6A) nearly cylindrical, but somewhat depressed; cephalothorax slightly longer than wide, subrectangular; rostrum (Fig. 1B) produced antero-ventrally or anteriorly, acutely pointed at tip (see Fig. 6B); lateral carapace folds poorly developed, only covering bases of postmandibular appendages (Fig. 6C); dorsal carapace fold absent. Pereion shorter than pleon; pereionite I small; pereionites II and III equal in length; pereionites IV–VI longer than pereionites I and II; pereionite VII slightly shorter than preceding pereionite. Pleonites (Fig. 1A, D, H) gradually increasing in length posteriorly; pleonite VI expanded posterolaterally; telson (Fig. 1G) tongue-like with concavity at apex, one-fifth wider than long, bearing 4 lateral pairs of simple spiniform setae, 1 terminal pair of setae, and 1 dorsal pair of slender setae; anus (Fig. 1D) located ventrodistally, longitudinal slit-like, with lateral valves (Fig. 6D).

Antennule (Fig. 2A, B) anteriorly directed, with 3-segmented peduncle and 4-segmented flagella of subequal length; peduncular segment 1 longest, bearing 2 proximal setae directed posteriorly, segment 2 with 6 terminal setae of unequal length, segment 3 with 4 long subterminal setae and 3 minute setules on terminal rectangular projection (Fig. 2B); setal formula of inner flagellum 1, 5, 1, 4; outer flagellum with setal formula of 0, 1, 1, 4; aesthetasc present on

segments 2 and 3 of outer flagellum.

Antenna (Fig. 2C) with 2-segmented protopod (peduncle), unisegmented scaphocerite (exopodal scale), and 9-segmented endopod comprising 3-segmented peduncle and 6-segmented flagellum; exopodal scale with 6 marginal setae; setal formula of endopod 1, 6, 12, 0, 4, 2, 3, 2, 5.

Labrum (Fig. 2H: slightly depressed in preparation) with numerous spinular rows on anterior surface; terminal portion truncate, slightly concave midway, ornamented with fine setules along distal margin.

Mandibular gnathobase (Fig. 2D, F, G) complex in structure; incisor and molar processes widely separate; incisors multicusped; left gnathobase with lacinia mobilis bearing spinules subterminally; 3 subequal stout setae near lacinia mobilis; 12 curved setae originating from round protuberance; right gnathobase with 1 stout spinulose spine and 15 long setae along inner margin; molar process (Fig. 2D, G) protruded from gnathobase, heavily chitinized only terminally, with several lamellar plates and grinding surface. Mandibular palp (Fig. 2E) 3-segmented, slender; segment 1 small, unarmed; segments 2 and 3 almost equal in length; segment 2 unarmed; segment 3 with 1 naked and 2 spinulose setae at tip.

Paragnath (Fig. 2I) bilobed; each lobe tapering distally, terminating in elongate hirsute projection (Fig. 8A); each lobe with inner spinulose round projection and 3 stout spines of unequal length midway.

Maxillule (Figs. 2J, 8C) bilobed, with numerous rows of minute spinules; inner lobe with 4 comb-like setae and 1 spinulose spine fused to lobe at base along inner margin; outer lobe curved inward at midlength, with 2 surface setae and 2 groups of marginal elements, proximal group of which consisting of 7 chitinized spines, distal group of 4 terminally curved spines and 6 spinulose long setae.

Maxilla (Fig. 3A–C) with quadrate protopod bearing 21 “pushing setae (with bulbous base)” (setal nomenclature following Fryer, 1965) and 9 spiniform setae along proximal inner margin; distal inner corner of protopod having 9 stout spines of various ornamentations and 8 setae; ventral surface almost entirely covered with short hairs and bearing irregularly longitudinal row of short spinules; distal margin of protopod near common base of basal endites with stout serrate spine; basal endite 1 with about 23 comb-like setae (Fig. 8B); basal endite 2 with 3 rows of spatulate setae (approximately 11, 9 and 8 setae, respectively) and longitudinal row of fine spinules.

Maxilliped (Fig. 3D, E) with elongate protopod; proximal part of protopod with 2 proximal, 1 middle spiniform and 1 plumose setae on surface and 1 minute spine and 9 well developed setae along inner margin; penultimate inner seta with serration at expanded tip; basal endite protruded distally, 7 hooked and 7 serrate spines and 1 spinulose and 1 plumose seta (Fig. 8D); palp 5-segmented, longer than basis, ischium small, with 1 seta and row of spinules along outer distal margin; merus about twice as long as ischium, with single seta; carpus as long as proximal 2 segments

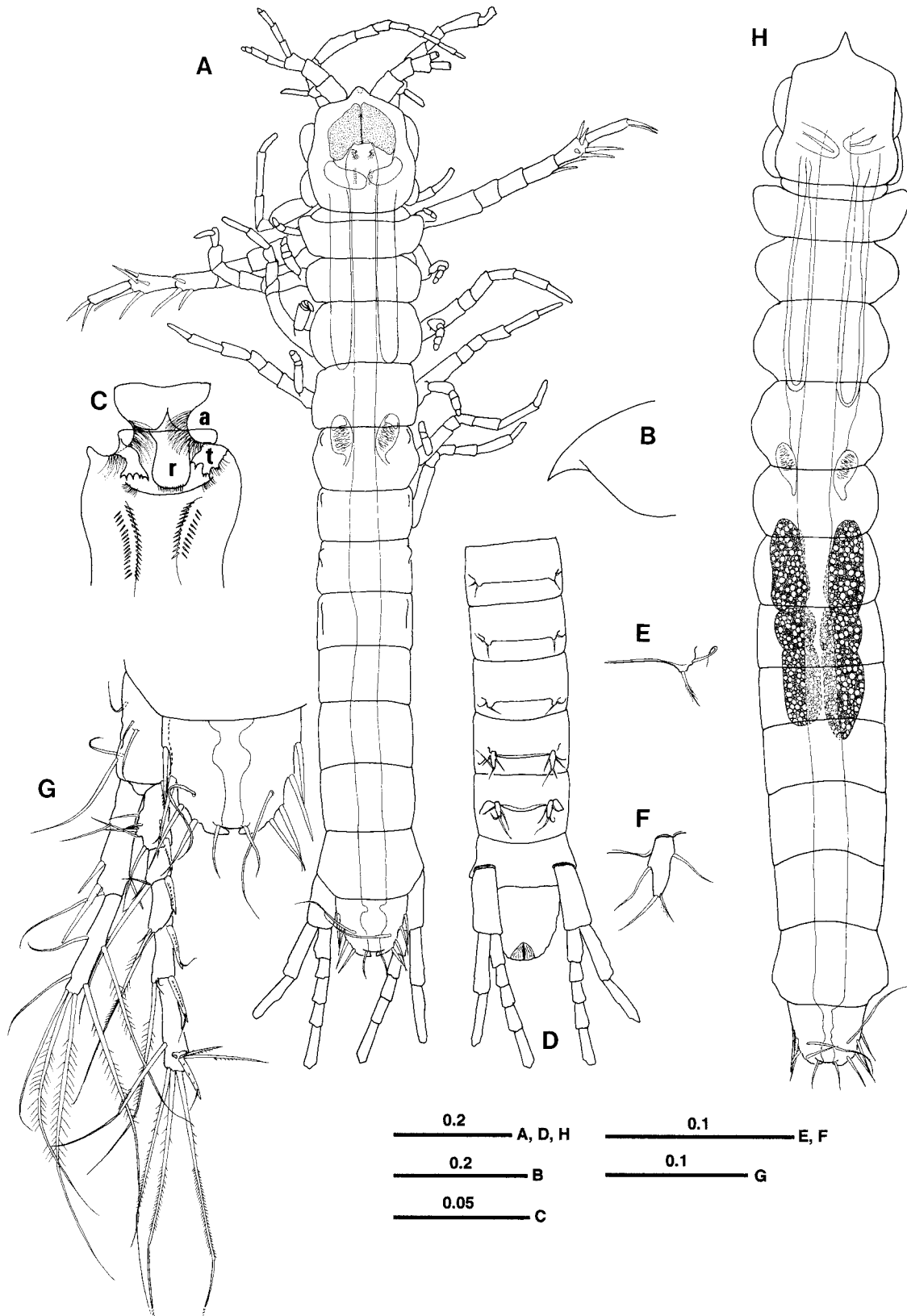


Fig. 1. *Thetispelecaris yurikago*, n.sp., female, holotype (A, B, D–G), paratype (C, H). A. Habitus, dorsal view; B. Rostrum, lateral view; C. Stomach, observed under transmitted light without dissection, dorsal view; D. Pleon, ventral view; E. Pleopod I, ventral view; F. Pleopod IV, ventral view; G. Telson and uropod, dorsal view; H. Habitus, dorsal view, appendages and uropods omitted, 3 pairs of mature eggs present in pereonite VI to pleonite III. a: lateral ampulla?; r: pyloric ridge?; t: lateral teeth? Scales in mm.

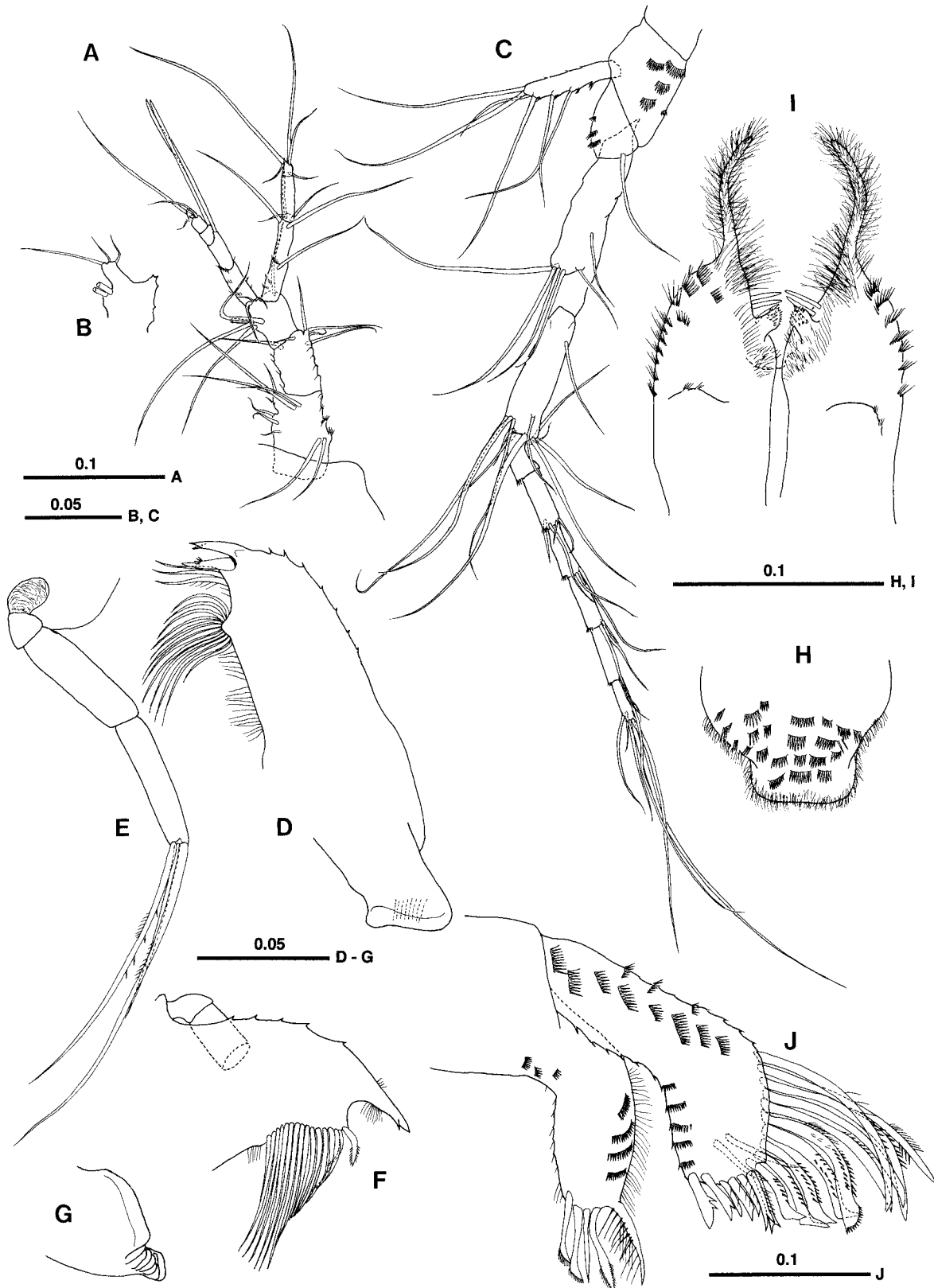


Fig. 2. *Thetispelecaris yurikago*, n.sp., female, holotype (A), paratype (B–J). A. Left antennule, dorsal view; B. Left antennary peduncle 3, dorsal view, more flattened than in Fig. 2A; C. Left antenna, ventral view; D. Left mandibular gnathobase, ventral view; E. Mandibular palp; F. Right mandibular gnathobase, ventral view, base of palp indicated; G. Molar process of right mandible; H. Labrum, ventral view; I. Paragnath, ventral view; J. Left maxillule, dorsal view. Scales in mm.

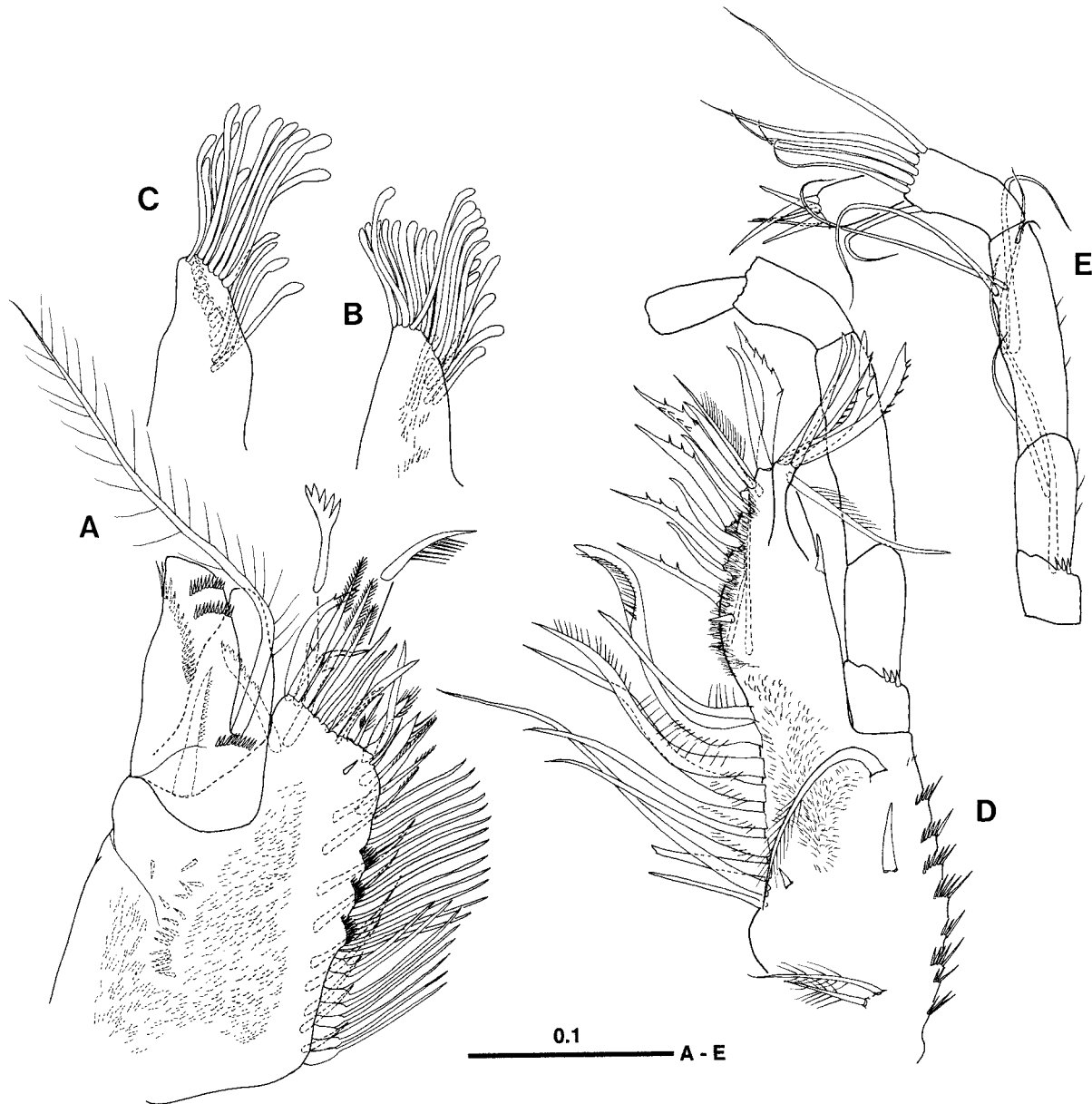


Fig. 3. *Thetispelecaris yurikago*, n.sp., female, paratype. A. Left maxilla, dorsal view, setae on basal endites omitted; B. Basal endite 1 of left maxilla, dorsal view, some setae omitted; C. Basal endite 2 of left maxilla, dorsal view, some setae omitted; D. Right maxilliped, dorsal view, setae on palp omitted (endite modified in preparation) E. Right maxillipedal palp, dorsal view. Scale in mm.

combined, bearing 2 middle, 2 subterminal and 1 minute distal setae; propodus inserted to preceding segment at angle of about 120° , with 6 distal setae; dactylus directed inwards, with 3 spiniform and 2 fine setae terminally.

Configuration of pereopods shown in Fig. 4A; pereopod I directed anterolaterally, modified into mouthpart appendage; pereopods II-VI with origins of exopod, endopod and epipod aligned along anterior-posterior direction paralleling long axis of body. Pereopods bearing short coxa and long basis, furnished with numerous spinular rows (Figs. 7B-D, 8E); pereopod I (Fig. 4A, B) biramous, lacking epipod; pereopods II-VI (Figs. 4A, C-E, 5A-C) biramous,

each with epipod; all pereopods each with 5-segmented endopod (ischium, merus, carpus, propodus, dactylus) and 2-(I), 3-(II), 4-(III, VI) or 5-(IV, V) segmented exopod; ischium incompletely (pereopod II) or almost completely (pereopods III-VI) coalescent to basis; pereopod VII (Figs. 4A, 5D) with basis separate from ischium, uniramous, lacking exopod and epipod. Within brooding chamber surrounded by both epipods of pereopods II-VI only one droplet-like embryo remaining in holotypic female (Fig. 4A); embryo approximately 0.06 mm in width.

Pereopod I (Fig. 4B) with basis bearing 1 anterior and 3 posterior setae; ischium having 1 posterior and 2 anterior

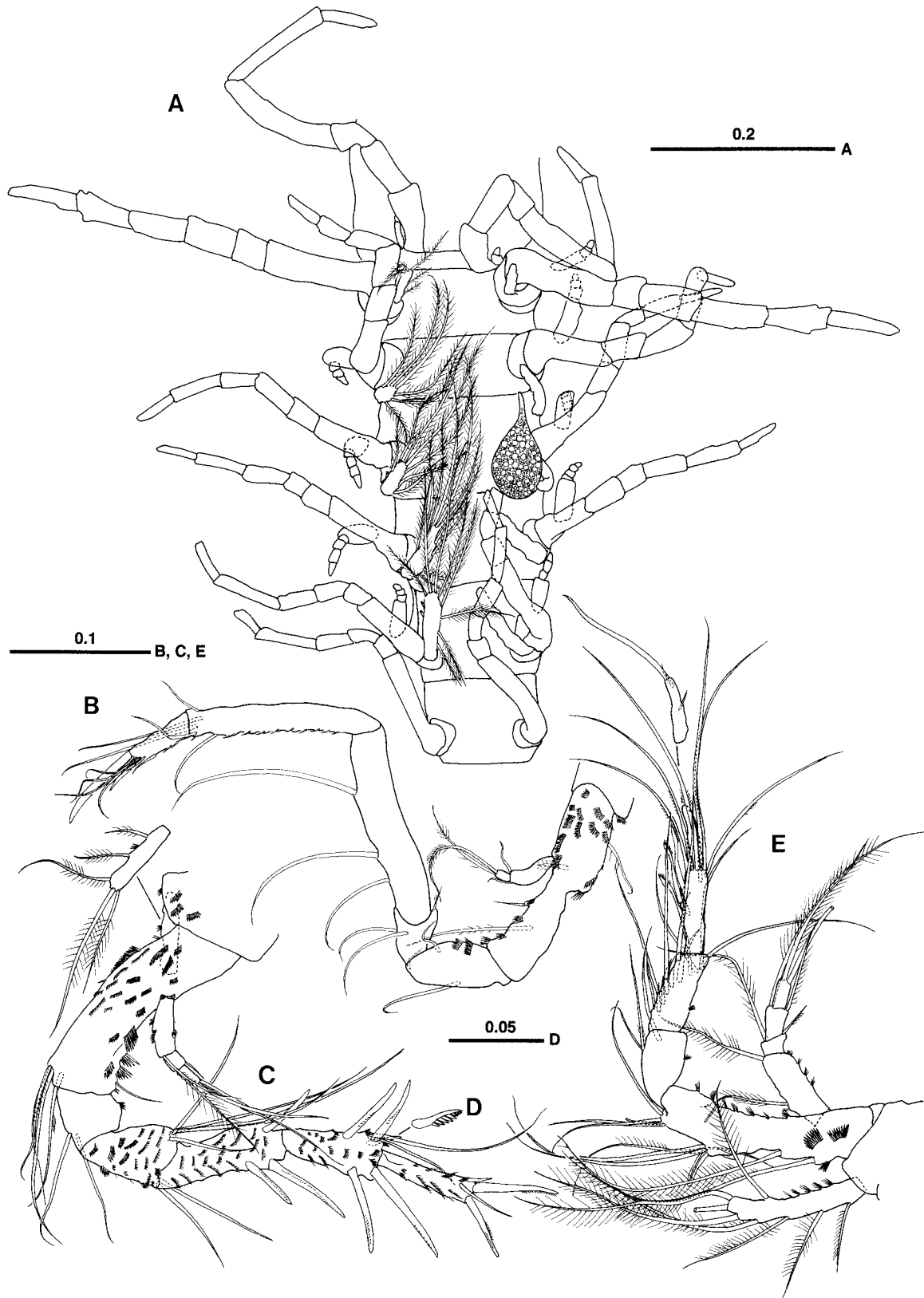


Fig. 4. *Thetispelecaris yurikago*, n.sp., female, holotype (A), paratype (B–E). A. Pereonites, ventral view, setae on appendages except on right epipods omitted, 1 embryo present within marsupium formed by plumose setae of epipods (oostegites); B. Left pereopod I, lateral view; C. Right pereopod II, lateral view; D. Terminal spine on fourth endopodal segment of right pereopod II; E. Right pereopod III, medial view. Scales in mm.

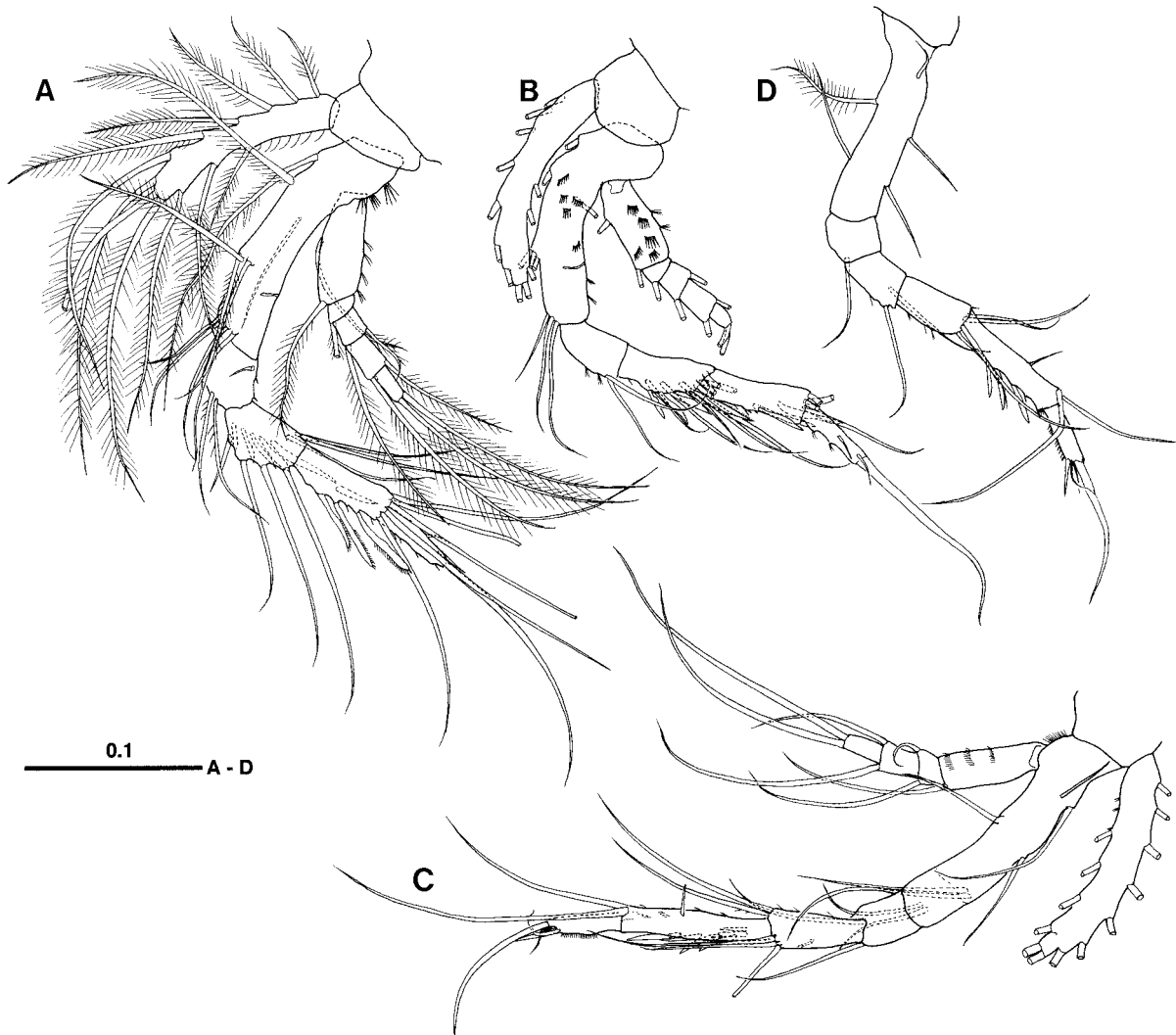


Fig. 5. *Thetispelecaris yurikago*, n.sp., female, paratypes. A. Left pereopod IV, medial view; B. Left pereopod V, medial view; C. Left pereopod V, lateral view; D. Right pereopod VII, lateral view. Scale in mm.

setae; merus short, with 1 short posterior and 2 anterior setae; carpus elongate, bearing 3 anterior setae increasing in length distally; propodus as long as carpus, with 3 subterminal setae; dactylus short, with 1 stout spine terminally and 2 spiniform and 5 setae subterminally; exopod short, 2-segmented, setal formula 1+1, 2.

Pereopod II (Fig. 4C, D) longest and thickest of pereopods (see Fig. 4A), covered entirely with spinular rows, much more than in other pereopods; epipod relatively short, bearing 4-5 marginal plumose setae; basis bearing 1 anterior and 4 posterior setae distally; ischium with 2 nearly equal setae terminally; merus slightly longer than ischium, bearing 2 posterior and 4 anterior setae distally; carpus longest, with 1 anterior and 2 posterior stout spines in addition to distal anterior seta; propodus with 2 posterior and 2 anterior long, stout spines distally and 1 short serrate spine and 2 setae at anterodistal corner; dactylus with 2 stout spines of unequal length and 1 spiniform and 1 slender seta terminally (see Fig. 8E); exopod 3-segmented, setal formula

1, 1+1, 2 (see Fig. 7C).

Pereopod III (Fig. 4A, E) shorter than preceding leg; epipod more developed than preceding one, with 8-9 setae in total; basis with 2 proximal and 4 terminal setae along posterior margin; ischium with 4 setae of unequal length terminally; merus bearing 3 terminal setae; carpus with 4 posterior marginal and 4 anterior terminal setae and 5 serrate surface spines increasing distally in length; propodus bearing 3 posterior and 2 surface serrate spines and 6 terminal setae; dactylus with 1 fine anterior middle, 1 short subterminal and 1 long terminal seta; exopod 4-segmented, setal formula 2, 1+1, 1+1, 2.

Pereopod IV (Figs. 4A, 5A) similar to preceding leg; epipod developed as in preceding one, with 12 setae in total; basis with 2 proximal, 1 surface and 3 terminal setae; ischium with 4 setae terminally; merus with 2 posterior setae and 1 anterior short spiniform seta; carpus bearing 4 posterior marginal and 3 anterior terminal setae and 5 serrate spines increasing gradually in length distally; propodus with

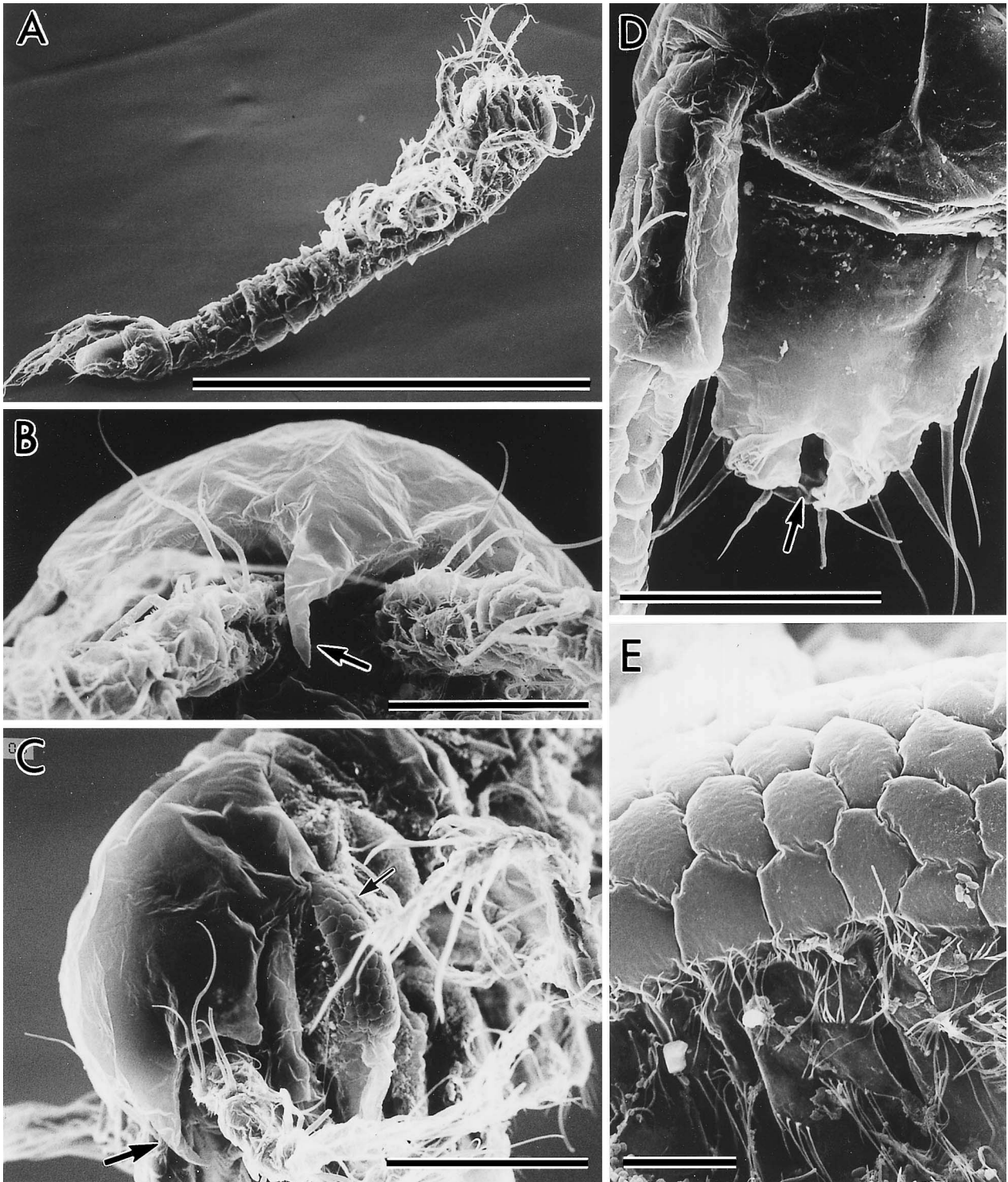


Fig. 6. SEM microphotographs of *Thetispelecaris yurikago*, n.sp., female. A. Habitus, ventrolateral view, left uropod missing; B. Rostrum, arrowed, ventral view; C. Cephalothorax, dorsolateral view (rostrum indicated by large arrow), note lateral cephalic fold covering only bases of mouthpart appendages (mandibular gnathobase indicated by small arrow); D. Telson, ventral view, anus indicated by arrow; E. Mandibular gnathobase, note honeycomb-like structure. Scales = 1 mm (A); 0.05 mm (B, D); 0.1 mm (C); 0.01 mm (E).

3 posterior marginal and 1 surface serrate spines and 5 terminal setae; dactylus with 1 fine anterior seta and 1 short and 1 long seta terminally; exopod 5-segmented, setal formula 2, 1, 1+1, 1+1, 2.

Pereiopod V (Figs. 4A, 5B) similar to pereiopod IV, but different in armature of endopod: ischium bearing only 3 setae terminally; merus lacking anterior spiniform seta; carpus with 5 posterior setae terminally in spite of 3 anterior

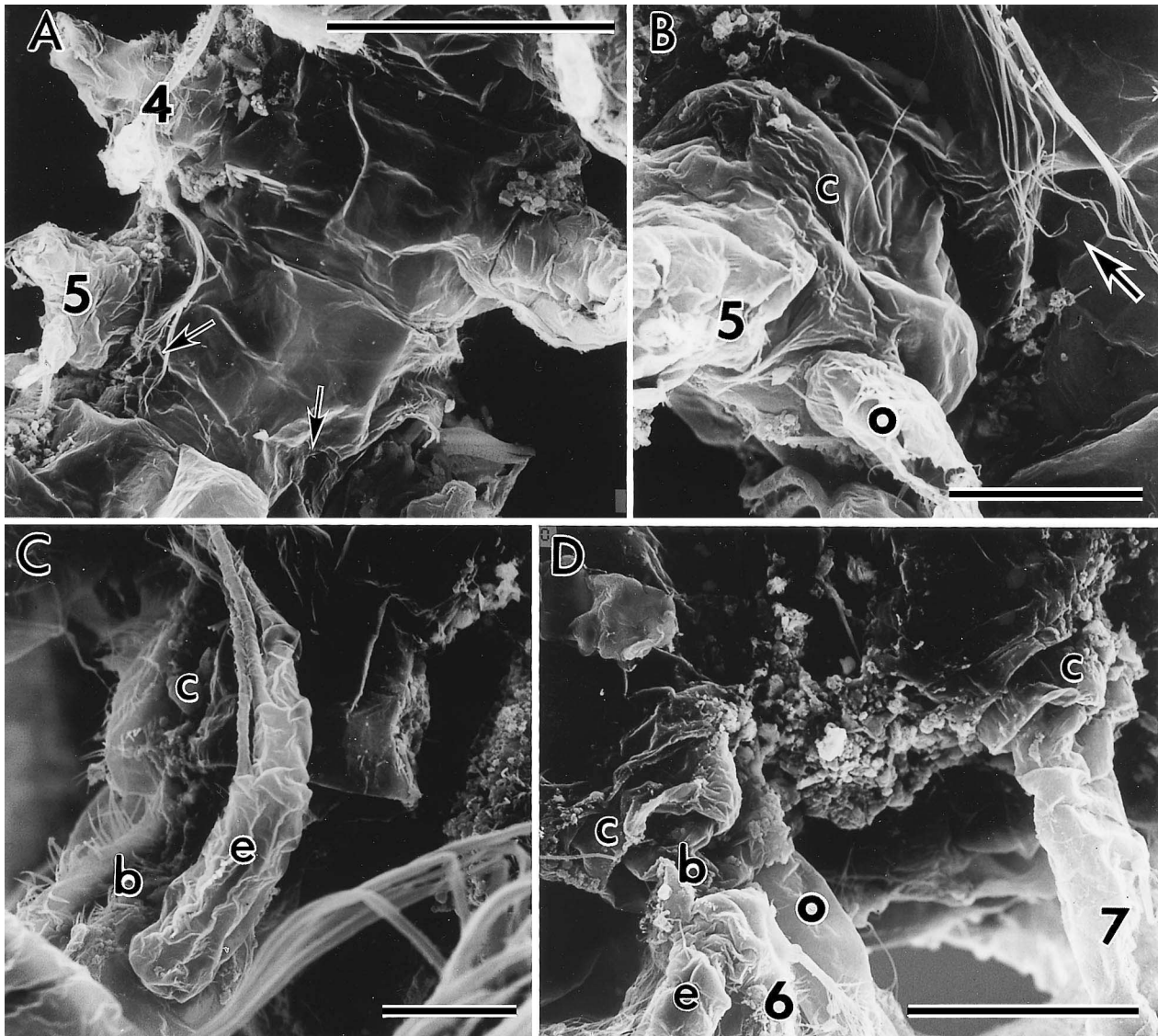


Fig. 7. SEM microphotographs of *Thetispelecaris yurikago*, n.sp., female. A. Pereionites IV and V, ventral view, gonopores indicated by arrows; B. Base of pereionite V, gonopore indicated by arrow; C. Pereionite II, lateral view, note distinct separation between coxa and body; D. Pereionites VI and VII, lateral view, note distinct separation between coxae and body. 4–7: pereionites IV–VII; b: basis; c: coxa; e: exopod; o: epipod (oostegite). Scales = 0.1 mm (A); 0.02 mm (B, C); 0.05 mm (D).

setae; propodus having only 3 spines along posterior margin and 4 setae terminally.

Pereionite VI (Figs. 4A, 5C; 7D also) with epipod bearing 10–13 marginal setae; basis incompletely fused to ischium with suture more clearly visible than in preceding legs, bearing 4 middle and 2 terminal setae; ischium, merus and carpus bearing 2, 2 and 4 distal setae, respectively; propodus longest, bearing 5–6 serrate inner spines and 1 spiniform middle and 2 distal setae along outer margin; dactylus with 2 unequal spiniform setae and 2 fine setules terminally and 1 short seta subterminally.

Pereionite VII (Figs. 4A, 5D; 7D also) with basis bearing 3 anterior and 2 posterior setae; ischium with 1 posterior terminal seta; merus as long as ischium, bearing 2 setae terminally; carpus with 2 posterior and 2 anterior setae; propo-

pus having 3 serrate spines along posterior margin and 1 middle and 2 terminal setae along anterior margin; dactylus with 2 spiniform and 2 short setae terminally, serrated along posterior margin.

Pleopods I–III (Figs. 1D, E) rudimentary, represented by triangular lobe with 1 terminal and 1 outer basal seta (see Fig. 9A); pleopods IV and V (Fig. 1D, F) distinctly articulated at base, unisegmented, bearing 1 inner and 1 outer seta midway and 1 terminal and 1 subterminal seta (see Fig. 9B).

Uropod (Fig. 1A, D, G) biramous; protopod approximately 2.8 times longer than wide, with inner distal spinulose spine, 3 outer setae and 2 dorsal surface setae; exopod 2-segmented, proximal segment with fine seta and 2 spines along outer margin and single fine inner spine, distal segment bearing 2 short outer, 2 long inner and 3 unequal distal

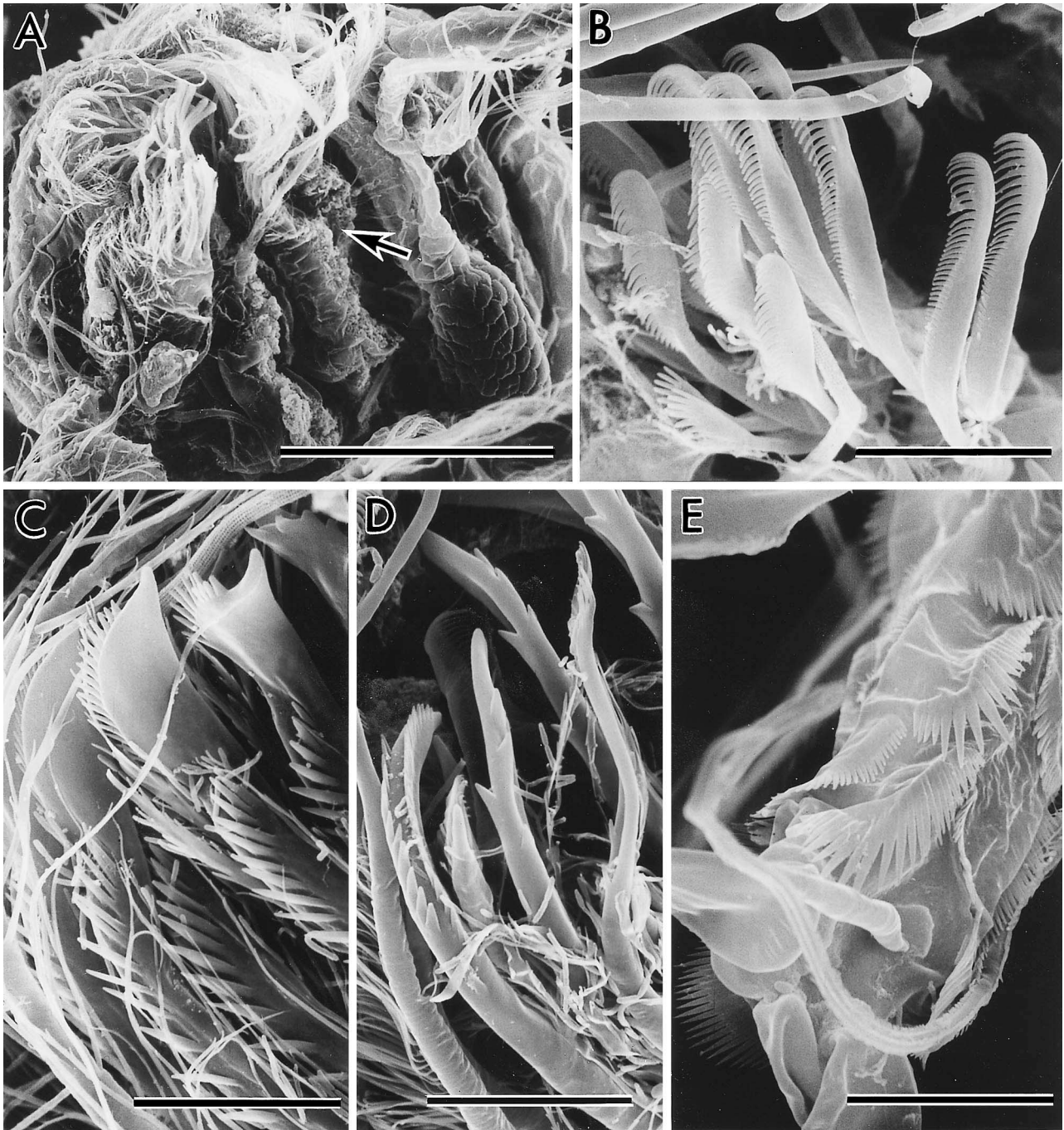


Fig. 8. SEM microphotographs of *Thetispelecaris yurikago*, n.sp., female. A. Mouthpart appendages, lateral view, paragnath with paired extension anteriorly indicated by arrow; B. Comb-like setae on basal endite of maxilla; C. Serrate setae on maxillulary endite; D. Various setae on basal endite of maxilliped; E. Spinular rows on dactylus of pereopod II. Scales = 0.1 mm (A); 0.01 mm (B–E).

setae; endopod about 1.3 times as long as exopod, 5-segmented, first segment with 6 outer setae and 1 distal and 1 middle spine, second to fourth segments each with 3 outer setae of unequal length and inner distal spine; fifth segment bearing single outer seta, 4 setae and 1 spinulose spine subterminally along inner margin, and 3 long setae terminally.

Stomach (Fig. 1C) with complex structure, and difficult to observe in detail with light microscope; some elements

observed, i.e., lateral ampullae (?) with fine hairs, lateral teeth (?) with acutely pointed processes, ventral pyloric ridge(?) with fine hairs posteriorly, and 4 longitudinal rows of minute spinules. Gut posterior to stomach almost uniformly straight with constriction near anus (Fig. 1A, H).

Female reproductive system tentatively identified as follows: ovary(?) in cephalothorax paired; oviducts parallel to gut (Fig. 1A, H); seminal receptacle(?) present in pereions V and VI; oviduct(?) directed anteroventrally to pereion V,

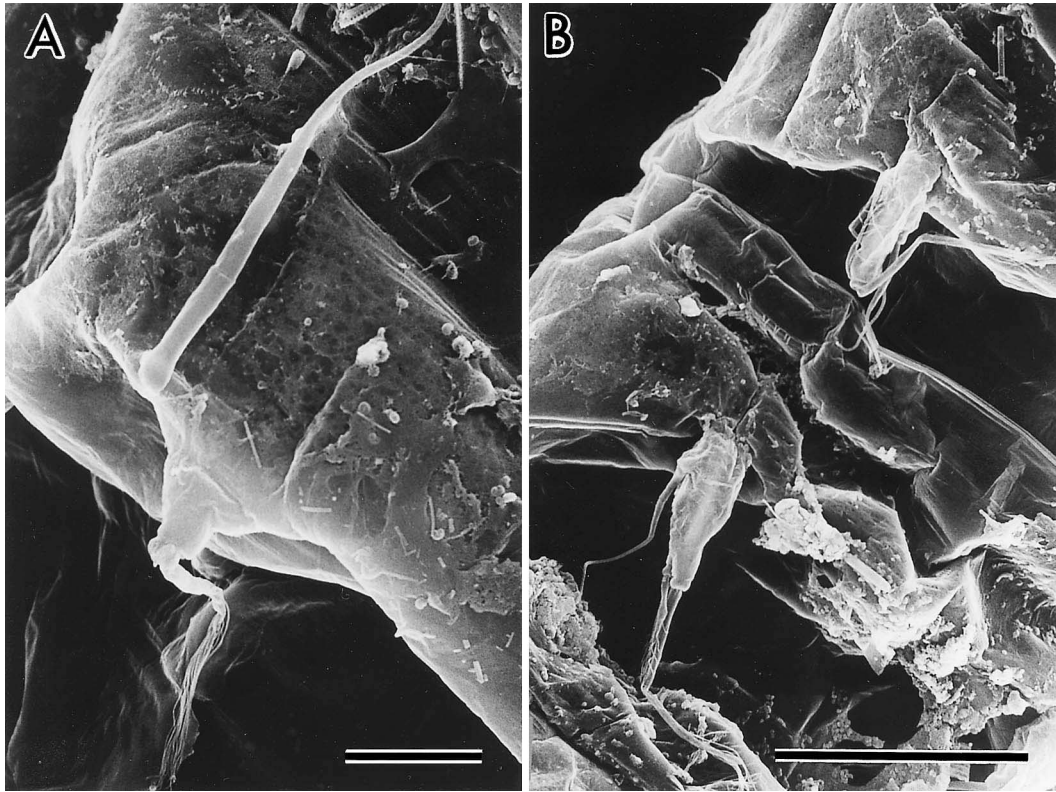


Fig. 9. SEM microphotographs of *Thetispelecaris yurikago*, n.sp., female. A. Pleopod III; B. Pleopods IV and V. Scale = 0.01 mm (A); 0.05 mm (B).

opening at base of pereiopod V. In a paratype 3 pairs of fully mature eggs present at posteriormost part of oviduct (Fig. 1H). Paired gonopores opening near bases of pereiopods V (sixth thoracic somite) on posteroventral surface (Fig. 7A, B).

SEM observation.—Four partly damaged adult females were observed with scanning electron microscopy (Figs. 6–9). Since most SEM micrographs complement the above description, only selected points are mentioned here. The mandibular gnathobase is expanded laterally with a honeycomb structure and numerous hairs (Fig. 6C, E). Gonopores were difficult to see under the light microscope, and could be observed with SEM only in the specimens whose pereiopods were cut off. The pores are located near the base of pereiopods V (on the sixth thoracic somite) on the sternite as in other malacostracans (Wilson, 1991) (Fig. 7A, B). The gonopore is slit-like, approximately 0.02 mm long, although the specimens examined were highly modified during dehydration and critical-point drying. The coxae of pereiopods are clearly separate from the body unlike in *Hirsutia bathyalis* (Fig. 7D). Setal elements on the mouthpart appendages are greatly diversified (Fig. 8A–D). Unisegmented pleopods IV and V are distinctly separate from the body (Fig. 9B).

Remarks.—The present new species is similar to *Thetispelecaris remex* from caves of Bahamas, but can be distinguishable from it by the following features: (1) the shape of the carapace (more narrowed anteriorly in *T. remex*); (2) the antennal scale bears 6 setae (only 4 in *T. remex*); (3) the

maxillipedal palp carries 3 spiniform and 2 fine setae terminally (only 3 slender setae in *T. remex*); (4) the number of exopodal segments of pereiopods IV and V is 5 (4 in *T. remex*); (5) the armature elements on pereiopods I to VII; (6) pereiopods III to VI with basis and ischium almost fused (separate in *T. remex*); (7) pleopods IV and V with 2 setae terminally (3 in *T. remex*).

All 16 type specimens examined of the new species were identified as female on the basis of the presence of eggs within the body or of an embryo in the marsupium. Although reproductive strategies of the Bochusacea are totally unknown, no record of males in the order may suggest parthenogenesis, as known in another peracaridan group, the Tanaidacea (Schram, 1986). This idea is supported also by a fact that 16 individuals of *Thetispelecaris remex* all were females. No male is known also in the genus *Hirsutia* (Sanders *et al.*, 1985; Just and Poore, 1988). In contrast the male is known in the Mictocarididae (which formerly belonged to the Mictacea but is now assigned to the suborder within the Cosinzenaeacea). In the holotypic female of the new species only a single embryo remains within the marsupium formed by plumose setae of the epipods (oostegites). Others were possibly lost during collection and/or processing, because three pairs of fully matured eggs were observed in the oviduct of a paratypic female and would probably be released simultaneously into the marsupium.

Etymology.—The specific name “*yurikago*” (Japanese, meaning baby cradle) alludes pereiopods II–VI with a highly

developed epipod which bears more numerous marginal setae than in *Thetispelecaris remex* and seems to function in brooding.

DISCUSSION

Close phylogenetic relationships of marine crustaceans living in shallow-water caves and in the deep-seas have attracted much attention from biologists (Stock and Vermeulen, 1982; Iliffe *et al.*, 1984; Hart *et al.*, 1985; Stock, 1986, 1993, Wilkens *et al.*, 1986; Boxshall, 1989; Boxshall and Jaume, 2000). The origins of cavernicolous forms have been intensively debated by these and other authors. Some groups such as thaumatocyridid ostracods (Wilkens *et al.*, 1986), misophrioid copepods (Boxshall and Jaume, 2000), pardaliscid and ingolfiellid amphipods (Stock and Vermeulen, 1982; Stock, 1986, 1993; Wilkens *et al.*, 1986) and galatheid decapods (Calman, 1912; Wilkens *et al.*, 1986) clearly show phylogenetic affinities between taxa from both habitats. Previous studies and present results reveal that the Bochusacea exhibits a close phylogenetic relationship between the cavernicolous and deep-sea inhabitants.

Some cave-living invertebrates were previously supposed to have originated from the deep-sea (Iliffe *et al.*, 1984; Boxshall, 1986; Wilkens *et al.*, 1986). However, Stock (1986) has strongly rejected their deep-sea origin theory on the basis of paleobiogeography, and proposed that the common ancestor of both lineages could have been distributed in shallow waters, and then invaded both habitats and evolved independently. This idea is supported also by a detailed cladistic analysis of misophrioid copepods (Boxshall and Jaume, 2000). The misophrioid genus *Misophriopsis* is distributed not only in hyperbenthic regions from deep oceanic (3000 m) to shallow coastal waters (less than 10 m), but also in caves (Boxshall and Jaume, 2000). This range extension is also explained by horizontal/vertical explorations of the shallow-water hyperbenthic ancestor (Boxshall and Jaume, 2000). According to Stock (1986, 1993), the anoxia in the deep waters (200–2000 m) in the Atlantic, which occurred in the Oligocene/Miocene boundary, would have entirely wiped out the Tethyan fauna. He argued that the deep-sea origin for cave-dwelling animals is therefore unlikely, and that the present cavernicolous and deep-sea inhabitants probably evolved from the shallow-water ancestor during or after the Miocene when the deep waters were reventilated (Stock, 1986, 1993).

It is noteworthy that both *Thetispelecaris* and *Hirsutia* exhibit very similar mouthpart structures. This suggests that both taxa essentially utilize similar types of food items irrespective of their different habitats. Sanders *et al.* (1985) supposed, on the basis of mouthpart and pereopod morphology, that *Hirsutia* is a facultative carnivore. Fryer (1965) carefully analyzed the feeding mode of the Thermosbaenacea from a functional morphological viewpoint, concluding that Thermosbaenacea is not a filter feeder but employs a feeding mode consisting of scraping, brushing and pushing

for detritus. Since the mouthparts of Bochusacea are basically similar to those of Thermosbaenacea (Bowman and Iliffe, 1985), the feeding of the latter is presumably similar to that of the former, i. e. bochusaceans are deposit feeders, as already pointed out by Just and Poore (1988). This is also supported by the new observation that the guts of 16 specimens of *Thetispelecaris yurikago* were full of fine particles. Just and Poore (1988) reported the gut of *H. sandersetalia* collected from 1500 m depth to be packed with fine-grained sedimentary material. In both genera, the well-developed, long pereopod II with heavily sclerotized serrate spines terminally, may be used in grasping and manipulating large detrital particles in association with the anteriorly directed pereopod I rather than holding prey (cf. Sanders *et al.*, 1985; Just and Poore, 1988).

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