

# THREE NEW SPECIES OF THE DEMERSAL CALANOID COPEPOD *PLACOCALANUS* (RIDGEWAYIIDAE) FROM OKINAWA, SOUTHERN JAPAN

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Three new species of *Placocalanus* are described from sandy bottoms off Nagannu Island, Okinawa, southern Japan, at a depth of ca 50 m. This is the first record of the genus in the Indo-Pacific region. A number of differences in segmentation and setation in appendages are found between the Pacific and Atlantic species. In particular the Pacific species have a reduced number of setae of the legs compared with their Atlantic congeners. Specialized characters of *Placocalanus* such as the laterally compressed prosome, expanded proximal plate of the antennule and markedly modified leg 1 are discussed from a functional point of view. Cooccurrence of several species of a genus is common among demersal calanoid copepods, and is briefly discussed.

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KEYWORDS: *Placocalanus*; Ridgewayiidae; calanoid; copepod; demersal.

## INTRODUCTION

Much attention has recently been paid to demersal and cavernicolous copepods because the discoveries of these copepods have led to the reconsideration of the phylogeny of the Copepoda (cf. FOSSHAGEN 1973; FOSSHAGEN & LILFFE 1985, 1989, 1994; BOXSHALL & LILFFE 1986; OHTSUKA & al. 1993, 1994). Some species exhibit the most plesiomorphic characters in each copepod order while others are extremely specialized for the adaptation to these special biotopes.

During our investigation of demersal copepods in subtropical regions of southern Japan, new taxa of Platycopioidea, Calanoida, Misophrioida, Harpacticoida, and Cyclopoida have hitherto been reported (OHTSUKA & al. 1991, 1992; HUYS & OHTSUKA 1993; HUYS & al. 1994; OHTSUKA & BOXSHALL 1994). This paper deals with descriptions of three new species of *Placocalanus* of the calanoid family Ridgewayiidae. *Placocalanus* was first described from two species collected from the bottoms in fairly shallow waters of the Bahamas (FOSSHAGEN 1970). Since no type species was selected at that time, the generic name is not available (ICZN Article 13b). In this paper a type species has been designated and the generic name *Placocalanus* is used to maintain the stability of nomenclature. Some morphological characteristics of

*Placocalanus* are considered from a functional point of view. Cooccurrence of several congeners is common in demersal calanoid copepods such as the families Arietellidae, Pseudocyclopidae, Ridgewayiidae, and Stephidae, and is discussed briefly.

## MATERIAL AND METHODS

Samples were collected from sandy bottoms off Nagannu Island, Okinawa, southern Japan at a depth of ca. 50 m during 1991-1993 with a dredge (mouth area: 50 cm wide and 15 cm high; mesh size 5 mm).

Specimens were preserved in 10 % neutralized formalin/seawater soon after capture, and examined with a differential interference contrast microscope (Nikon Optiphoto). Type specimens are deposited in the Natural History Museum and Institute, Chiba, Japan. The morphological terminology is based on HUYS & BOXSHALL (1991).

## SYSTEMATICS

Family Ridgewayiidae M. S. WILSON, 1958

Diagnosis (emend.). Body small, about 1 mm long or smaller. Prosome oval in dorsal view and, rarely, compressed laterally. Cephalosome completely or incompletely

separated from first pedigerous somite; fourth and fifth pedigerous somites separated or coalescent. Rostrum with or without filaments, bifurcated or sharply or bluntly pointed at tip. Urosome 4-segmented in female and 5-segmented in male. Genital double-somite of female with single genital operculum ventromedially or laterally on right side.

Antennule of female 22- to 27-segmented; right antennule of male geniculate, 20- to 23-segmented. Antenna, mandible, maxillule, and maxilla of a primitive calanoid type without excessive modifications. Maxilliped endopod with or without some specialized setae. Leg 1 rather modified or not. Legs 2-4 usually 3-segmented in both rami. Leg 5 of female biramous, symmetrical; exopod 3-segmented, third exopod segment constricted basally and arising from middle of second segment; endopod 1- to 3-segmented. Leg 5 of male biramous, extremely asymmetrical; exopod 2- or 3-segmented; endopod 1- to 3-segmented.

Type genus. *Ridgewayia* THOMPSON & SCOTT, 1903

Other genera. *Exumella* FOSSHAGEN, 1970; *Brattstromia* FOSSHAGEN, 1991 (in FOSSHAGEN & ILIFFE, 1991); *Placocalamus* OHTSUKA, FOSSHAGEN & SOH, 1996.

Genus *Placocalamus* OHTSUKA, FOSSHAGEN & SOH, 1996

Synonymy: *Placocalamus* FOSSHAGEN 1970:44-45 (nomen nudum)

Diagnosis. Body compressed laterally, less than 1 mm in length; cephalosome separate from first pedigerous somite; fourth and fifth pedigerous somites fused. Urosome elongate, slender, 4-segmented in female and 5-segmented in male; genital double-somite of female with single genital operculum ventromedially; third urosomal somite in female and fourth in male longest in urosome; anal somite small, partly or almost completely covered by the preceding somite; subterminal outermost caudal seta spiniform.

Rostrum bluntly or sharply pointed at tip without terminal filaments. Antennules of both sexes unique in having first segment with posterior distal margin expanded and produced into flattened, triangular process, reaching, at most, to the end of cephalosome, 22- or 23-segmented in female and 20- or 21-segmented in right geniculate antennule in male; compound segment XV-XVI with large aesthetasc in both sexes. Sheath present between segments XIV and XV-XVI in right antennule of male. Mouthpart appendages showing neither extreme modification nor reduction in any sex.

Leg 1 conspicuously modified: basis with or without anvil-like process; endopod 1- to 3-segmented, tapering distally; exopod slender, 3-segmented. Both rami of legs

2-4 usually 3-segmented, but proximal two endopod segments of leg 4 may be fused. Second endopod segments of legs 2-4 sharply produced at outer distal corner, with 1 or 2 inner setae. Leg 5 of female: endopod 1- or 3-segmented, third segment originating from halfway along inner margin of second, as in other ridgewayiids. Leg 5 of male: endopod 1- or 2-segmented, second segment unarmed or bearing several elements terminally; right exopod 2-segmented, furnished with 2 or 3 spines and 1 inner seta; left exopod 3-segmented, first segment with outer distal spine, second bearing outer distal spine and expanded process or foliaceous spine or process on inner distal corner, third segment tapering distally to acute process or ending in spine.

Type species. *Placocalamus insularis* FOSSHAGEN, 1970 (by original designation).

Other species. *Placocalamus brevipes* sp. n.; *P. inermis* sp. n.; *P. longicauda* sp. n.; *P. nannus* FOSSHAGEN, 1970.

Remarks. The generic name *Placocalamus* was first established by FOSSHAGEN (1970), in which two new species were involved. However, he did not designate either of them as the type species. Based on ICZN Art. 13b, *Placocalamus* FOSSHAGEN, 1970 is unavailable. To maintain the stability of nomenclature we employ the name *Placocalamus* and designate *P. insularis* as the type species.

In spite of its unusual body shape and antennules, *Placocalamus* is assigned to the family Ridgewayiidae by the unique structure of legs 5 of females and the female genital double-somite with single genital operculum medially. In addition to *Placocalamus* the family consists of three genera, *Ridgewayia* THOMPSON & SCOTT, 1903, *Exumella* FOSSHAGEN, 1970, and *Brattstromia* FOSSHAGEN, 1991 (in FOSSHAGEN & ILIFFE 1991), all of which have been recorded from near bottom in shallow water or caves. *Placocalamus* is readily distinguishable from the other genera by its compressed prosome, the relatively elongate slender urosome, the short, specialized antennule, and the modified leg 1.

## DESCRIPTION

*Placocalamus longicauda* sp. n. (Figs 1-3)

Material examined. 2 ♀♀ & 3 ♂♂. Sandy bottom off Nagannu Island, Okinawa, southern Japan: 26°14' N, 127°33' E, depth 52 m, local time 1155-1208, 14 May 1991 (1 ♀); 26°14' N, 127°33' E, depth 47-51 m, local time 0943-1031, 10 April 1992 (1 ♀, 2 ♂♂); 26°14.5' N, 127°32.0' E, depth 52-53 m, local time 1311-1328, 18 November 1993 (1 ♂).

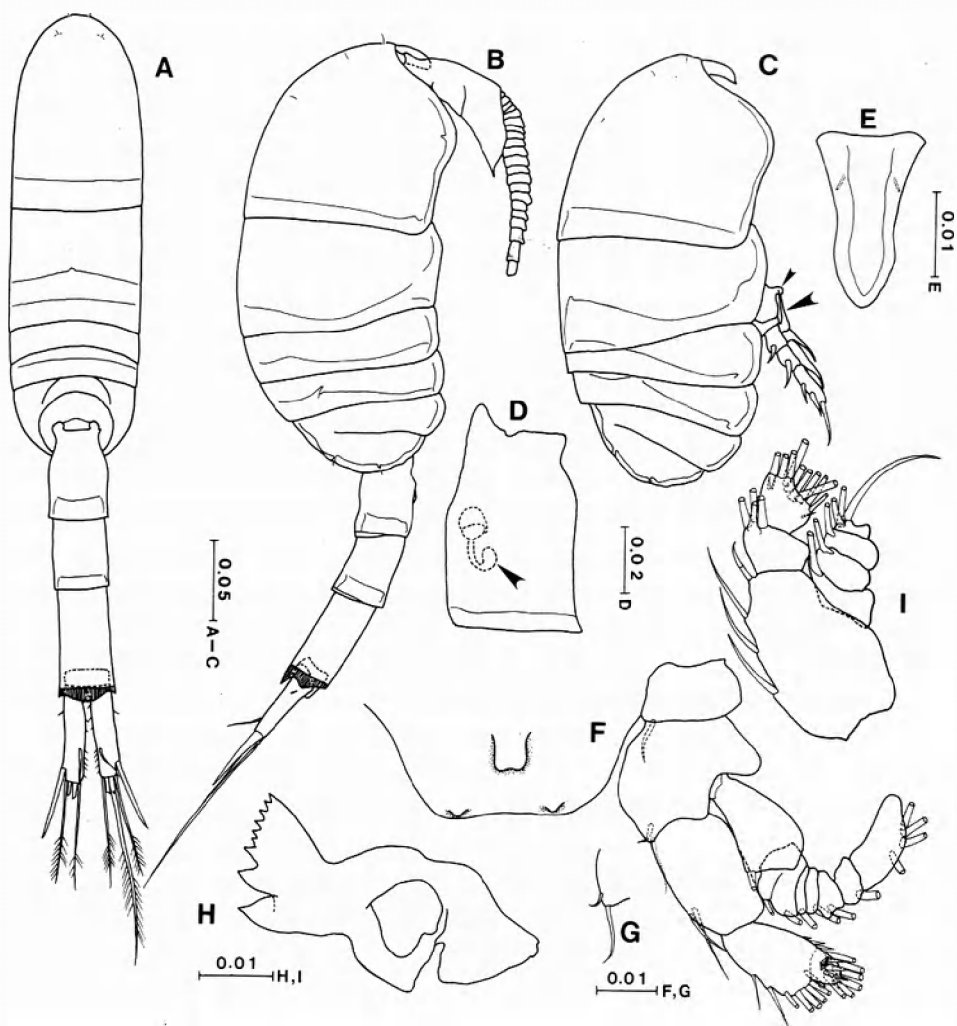


Fig. 1. *Placocalanus longicauda* sp. n., female (A, B, D-F, H, I: holotype; C, G: paratype). A. Habitus, dorsal view. B. Habitus, lateral view. C. Prosoma, lateral view, anvil-like basal process of leg I indicated by large arrow, round coxal process by small arrow. D. Genital double-somite, dorsolateral view, seminal receptacle arrowed. E. Rostrum. F. Labrum and antenna. G. Basal setae of antenna. H. Mandibular gnathobase. I. Mandibular palp. Scales in mm.

**Types.** Holotype: 1 ♀, body length 0.46 mm collected on 14 May 1991, dissected and mounted on glass slides. Reg. no. CBM-ZC 2517. Paratypes: 1 ♀ collected on 10 April 1992, body length 0.48 mm, dissected and mounted on glass slides; 2 ♂♂ collected 10 April 1992, body length 0.44 mm, dissected and mounted on glass slides; 1 ♂ collected on 18 November 1993, body length 0.44 mm, whole specimen. Reg. nos CBM-ZC 2518-2521.

**Etymology.** The new specific name *longicauda* (Latin *longus* meaning long, *cauda* meaning tail) refers to its elongate caudal rami.

**Female.** Body (Fig. 1A-C) laterally compressed; fourth and fifth pedigerous somites incompletely fused, with distinct suture laterally. Rostrum (Fig. 1E) movable at base, rounded at tip, constricted at mid-length. Posterior end of prosoma rounded in lateral view. Labrum (Fig. 1F) with medial swelling and lateral pair of minute prominences. Urosome 4-segmented, slender; genital double-somite slightly produced ventromedially, with small genital operculum medially; seminal receptacle (Fig. 1D) elongate, coiled terminally; second urosomal somite as long as genital double-

somite, third somite longest with posterior margin striated; anal somite almost completely telescoped into preceding somite; caudal rami symmetrical, relatively long, about 4 times longer than wide; caudal anterolateral seta minute; subterminal outermost seta chitinized; subterminal dorsal seta relatively short.

Antennule (Fig. 2A) 22-segmented, reaching posteriorly to near posterior end of first pedigerous somite; first segment flattened, with distal margin expanded posteriorly to form triangular acutely pointed process. Fusion pattern and armature element as follows: I-IV-7 + 2 aesthetascs (only base of aesthetasc illustrated in Fig. 2A), V-2, VI-3, VII-2, VIII-2, IX-2, X-XI-4, XII-2 (one seta missing in Fig. 2A), XIII-2, XIV-2, XV-XVI-2 + aesthetasc, XVII-2, XVIII-2, XIX-2, XX-2, XXI-3, XXII-1, XXIII-1, XXIV-1 + 1, XXV-1 + 1, XXVI-1 + 1, XXVII-XXVIII-5. Aesthetasc on compound segment XV-XVI extremely elongate and thick.

Antenna (Fig. 1F, G): coxa with minute inner seta terminally; basis bearing 2 inner apical setae of unequal lengths. Endopod incompletely 3-segmented with suture of terminal 2 segments visible only on one surface, first segment with 2 inner medial setae, second with 2 inner and 6 subterminal and terminal setae, third with 7 setae (one seta missing in Fig. 1F) terminally and spinular rows. Exopod incompletely 8-segmented, second and third almost fused, first to seventh segments each having inner seta, terminal segment with 1 medial and 3 terminal setae, its outer distal corner protruded. Mandibular gnathobase (Fig. 1H) heavily chitinized, with 9 cusps, the ventralmost one largest. Mandibular palp (Fig. 1I): basis with 4 marginal setae, terminal one with its basal part chitinized and incompletely fused to basis; endopod 2-segmented, proximal segment bearing 4 terminal setae, apical segment 10 setae terminally; exopod 4-segmented, first to third segments each bearing inner seta terminally, terminal segment small with 3 setae of unequal lengths.

Maxillule: praecoxal arthrite (Fig. 2B) with 2 spiniform prominences and 13 setae, 2 of which heavily chitinized; coxal endite (Fig. 2B) with 3 short setae; coxal epipodite (Fig. 2C) with 3 short and 6 thick setae; first and second basal endites (Fig. 2C) having 3 and 5 setae, respectively; basal epipodite (Fig. 2C) bearing minute seta; endopod (Fig. 2C) 2-segmented, proximal with 2 middle and

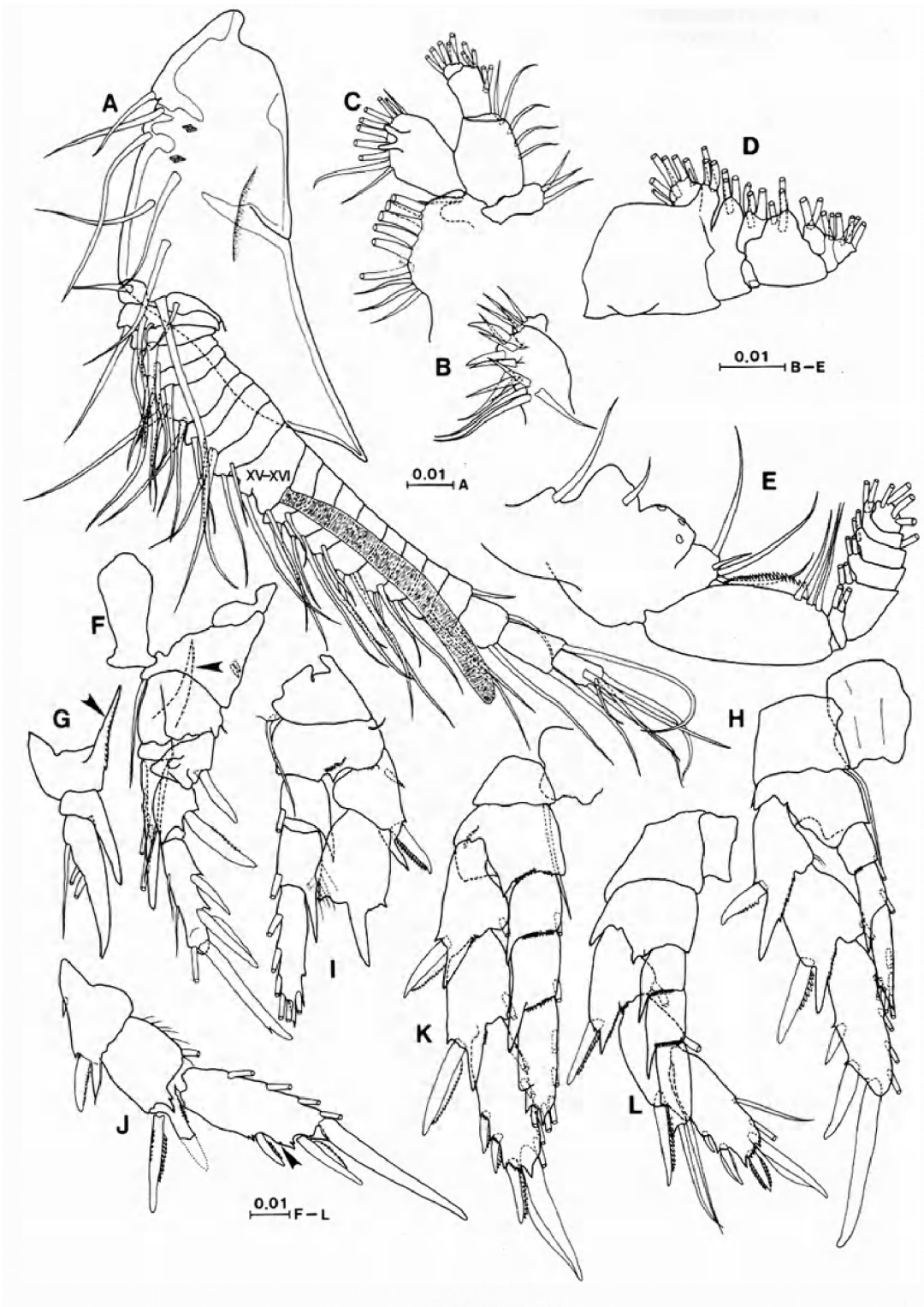
3 terminal setae, apical with 5 setae; exopod (Fig. 2C) lamellar, bearing 10 setae and unique V-shaped process. Maxilla (Fig. 2D): first and second coxal and basal endites each with 3 setae; endopod segments almost fused, with 8 setae in total. Maxilliped (Fig. 2E): syncoxa stout, 4 endites bearing 1, 1, 3 (missing in Fig. 2E) and 4 setae, respectively; basis with serrate plate along inner margin and 3 setae subterminally; endopod distinctly 6-segmented, with setal formula of 2, 2, 2, 2 + 1, 4.

Setation and spinulation of legs 1-4 presented in Table 1. Leg 1 (Fig. 2F, G): coxa with proximal rounded process on posterior surface (not figured in Fig. 2F) and outer middle spinules; basis having large, proximally directed process on posterior surface, reaching to proximal end of coxa and serrated along length (indicated by arrow in Fig. 2F, G); endopod 2-segmented, first segment unarmed, with long distal process reaching to almost half second segment, second tapering distally, bearing 3 setae along inner medial margin; exopod 3-segmented, first segment with 2 small irregular processes on anterior surface, third slender. Leg 2 (Fig. 2H): both rami 3-segmented, first exopod segment with outer distal process longer than outer spine. Third endopod segments of legs 3 (Fig. 2I, J) and 4 (Fig. 2K) each with outer middle prominence. Leg 3: basis with medial row of minute spinules along distal margin and outer minute seta; first exopod segment with outer spinule proximally, second with long outer distal process, third bearing 2 outer spines and scar which possibly represents position of middle outer spine (indicated by arrow in Fig. 2J). Leg 4: third exopod segment with 3 outer spines. Leg 5 (Fig. 2L): basis produced into outer distal process; both rami 3-segmented; first and second endopod segments unarmed, third segment with 2 setae of equal length terminally; third exopod segment bearing 2 small outer, 1 serrate terminal and 1 large inner spines plus 2 inner setae.

**Male.** Body (Fig. 3A) similar to that of female, but smaller. Urosome 5-segmented, genital somite short, penultimate urosomal somite longest; anal somite shortest and almost concealed by preceding somite as in female.

Right antennule (Fig. 3B) 21-segmented, geniculate between segments 16 and 17; compound segment I-IV as in female. Armature element and fusion pattern as follows:

Fig. 2. *Placocalanus longicauda* sp. n., female (A-C, E-L: holotype; D: paratype). A. Antennule, posterior surface. B. Maxillary praecoxal arthrite and coxal endite. C. Maxillary coxa, basis and rami. D. Maxilla. E. Maxilliped, three elements on third syncoxal endite missing. F. Leg 1, anterior surface, anvil-like basal process arrowed. G. Basis and endopod of leg 1, anvil-like basal process arrowed. H. Leg 2, anterior surface. I. Leg 3, posterior surface. J. Exopod of leg 3, anterior surface, scar of middle spine arrowed. K. Leg 4, anterior surface. L. Leg 5, anterior surface. Scales in mm.



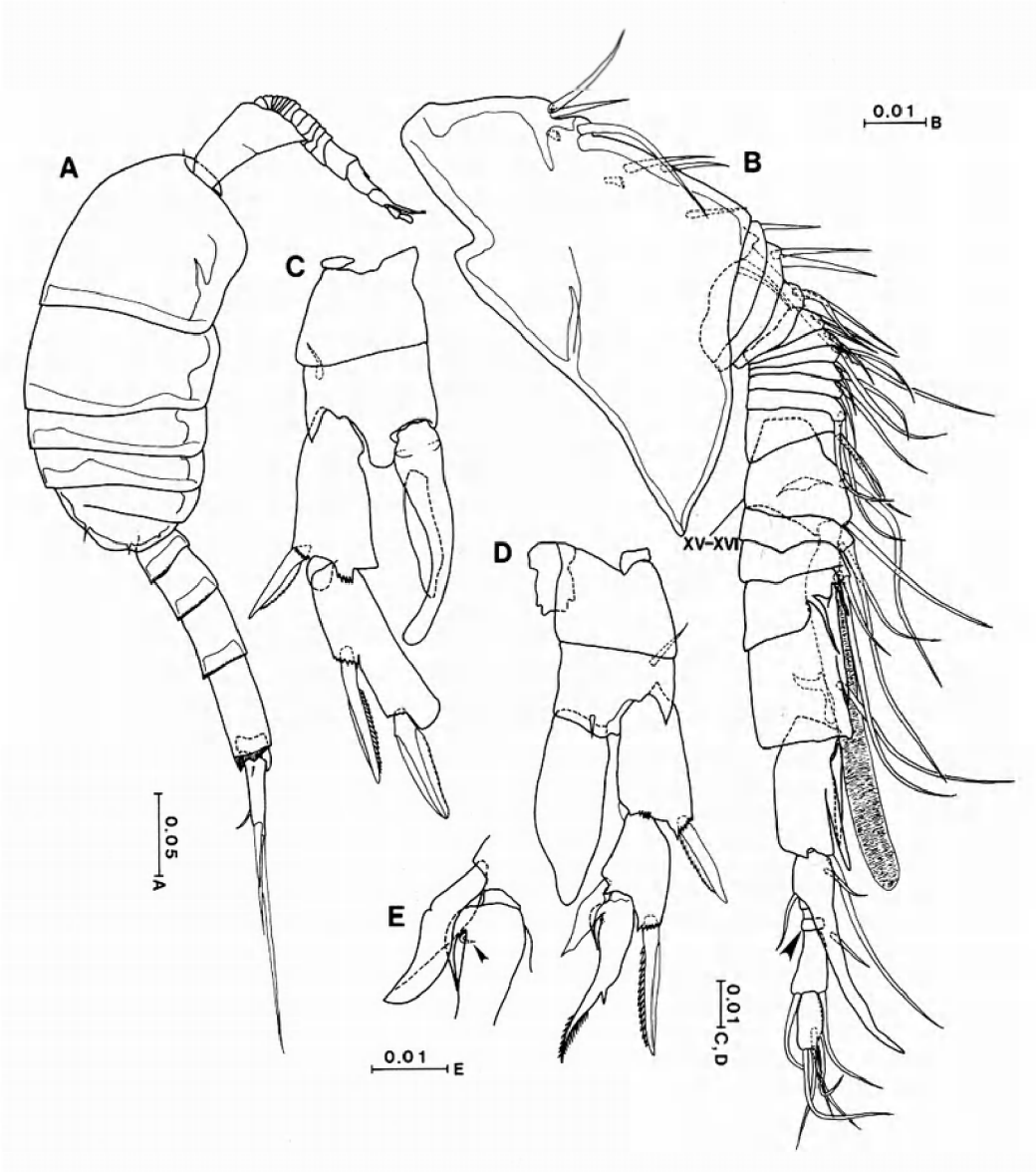


Fig. 3. *Placocalamus longicauda* sp. n., male (paratype). A. Habitus, lateral view. B. Right antennule, anterior surface, segment XXV arrowed. C. Right leg 5, anterior surface. D. Left leg 5, anterior surface. E. Second and third exopod segments of left leg 5, anterior surface, minute seta arrowed. Scales in mm.

I-IV-7 + 2 aesthetascs, V-2, VI-2, VII-2, VIII-2, IX-2, X-2, XI-2, XII-2, XIII-2, XIV-2, XV-XVI-2 + aesthetasc, XVII-2, XVIII-2, XIX-2 processes, XX-1 + process, XXI-XXII-1 + 2 processes, XXIII-XXIV-3 + process, XXV-unarmed, XXVI-1 + 1, XXVII-XXVIII-5. Sheath present between segments XIV and XV-XVI as found in some misophrioid and cyclopoid males (cf. HUYS & BOXSHALL 1991, figs 2.3.3, 2.8.5).

Leg 5 (Fig. 3C-E): coxa unarmed; basis sharply pointed on outer distal corner, with short seta on posterior surface; right basis with minute spinule distally on anterior surface. Right leg (Fig. 3C): endopod unarmed, incompletely 3-segmented, proximal two segments almost fused on posterior surface, third segment spatulate, originating from basal outer portion of second segment; exopod 2-segmented, first segment with outer flanged spine and round lobe distally, second segment truncate terminally, with 2 flanged outer spines. Left leg (Fig. 3D, E): endopod 1-segmented, unarmed; exopod 3-segmented, middle segment bearing flanged outer spine and spatulate inner spine, third segment tapering distally and slightly curved inward, with minute seta and curved spiniform process along inner basal margin and short pointed process at outer midlength, the latter half of the segment flanged on both sides.

Remarks. All the present three new Pacific species have only one inner setae on the second endopod segment of legs 3 and 4 while the Atlantic species, *Placocalanus insularis* and *P. namus* have 2 setae on the same segment. In addition, the antennule is 22-segmented in females of the new Pacific species and 23 in the Atlantic species. In males the right antennule is 21-segmented in the Pacific species and 20 in the Atlantic species. The new species is distinguishable from the other Pacific species described below in: (1) the rostrum rounded at tip; (2) the elongate caudal rami; (3) the coiled seminal receptacle of female; (4) the proximally directed serrated basal process of leg 1; (5) the 2-segmented endopod of leg 1, with the first segment strongly produced on outer distal corner; (6) the third exopod segment of leg 3 with only 2 outer spines in both sexes; (7) the endopod of the female leg 5 without inner setae; (8) the third exopod segment of the female leg 5 with 2 inner setae; (9) the endopod of leg 5 of female 3-segmented, first and second segments unarmed, third with 2 terminal setae; (10) the second exopod segment of the male right leg 5 without a scythe-like inner process proximally; (11) the endopod of the male right leg 5 unarmed.

Table 1. Setation and spinulation of legs 1-4 of the three new species of *Placocalanus*. Bold letters mean differences between species.

Species	Leg	Coxa	Basis	Exopod			Endopod		
				1	2	3	1	2	3
<i>P. longicauda</i>	1	0-1	1-0	I-0; I-1; II, I, <b>3</b>	<b>0-0; 0, 0, 3</b>				
	2	0-1	0-0	I-0; I-1; II, I, 4	0-1; 0-1; 1, 2, 2				
	3	0-1	1-0	I-0; I-1; <b>II</b> , I, 4	0-1; 0-1; 1, 2, 3				
	4	0-1	1-0	I-1; I-1; III, I, 4	0-1; 0-1; 1, 2, 2				
<i>P. inermis</i>	1	0-0	1-1	I-0; I-1; II, I, <b>2</b>	<b>0, 0, 3</b>				
	2	0-0	0-0	I-0; I-1; II, I, 4	0-0; 0-1; 1, 2, 2				
	3	0-0	0-0	I-0; I-1; <b>III</b> , I, 4	0-1; 0-1; 1, 2, 3				
	4	0-0	1-0	I-0; I-1; III, I, 4	0-1; 0-1; 1, 2, 2				
<i>P. brevipes</i>	1	0-1	1-0	I-0; I-1; II, I, <b>3</b>	<b>0, 0, 4</b>				
	2	0-1	0-0	I-0; I-1; II, I, 4	0-1; 0-1; 1, 2, 2				
	3	0-1	1-0	I-1; I-1; <b>III</b> , I, 4	0-1; 0-1; 1, 2, 3				
	4	0-1	1-0	I-1; I-1; III, I, 4	0-1; 0-1; 1, 2, 2				

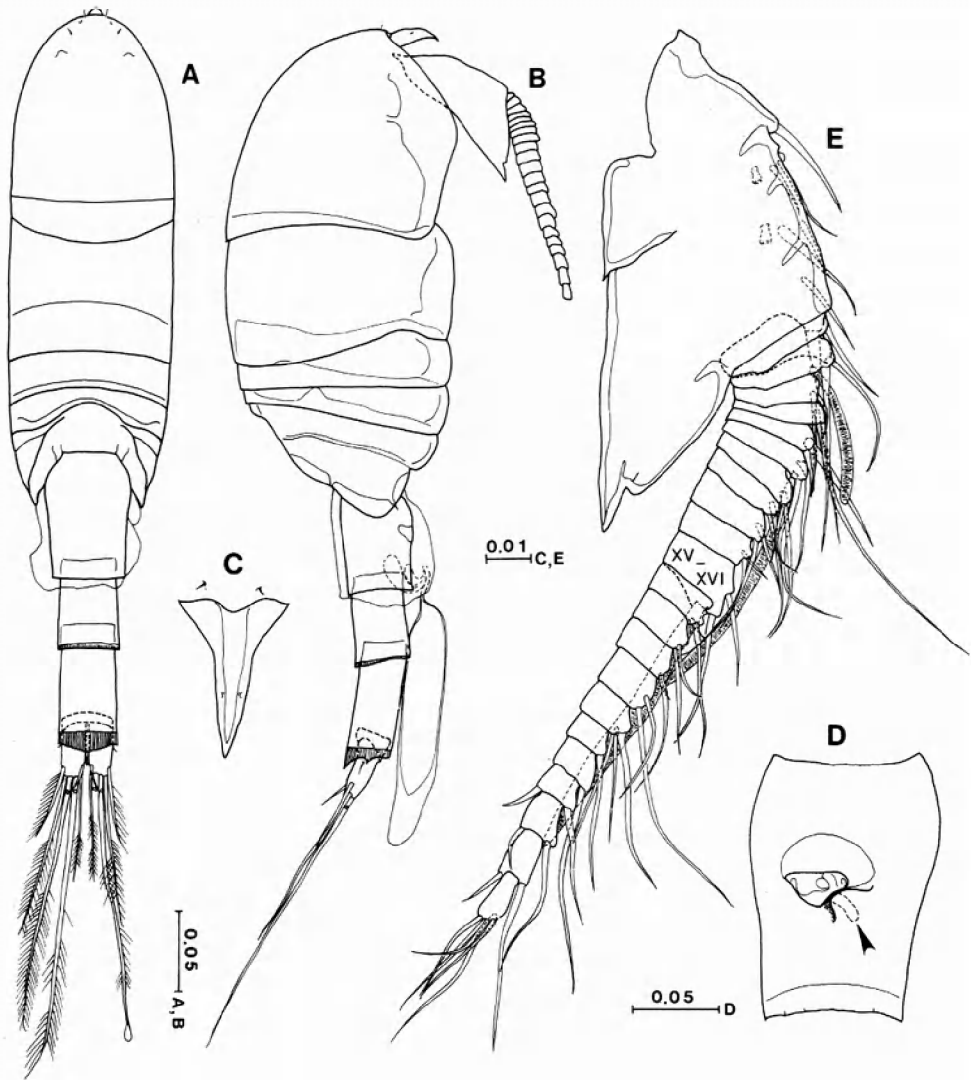


Fig. 4. *Placocalanus inermis* sp. n., female (holotype). A. Habitus, dorsal view. B. Habitus, lateral view. C. Rostrum. D. Genital double-somite, ventral view, seminal receptacle arrowed. E. Antennule. Scales in mm.

*Placocalanus inermis* sp. n. (Figs 4-6)

Material examined. 3 ♀♀ & 1 ♂. Sandy bottom off Nagannu Island, Okinawa, South Japan (26°14'N, 127°33'E), depth 47-51 m, local time 0943-1031, 10 April 1992.

Types. Holotype: 1 ♀, body length 0.45 mm, dissected and mounted on glass slides. Reg. no. CBM-ZC 2522. Paratypes: 1 ♀, body length 0.47 mm, dissected and mounted on glass slides. 1 ♀, body length 0.48 mm, whole specimen; 1 ♂, body length 0.49 mm, rostrum, right antennule and leg 5 detached

and mounted on glass slides, prosome and urosome in vial. Reg. nos CBM-ZC 2523-2525.

Etymology. The specific name *inermis* (Latin, meaning unarmed) refers to the basis of leg 1 without a proximally directed large process.

Female. Body (Fig. 4A, B) similar to *P. longicauda*, but stouter and thicker. Rostrum (Fig. 4C) sharply pointed at tip, movable basally. Posterior end of prosome bilobed in lateral view, reaching to anterior part of genital

operculum. Urosome: genital double-somite (Fig. 4D) slightly produced ventromedially, widest at a part of anterior one-fourth; seminal receptacle (arrowed) small, finger-like; spermatophore sausage-like, ca. 0.29 mm, coupling device covering the whole somite; genital operculum (Fig. 4D) located ventromedially, slightly asymmetrical; second urosomal somite shorter than genital double-somite, third subequal to genital double-somite with striated rounded process dorsoposteriorly; anal somite almost completely telescoped into preceding somite; caudal rami symmetrical, relatively short, longer than wide, with 7 setae; anterolateral seta minute; subterminal outermost seta short, stout; terminal setae plumose, second innermost seta longest and as long as urosome; subterminal dorsal seta short.

Antennule (Fig. 4E) 23-segmented, reaching posteriorly to near posterior end of first pedigerous somite; first segment flattened as in *P. longicauda*, with posterior distal corner sharply pointed and with notch on inner side; fusion pattern and armature element as follows: I-IV-7 + 2 aesthetascs (only base of aesthetasc illustrated in Fig. 4E), V-2, VI-1 + aesthetasc, VII-2, VIII-2, IX-2, X-2 + aesthetasc, XI-2, XII-2, XIII-2, XIV-2, XV-XVI-2 + aesthetasc, XVII-2, XVIII-2, XIX-2, XX-2, XXI-3, XXII-1, XXIII-1, XXIV-1 + 1, XXV-1 + 1, XXVI-1 + 1, XXVII-XXVIII-5. Aesthetasc on segments VI, X, and XV-XVI elongate.

Antenna to maxilliped (Fig. 5A-G) essentially similar to those of *P. longicauda*, with the following features unique to *P. inermis*. Antenna (Fig. 5A, B): second endopod segment lacking subterminal row of spinules; terminal exopod segment not as protruded distally as in *P. longicauda*. Mandible (Fig. 5C, D): terminal seta of basis completely free from the segment. Maxillule (Fig. 5E): praecoxal arthritis with 9 spiniform and 4 fine setae and 3 low pointed prominences; coxal exite bearing digitiform process subterminally (indicated by large arrow); exopod with square process subterminally (indicated by small arrow). Maxilla (Fig. 5F) and maxilliped (Fig. 5G) with the same segmentation and setation as in *P. longicauda*.

Setation and spinulation in legs 1-4 shown in Table 1. Leg 1 (Fig. 5H, I): coxa unarmed; basis lacking large, proximally directed process, with minute seta on inner distal corner; endopod 1-segmented, spiniform, with 3 inner setae of unequal lengths medially; exopod 3-segmented, slender, third exopod segment with only 2 inner setae. Leg 2 (Fig. 5J): coxa with row of setules near inner medial margin; basis unarmed; first endopod segment lacking inner seta. Leg 3 (Fig. 5K): first exopod segment without outer spinule proximally; third exopod segment having 3 outer spines. Leg 4 (Fig. 5L): first exopod segment without inner seta. Leg 5 (Fig. 5M, N): endopod 3-segmented, first and second segments each with stout spiniform seta at inner distal corner, third segment with spiniform inner seta and

2 terminal setae; first and second exopod segments with short thick spiniform seta on inner distal corner, third segment bearing 2 outer, 1 terminal and 1 inner spines.

Male. Body (Fig. 6A) similar to that of the female; relatively large spermatophore visible in prosome, compared with that of *P. brevifores* (see Fig. 7A). Rostrum sharply pointed as in female.

Right antennule (Fig. 6B) basically similar to that of *P. longicauda*. First compound segment with posterior distal corner having notch as in female. Fusion pattern and armature element basically similar to those of *P. longicauda*: I-IV-7 + 2 aesthetascs, V-2, VI-2 + aesthetasc, VII-2, VIII-2, IX-2, X-2 + aesthetasc, XI-2, XII-2, XIII-2, XIV-2, XV-XVI-2 + aesthetasc, XVII-2, XVIII-2, XIX-2 elements (setae or processes), XX-1 + process, XXI-XXII-2 + process, XXIII-XXIV-4 + process, XXV (arrowed) - unarmed, XXVI-1 + 1, XXVII-XXVIII-5 + aesthetasc. Aesthetasc on segments VI, X, and XV-XVI elongate as in female. Spinulose seta on segment XIII swollen proximally. Compound segment XXI-XXII with fine middle seta instead of chitinized process as found in male *P. longicauda*.

Left leg 5 (Fig. 6C): endopod 2-segmented, first segment small, unarmed, second produced into acute process terminally, with lamellar process proximally and 2 subequal plumose setae terminally; exopod 3-segmented, first segment with semicircular lamellar process along distal margin, second produced into bifurcated process at inner distal corner, third with 1 minute and 1 spiniform seta along inner margin and minute pointed process at outer midlength. Right leg 5 (Fig. 6D): basis with minute sharply pointed prominence at base of endopod and slightly larger prominence located near inner distal corner; endopod 2-segmented, first segment unarmed, curved outward at inner distal end, second expanded proximally, bearing 1 inner spine and 2 terminal plumose setae of equal length; exopod 2-segmented, second segment having large curved process and 1 inner seta proximally, 1 middle and 2 terminal flanged spines.

Remarks. This new species is readily discernible from other congeners in: (1) antennular compound segment I-IV of both sexes with posterior distal corner indented; (2) antennular segments VI and X of both sexes each with 1 large aesthetasc; (3) basis of leg 1 without anvil-like process; (4) leg 1 with 1-segmented endopod bearing 3 inner setae; (5) third exopod segment of leg 1 with 2 inner setae; (6) coxal and basal setae absent on legs 2 and 3; (7) first exopod segment of leg 4 lacking inner seta; (8) stout spiniform setae on endopod of female leg 5; (9) third exopod segment of female leg 5 armed with only 4 spines; (10) third exopod segment of right leg 5 of male with 3 spines; (11) endopod of left leg 5 of male with 2 terminal setae and subterminal spine.

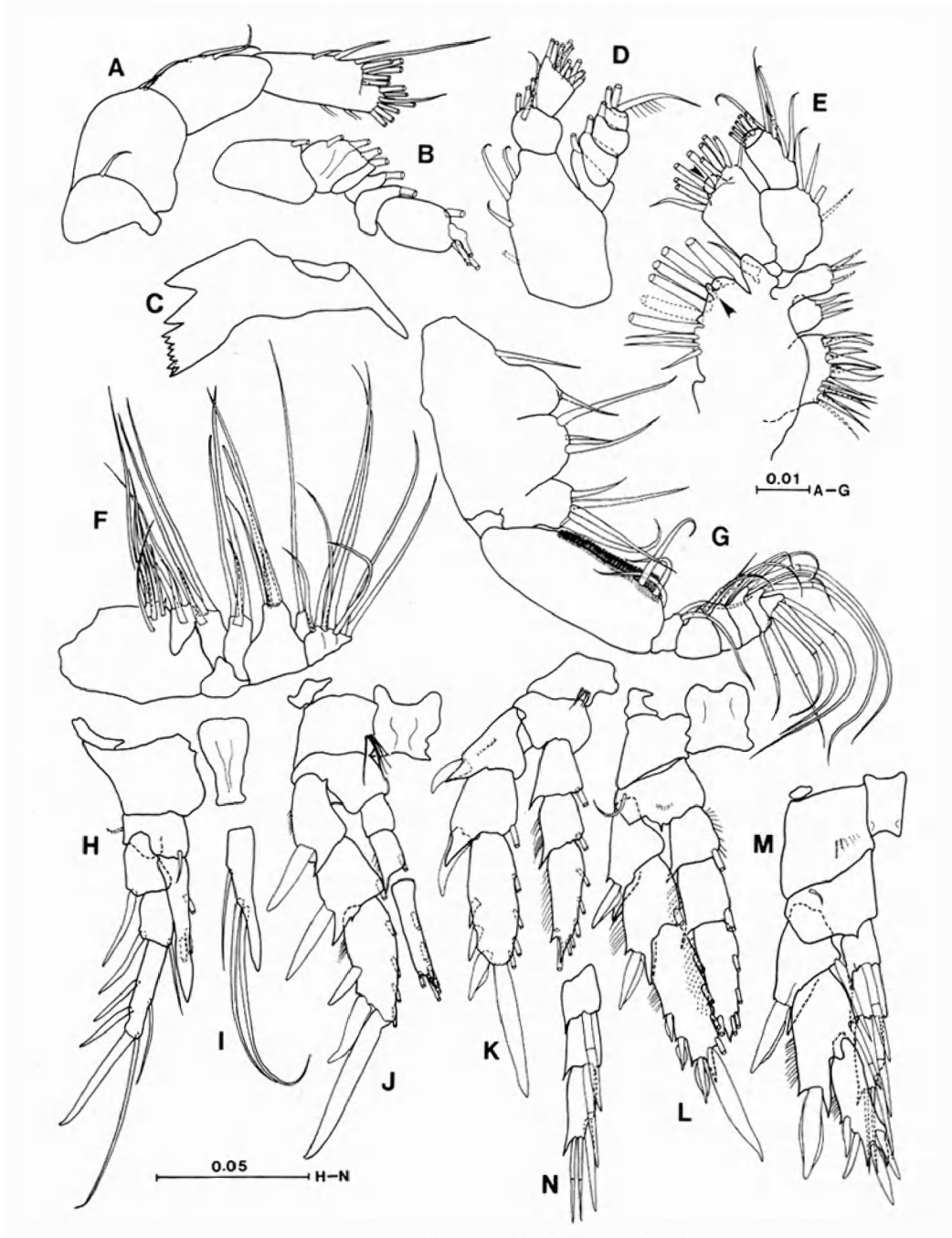


Fig. 5. *Placocalanus inermis* sp. n., female (A-F, H-N: holotype; G: paratype). A. Antennary coxa, basis and endopod. B. Antennary exopod. C. Mandibular gnathobase. D. Mandibular palp. E. Maxillule. F. Maxilla. G. Maxilliped. H. Leg 1, anterior surface. I. Endopod of leg 1. J. Leg 2, anterior surface. K. Leg 3, anterior surface. L. Leg 4, posterior surface. M. Leg 5, posterior surface. N. Endopod of leg 5. Scales in mm.

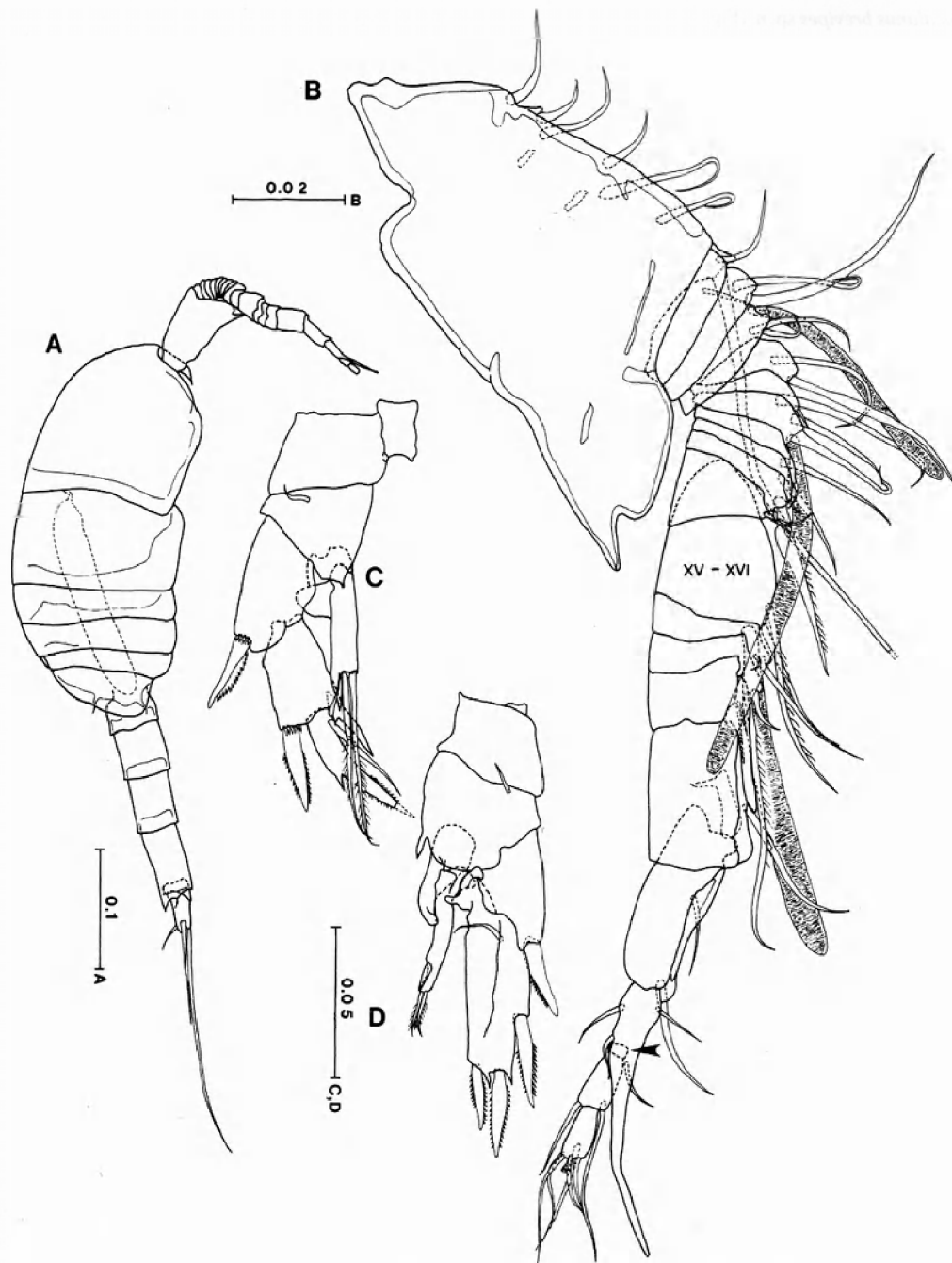


Fig. 6. *Placocalanus inermis* sp. n., male (A-D: paratype). A. Habitus, lateral view. B. Right antennule, segment XXV arrowed. C. Left leg 5, posterior surface. D. Right leg 5, posterior surface. Scales in mm.

*Placocalamus brevipes* sp. n. (Fig. 7)

**Material examined.** 3 ♂♂. Sandy bottom off Nagannu Island, Okinawa, South Japan (26°14' N, 127°33' E), depth 47-51 m, local time 0943-1031, 10 April 1992.

**Types.** Holotype: 1 ♂, body length 0.38 mm, dissected and mounted on glass slides, Reg. no. CBM-ZC 2526; paratypes: 2 ♂♂, body length 0.38 and 0.39 mm, whole specimens. Reg. no. CBM-ZC 2527.

**Etymology.** The new specific name *brevipes* (Latin *brevis* meaning short, *pes* meaning foot) refers to the relatively short third exopod segment of left leg 5 of the male.

**Male.** Body (Fig. 7A) similar to that of *Placocalamus inermis* in having relatively short caudal rami, but much smaller than the latter; sausage-like spermatophore visible in posterior part of prosome. Rostrum (Fig. 7B) bluntly pointed at tip.

Right antennule (Fig. 7C) 21-segmented, geniculate between segments 16 and 17; segments I-IV as in female of *P. longicauda*. Fusion pattern and armature elements essentially similar to those of *P. longicauda*: I-IV-7 + 2 aesthetascs (only base of aesthetasc illustrated in Fig. 7C), V-2, VI-2, VII-2, VIII-2, IX-2, X-2, XI-2, XII-1, XIII-2, XIV-2, XV-XVI-2 + aesthetasc, XVII-2, XVIII-2, XIX-1 + 2 processes, XX-1 + process, XXI-XXII-1 + 2 processes, XXIII-XXIV-3 + process, XXV (arrowed)-unarmed, XXVI-1 + 1, XXVII-XXVIII-5. Because of its small size, it was difficult to dissect the antenna and mouthpart appendages without damages. However, following features were found to differ from *P. longicauda*: (1) terminal exopod segment of antenna with transverse row of relatively long spinules subterminally; (2) outer process of maxillulary exopod tapering distally and not bifurcated at tip.

Setation and spinulation of legs 1-4 are shown in Table 1. Leg 1 (Fig. 7D): large, proximally directed basal process present, with minute hook at base and smooth outer margin unlike *P. longicauda* (Fig. 2G); endopod 1-segmented, with suture visible on proximal outer portion, tapering distally, bearing 4 setae of unequal lengths along inner margin. Leg 2 (Fig. 7E): outer distal processes of second endopod and first exopod segments not as protruded as those of *P. longicauda*. Leg 3 (Fig. 7F): minute seta present on inner distal corner of first exopod segment; third exopod segment with 3 outer spines. Leg 4 (Fig. 7G, H): first and

second endopod segments completely coalescent on posterior surface. Leg 5 (Fig. 7I): coxa unarmed. Right leg: basis with 2 pointed processes on inner distal corner, minute seta on posterior surface and spinular row on anterior surface; endopod 2-segmented, first segment unarmed, swollen proximally, produced into rounded lobe reaching beyond second segment, second massive, with 1 plumose seta apically; exopod 2-segmented, first segment with large outer process and outer distal spine, second segment expanded, with 2 stout outer spines, inner middle seta, round apex and well-developed U-shaped inner proximal process. Left leg: basis with stout process and minute seta on posterior surface; endopod 2-segmented, unarmed, first small, second elongate, nearly reaching the distal end of second exopod segment; exopod 3-segmented, second with stout outer spine and bulb-like inner distal process, third small, with 2 inner setae of unequal lengths and terminal spine.

**Female.** Unknown.

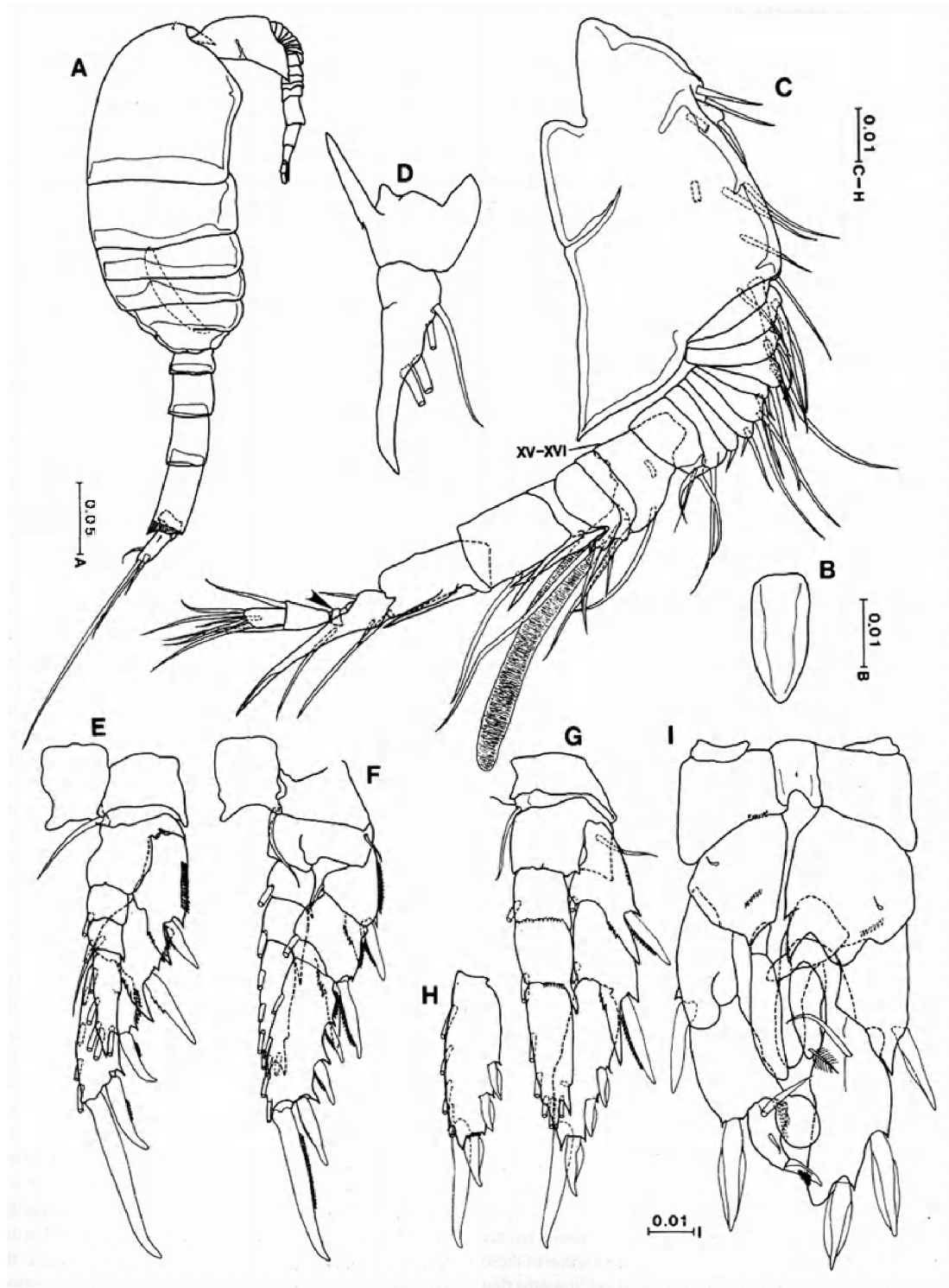
**Remarks.** The new species is similar to *P. inermis* in that both species have relatively short caudal rami. This species is separated from *P. inermis* by the following features of the legs: (1) the presence of a proximally directed basal process of leg 1; (2) the different setation in the endopod of leg 1 (see Table 1); (3) the presence of an inner seta on the first exopod segments of legs 3 and 4; (4) fusion on posterior surface of the first and second endopod segments of leg 4.

In Harpacticoida sexual dimorphism in the segmentation and setation is commonly found in legs other than leg 5, whereas in Calanoida this is rare. Exceptionally, leg 4 exhibits sexual dimorphism in some species of the hyperbenthic calanoid family Pseudocyclopiidae (OHTSUKA 1992). The differences of the legs certainly make its separation from *P. inermis* reasonable.

## DISCUSSION

As FOSSHAGEN (1970) suggested, *Placocalamus* can be assigned to the family Ridgewayiidae solely based on the structures of the female genital double-somite, which has a single genital operculum ventromedially or laterally, and the exopod of leg 5 of the female, in which the third exopod

Fig. 7. *Placocalamus brevipes* sp. n., male (holotype). A. Habitus, lateral view. B. Rostrum. C. Right antennule, segment XXV arrowed. D. Basis and endopod of leg 1, anterior surface. E. Leg 2, anterior surface. F. Leg 3, posterior surface. G. Leg 4, anterior surface, inner setae on third exopod segment omitted. H. Third exopod segment of leg 4. I. Leg 5, posterior surface. Scales in mm.



segment is constricted basally and set into a narrowed socket on the inner side of the second segment (WILSON 1958; FOSSHAGEN 1970; FOSSHAGEN & ILIFFE 1991). Although the former character is convergently shared by many other calanoid families, the latter is unique to this family, and seems to be the only synapomorphic character to accommodate the four genera. These genera exhibit markedly different morphologies, and seem to live in microhabitats on or close to the bottom. *Ridgewayia* is reported to be loosely associated with cnidarians, corals and, possibly, other invertebrates and often in swarms (HUMES & SMITH 1974; FOSSHAGEN & ILIFFE 1991; FERRARI 1995). *Exumella* was collected at 5-15 m depths close to bottom in oxygen-depleted water, and from marine caves (FOSSHAGEN 1970; GRAHAME 1979; FOSSHAGEN & ILIFFE 1991; JAUME & BOXSHALL 1995) while *Brattstromia* is only taken in marine caves (FOSSHAGEN & ILIFFE 1991). Since these three genera have relatively long antennules reaching at least to the prosomal end, they are most certainly free-swimmers near sediments or in the vicinity of associated invertebrates like some hyperbenthic species of *Stephos* with long symmetrical antennules (OHTSUKA & HIROMI 1987). In contrast to these ridgewayiids, *Placocalamus* with its flattened body and the short specialized antennules may temporarily borrow into sediments.

The relationship of *Placocalamus* to the family is enigmatic. The extremely specialized characters of body, antennule, and leg 1 of the genus conceal its relationship to the family. However, several possible synapomorphies are shared between *Placocalamus* and *Ridgewayia*: (1) the spiniform terminal outermost caudal seta; (2) the terminal exopod segment of the right leg 5 of the male truncate or rounded, with 2 flanged outer spines; (3) the endopods of legs 5 of the male unarmed or bearing a few elements. No filaments on the rostrum are found in these two genera and *Brattstromia*, but in the former two genera the tip is sharply or bluntly pointed whereas in the latter bifurcated. Since ridgewayiids are abundant in shallow-water caves in subtropical areas (YEATMAN 1969; FOSSHAGEN & ILIFFE 1991), future discoveries of new taxa may clarify the relationships between the genera in the family.

The numerous autapomorphic characters found in the strongly modified antennule and leg 1 of *Placocalamus* may have been secondarily evolved for the adaptation to a demersal life. FOSSHAGEN (1970) pointed out that these unique characters are in common with some benthic harpacticoids. The laterally compressed prosome and the triangular expanded plate of the antennule of *Placocalamus* are reminiscent of the epibenthic harpacticoid family Tegastidae (cf. LANG 1965). Although the function of these compressed bodies is not fully disclosed yet, it seems that they can readily burrow into narrow space or loose sediment (not interstitial space).

The triangular expanded plate of the antennule of *Placocalamus* may functionally correspond to the lateral expansion of cephalothorax of the Tegastidae in protecting delicate mouthparts.

FOSSHAGEN (1970) speculated that the modified leg 1 of *Placocalamus* is adapted for digging or clinging to the substrate. Recently DAHMS & POTTEK (1992) and DAHMS (1993) have found extreme modifications in legs 1 of the harpacticoid burrowers, *Talpina* and *Metahunteammia* for digging: (1) the development and compactness of the exopod; (2) heavily chitinized, stout outer spines on the exopod; (3) the reduction of the endopod. Such a tendency as in these harpacticoids can be only weakly recognized in *Placocalamus*, suggesting that *Placocalamus* is a temporary burrower into loose sediment. Since sexual dimorphism is not found in the leg 1 of *Placocalamus*, its modification is not related to mating behaviour.

The present study reveals that the genus *Placocalamus* exhibits a wide variety of ornamentation, segmentation and setation/spinulation in the legs, and in particular, in the endopods of legs 1 and 5. Usually the segmentation and, to less extent, the armature elements of legs 1-4 are relatively constant within a calanoid family (e.g. Arietellidae, see OHTSUKA & al. 1994). The variable segmentation of the legs and the presence and absence of the large, proximally directed basal process in leg 1 may reflect their different reliance to the sediment. In legs 2-4 of the Pacific species there are reductions in setation as follows: (1) third exopod segments bearing 4 inner setae in the Pacific species and 5 in the Atlantic ones; (2) second endopod segments of legs 3 and 4 carrying 1 seta in the Pacific species and 2 in the Atlantic ones. The number of setae on the third exopod and the second endopod segments of legs 3 and 4 are used by both ANDRONOV (1974) and PARK (1986) to separate superfamilies. The present finding weakens the validity of these characters as diagnostic for the superfamilies.

The coexistence of several congeners of demersal calanoid copepods is commonly found not only in shallow-water but also in deep-water families (Table 2). The three new species of *Placocalamus* in the Pacific and the two species in the Atlantic each occurred simultaneously at the same locality (FOSSHAGEN 1970; present study). This tendency is apparent, in particular, in the families Pseudocyclopididae and Stephidae. JACOBY & GREENWOOD (1991) reported on the coexistence of up to eight species of *Stephos*. Such a high diversity of sympatric congeners has also been found in *Pseudocyclops* in subtropical waters in the Bahamas (FOSSHAGEN 1968) and Japan (S. Ohtsuka pers. obs.). FOSSHAGEN (1968) suggested that different microhabitat preference can make possible the sympatry of several species of *Pseudocyclops*: interstices of filamentous algae attached to the lower parts of turtle

grasses; open sandy bottom; interstitial space etc. This is also supported by the suggestion that two parapatric shallow-water species of *Paramisophria* exhibit different

zonations at the same locality (OHTSUKA & MITSUZUMI 1991). Generally a high variability of benthic environments may allow the coexistence of several congeners.

Table 2. Coexistence of congeners of demersal calanoid copepods.

Family	Genus	Specific name	Locality (depth)	Reference
Aetideidae	<i>Bradyidius</i>	<i>dentatus, spinibasis</i>	New Zealand slope (1697-1690 m)	BRADFORD (1969)
	<i>Pseudeuchaeta</i>	<i>flexuosa, magna</i>	New Zealand slope (1697-1690 m)	BRADFORD (1969)
Arietellidae	<i>Metacalanus</i>	spp.	Ryukyu Islands, Japan (167 m)	OHTSUKA & al. (1994)
	<i>Paramisophria</i>	<i>japonica, sp.</i>	Ryukyu Islands, Japan (167 m)	OHTSUKA & al. (1991)
Diaixidae	<i>Anawekia</i>	<i>robusta, bilobata</i>	Gulf of Carpentaria, Australia	OTHMAN & GREENWOOD (1994)
Phaennidae	<i>Xanthocalanus</i>	<i>macilenta, rotunda</i>	Off Woods Hole, U.S.A.	GRICE & HULSEMANN (1970)
		<i>obtusus, pinguis</i>	Northwestern Atlantic (1500 m)	GRICE (1973)
Pseudocyclopiidae	<i>Pseudocyclops</i>	<i>cokeri, paulus,</i> <i>rostratus, rubrocinctus</i>	Magüeyes Island, Puerto Rico	BOWMAN & GONZALEZ (1961)
		<i>bahamensis, cokeri,</i> <i>lernerii, oliveri,</i> <i>rostratus, rubrocinctus,</i> <i>spinulosus, spp.</i>	Bahamas (3-9 m)	FOSSHAGEN (1968)
		spp.	Laccadives, India	MADHUPRATAP & al. (1991)
		spp.	Heron Reef, Australia (0.75-5.5 m)	JACOBY & GREENWOOD (1988)
		spp.	Ryukyu Islands, Japan	S. Ohtsuka (pers. obs.)
Pseudocyclopiidae	<i>Pseudocyclopia</i>	<i>giesbrechti, crassicornis</i>	Korshavn, Norway (ca 108 m)	SARS (1921)
		<i>insignis, stephoides</i> spp.	Cape Blanc, Mauritania (20 m) Ryukyu Islands, Japan	ANDRONOV (1986) S. Ohtsuka (pers. obs.)
Ridgewayiidae	<i>Placocalanus</i>	<i>brevipes, inermis,</i> <i>longicauda</i>	Ryukyu Islands, Japan	Present study
		<i>insularis, nannus</i>	Conception Island, Bahamas (12-45 m)	FOSSHAGEN (1970)
	<i>Ridgewayia</i>	<i>gracilis,</i> <i>schoemakeri, sp.</i>	Florida, U.S.A.	WILSON (1958)
Stephidae	<i>Stephos</i>	<i>pacificus, robustus</i> <i>tropicus, spp.</i>	Middle Japan (6 m) Heron Island, Australia (0.75-3.75 m)	OHTSUKA & HIROMI (1987) JACOBY & GREENWOOD (1991)
		<i>morii, spp.</i>	Moreton Bay, Australia (0.7-3.5 m)	JACOBY & GREENWOOD (1991)

*Key to genera of the family Ridgewayiidae*

1. Body extremely compressed laterally; antennule with triangular expanded plate proximally, short, reaching, at most, to first pedigerous somite ..... *Placocalanus* OHTSUKA, FOSSHAGEN & SOH, 1996
- Body not compressed laterally; antennule without triangular expanded plate proximally, reaching to or beyond end of prosome ..... 2
2. Rostrum with pair of filaments; maxilliped powerfully developed, endopod with 2 extremely elongate setae ..... *Exumella* FOSSHAGEN, 1970
- Rostrum without filaments; maxilliped endopod without extremely elongate setae ..... 3
3. Rostrum bifurcated at tip; maxilliped endopod bearing modified setae with comb-like tip ..... *Brattstromia* FOSSHAGEN, 1991
- Rostrum produced downwards to rounded or pointed tip; maxilliped without modified setae ..... *Ridgewayia* THOMPSON & SCOTT, 1903

*Key to species of Placocalanus*

1. Four setae on inner side of third exopod segments of legs 2-4; second endopod segments of legs 3 and 4 with 1 seta ..... 2
- Five setae on inner side of third exopod segments of legs 2-4; second endopod segments of legs 3 and 4 with 2 setae ..... 4
2. Endopod of leg 1 2-segmented; right exopod segment of male leg 5 without distinct inner process proximally .. *P. longicauda* sp. n.
- Endopod of leg 1 1-segmented; right exopod segment of male leg 5 with curved or irregular process ..... 3
3. Basis of leg 1 with large, proximally directed process; 3 aesthetascs on right antennules of male *P. brevipes* sp. n.
- Basis of leg 1 without large, proximally directed process; 5 aesthetascs on right antennule of male *P. inermis* sp. n.
4. Endopod of leg 1 3-segmented; terminal, second innermost caudal seta of female not modified; in male distal process on second segment from geniculation not reaching to antennular tip ..... *P. insularis* FOSSHAGEN, 1970
- Endopod of leg 1 1-segmented; terminal, second innermost caudal seta of female broadened; in male distal process on second segment from geniculation flattened distally, extending beyond antennular tip ..... *P. nannus* FOSSHAGEN, 1970

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