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To cite this article: Janet M. Bradford-Grieve (2004) Two new species of *Xanthocalanus* and the first record of *Brachycalanus* (Copepoda: Calanoida: Phaennidae) from the upper slope, north-eastern New Zealand, *New Zealand Journal of Marine and Freshwater Research*, 38:4, 621-647, DOI: [10.1080/00288330.2004.9517267](https://doi.org/10.1080/00288330.2004.9517267)

To link to this article: <https://doi.org/10.1080/00288330.2004.9517267>



Published online: 30 Mar 2010.



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## Two new species of *Xanthocalanus* and the first record of *Brachycalanus* (Copepoda: Calanoida: Phaennidae) from the upper slope, north-eastern New Zealand

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**Keywords** Copepoda; Calanoida; benthopelagic; Phaennidae; new species; *Xanthocalanus longispinus* n. sp.; *Xanthocalanus stewarti* n. sp.; *Xanthocalanus fallax* Sars, 1924; *Xanthocalanus minor* Giesbrecht, 1892; *Brachycalanus* sp.; New Zealand

**Abstract** Two new species of *Xanthocalanus* are reported from the New Zealand continental slope. The female and male of *X. longispinus* n. sp. is described as well as the female of *X. stewarti* n. sp. Aspects of *X. fallax* and *X. minor* from Norway are re-described and illustrated where observations differed from previous descriptions. Females of the two new species are distinguished from all other *Xanthocalanus* by a combination of characteristics of the female leg 5. The terminal segment has 4 spines and the inner terminal spine is completely fused to its segment in both species but is straight in *X. longispinus* and bent outwards in *X. stewarti*. The inner lateral spine extends beyond the base of the outer terminal articulated spine in *X. longispinus* and as far as the base of the outer terminal articulated spine in *X. stewarti*. The coxal inner border spinules are large, stout and cover a wide area in *X. longispinus* and are small, pointed and cover a narrow area in *X. stewarti*. The male may be distinguished from other known males with a styliform right leg 5 because leg 5 does not extend beyond the caudal rami, there are a series of about 8 stiff spines, graded in size, on the distal border of the left exopod segment 2, and the antennule has ancestral segments X–XV, XVI–XVII fused on both sides as well as XXII–XXIII on the right side. *Brachycalanus* is recorded for the first time from New Zealand waters, although the single, damaged, female specimen is illustrated but not named.

### INTRODUCTION

The benthopelagic calanoid copepod fauna of the New Zealand region is being described from samples taken from Wellington Harbour and the upper slope of the south-eastern coast of the North Island (Bradford 1969; Bradford-Grieve 1999, 2001a,b, 2003). The families most heavily represented in these samples, are those that have setae on the endopod of the maxilla modified into sensory structures. These families (Phaennidae, Scolecitrichidae, Stephidae, and Tharybidae) made up 16–24% of the individuals in samples (Bradford-Grieve 2001a). Amongst these families the Phaennidae was dominant. This family is now more precisely defined (see Ohtsuka et al. 1998, 2003) but work remains to be done to refine our knowledge of the morphology of species to determine if genera and species are accurately assigned in this family.

Coincidentally, specimens of *Xanthocalanus fallax* Sars, 1924 and *X. minor* Giesbrecht, 1892, from Norway (Hovda & Fosshagen 2003), were made available by Dr Audun Fosshagen. Because the new species described here are closely allied to *X. fallax* it was opportune that I was able to examine the Norwegian species, as earlier descriptions of *X. fallax* (Sars 1902 as *X. borealis*; Matthews 1964) and of *X. minor* (Sars 1921; Matthews 1964) do not include the mouthpart detail. The Norwegian specimens were in excellent condition and much of the fine detail not visible in New Zealand specimens, was easily observed on the Norwegian specimens.

This paper reports on two new species of *Xanthocalanus* from New Zealand and they are compared with *X. fallax* and *X. minor* from Norway.

The genus *Brachycalanus* is here recorded for the first time from New Zealand waters.

## METHODS

Calanoid copepods were collected in a non-closing plankton net with 250 µm mesh net that was attached to the warps of the trawl boards of the R.V. *Kaharoa* (Bradford-Grieve 2001a). The net was set so that it fished 4–6 cm above the sea floor in 299–452 m water depth. The sediment and organisms taken by the net were preserved in 2% formaldehyde. Specimens of *Xanthocalanus fallax* and *X. minor* were also examined from light trap samples taken at night 19, 20 October 1999 at 120 m depth from Raunefjord, made available by Dr Audun Fosshagen, University of Bergen, Norway.

Sorted copepods were observed whole in glycerine, and dissected parts mounted, unstained, or stained with chlorazol black, in gum-chloral (Pantin 1964). Mounted specimens were observed using Nomarski differential interference contrast microscopy. The system of morphological nomenclature used is based on that of Huys & Boxshall (1991). The description of *X. longispinus* n. sp. is given in full, whereas the remaining *Xanthocalanus* species are described with reference to *X. longispinus* and any original descriptions.

## SYSTEMATICS

*Xanthocalanus* Giesbrecht, 1892

### *Xanthocalanus longispinus* n. sp.

#### Material examined

**Holotype** Female (adult, not dissected) off south-eastern coast of North Island, New Zealand, 41°04.67'S 176°23.48'S. 13 April 2000, near sea floor, 452 m depth, KAH0005/05 (NIWA H833).

**Paratypes** 3 females (#1–3) and 2 males (#4 and 5) all dissected, further 16 females and 11 males not dissected (#6), same data as holotype (NIWAP1382).

**Additional material:** (4 females and 2 males) taken from 41°04.10'S 176°22.05'E (KAH0001/79) and 1 female from 37°25.22'S 178°09.92'E (KAH0001/71). Total length: 27 females 2.00–2.31 mm total length (mean 2.21 mm), 13 males 1.70–1.90 mm total length (mean 1.80 mm). The descriptions are based on specimens from the paratype series (P1382

#1–6). Types are deposited in the collection of the National Institute of Water and Atmospheric Research.

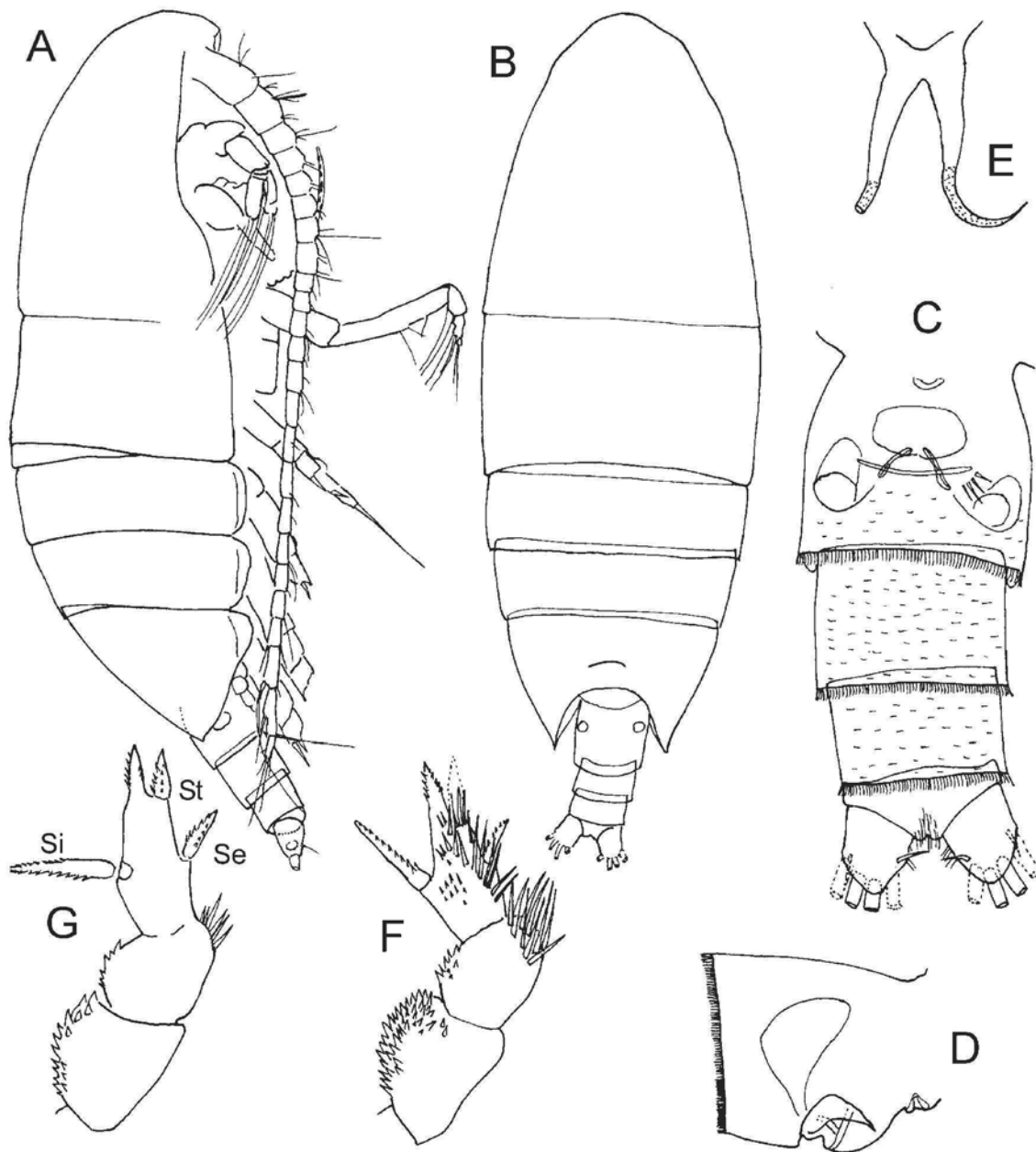
## Female

(Fig. 1–3)

**Body** Rostrum in form of pair of strong, ventrally directed, not articulated, cuticular extensions, distal part of which similar to aesthetasc (Fig. 1E). Cephalosome partially separate from pedigerous somite 1 on dorsal surface and round onto the lateral surface; pedigerous somites 4 and 5 fused with fusion line visible only dorsally (Fig. 1A,B). Posterolateral corners of prosome extend posteriorly into triangular flaps that are pointed in dorsal and lateral views and cover more than half of genital double-somite. Urosome of 4 free somites (Fig. 1C); surfaces of somites (not including anal somite) covered in very small semicircular thickenings that probably represent place of attachment of scales. Genital double-somite with pair of seminal receptacles, pear-shaped in lateral view and common oval anteroventral genital opening containing visible, paired gonopores; posterior to operculum is transverse fold posterior to which, on left side, are several soft spinules (Fig. 1C,D); posterior border of somite bordered by hyaline frill. Urosomites 2 and 3 with posterior hyaline frill. Anal somite very short, not visible on dorsal surface, bearing hairs on ventral surface in posterior midline. Genital double-somite and 2 following somites covered in what appears to be scars where scales may have been attached. Caudal rami symmetrical, slightly longer than wide (both dimensions measured at widest point), without seta in position I, seta II small, located dorsally near base of seta III, four strong terminal plumose setae in positions III–VI, seta VII small, situated on ventral surface, directed into midline (see Fig. 1C).

**Antennule** (Fig. 2A) 24-segmented, extending slightly beyond posterior border of genital double-somite; armature elements referring to ancestral segments as follows: I-3 (2 of these plumose), II–IV-6 + aesthetasc, V-2 + aesthetasc, VI-2, VII-2 + aesthetasc, VIII-2, IX-2 + aesthetasc, X–XI-4 + aesthetasc, XII-1, XIII-1, XIV-2 + aesthetasc, XV-1, XVI-2 + aesthetasc, XVII-1, XVIII-2, XIX-1, XX-2, XXI-1 + aesthetasc, XXII-1, XXIII-1, XXIV-1 + 1, XXV-1 + 1, XXVI-1 + 1, XXVII–XXVIII-5 (2 small) + aesthetasc.

**Antenna** (Fig. 2B) With endopod 2/3 length of exopod; coxa and basis separate, coxa with seta and tuft of posterior surface hairs, basis with 2 setae; endopod segment 1 with 2 setae, segment 2 with a

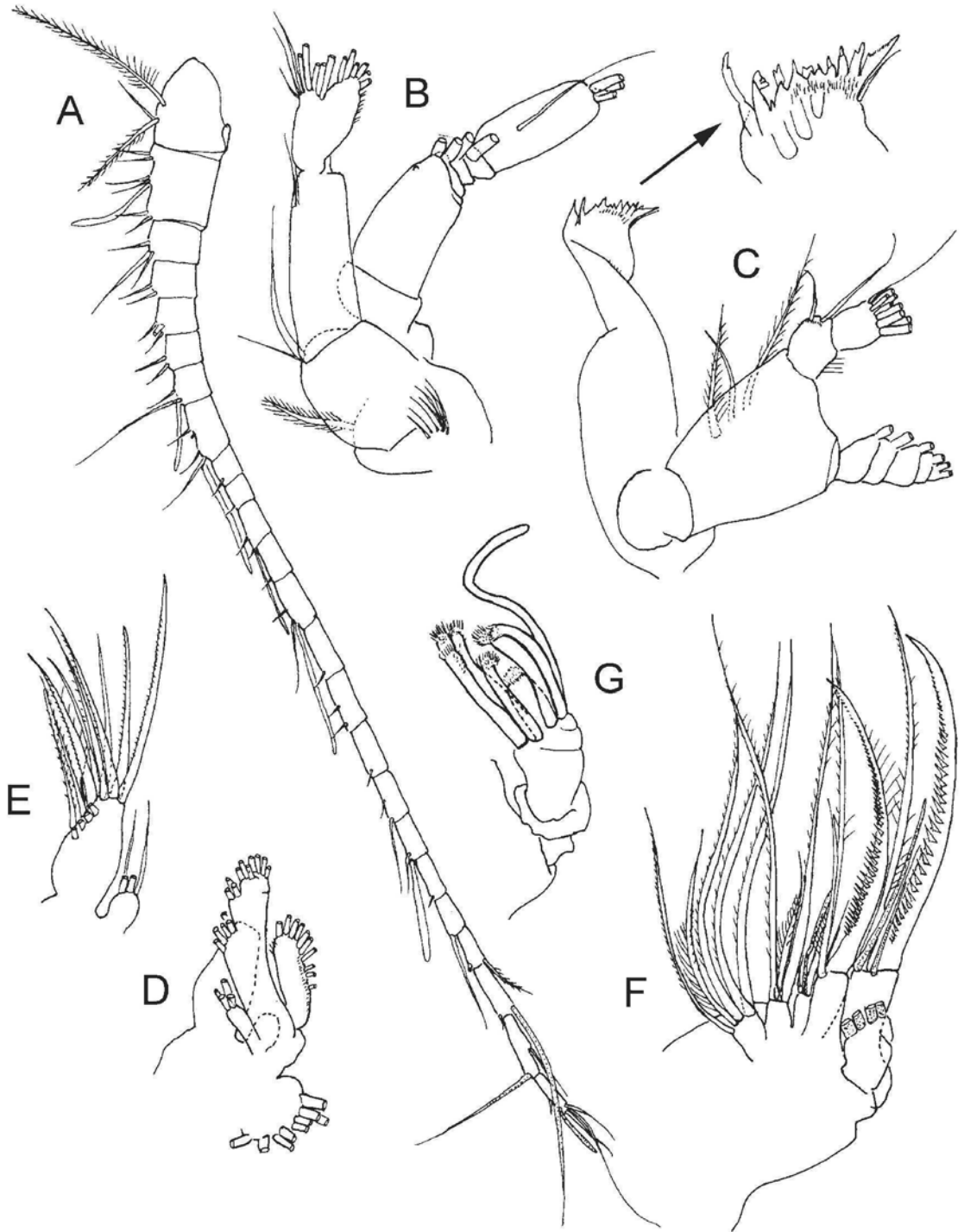


**Fig. 1** *Xanthocalanus longispinus* n. sp. Female illustrated from paratype specimens P1382: **A**, lateral view; **B**, dorsal view; **C**, urosome, ventral view (flattened); **D**, genital double-somite, lateral view; **E**, rostrum; **F**, leg 5, posterior view; **G**, leg 5, anterior view. (Se, outer spine, Si, inner spine, St, outer terminal articulated spine.)

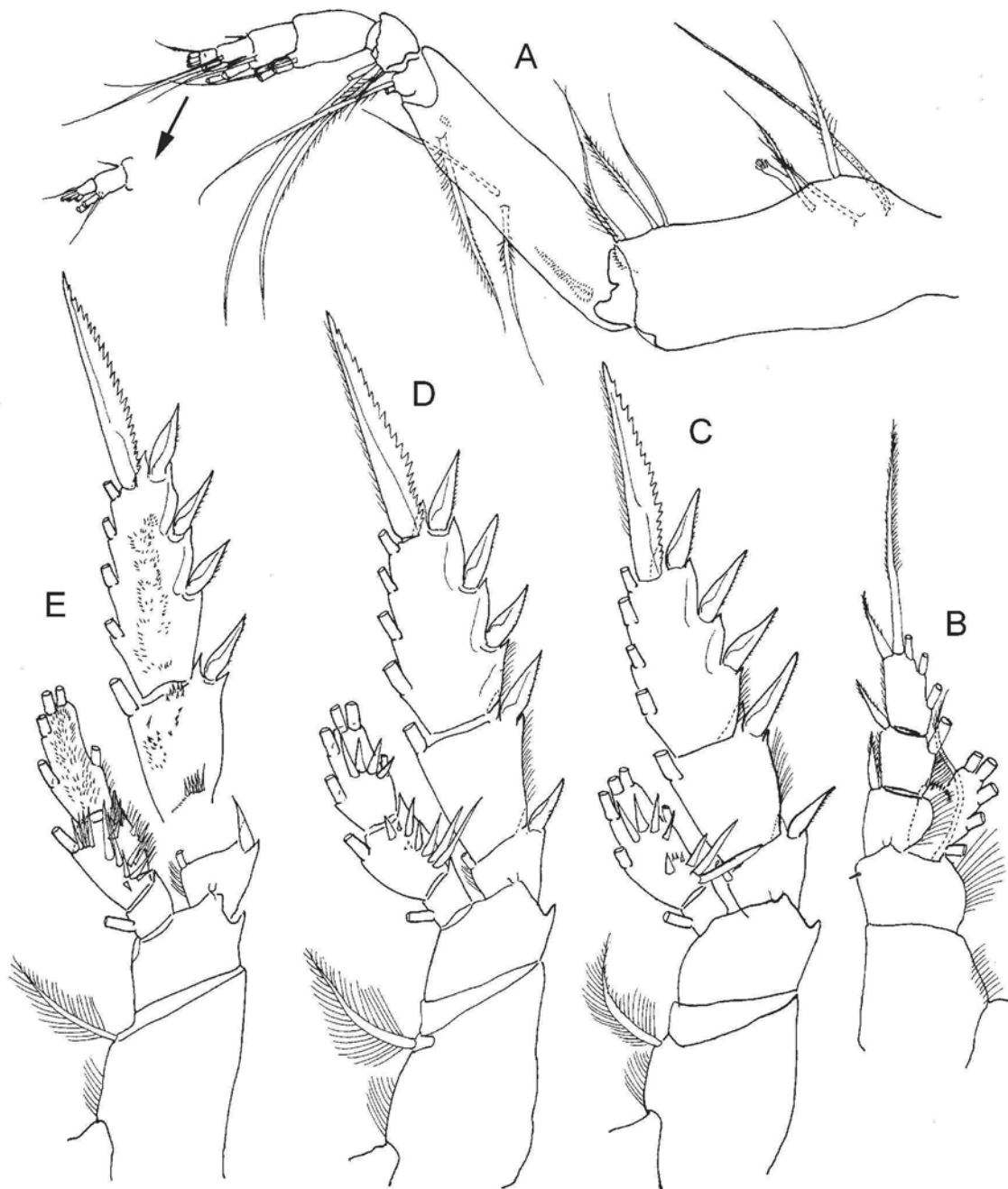
total of 14 (8 + 6) setae and with outer border lined with small spinules; exopod 6-segmented, segment 1 without seta, segment 2 probably includes ancestral segments II–V, segments 2–5 with 1 seta each, segment 6 with 3 terminal setae and 1 proximally placed smaller seta.

**Mandible** (Fig. 2C) Gnathobase with about 10 teeth and 1 setose dorsal seta; anterior and posterior surfaces of cutting edge with rows of spinules; basis with 3 strong short setae, 2 of them plumose; endopod segment 1 with 2 unequal setae and row of outer edge long hairs, segment 2 with 9 distal setae; exopod with 6 setae.





**Fig. 2** *Xanthocalanus longispinus* n. sp. Female illustrated from paratype specimens P1382: **A**, antennule; **B**, antenna; **C**, mandible; **D**, maxillule, praecoxal arthrite and coxal endite omitted; **E**, maxillule, praecoxal arthrite and coxal endite; **F**, maxilla; **G**, maxilla, endopod.



**Fig. 3** *Xanthocalanus longispinus* n. sp. Female illustrated from paratype specimens P1382: **A**, maxilliped; **B**, leg 1, posterior view; **C**, leg 2, posterior view; **D**, leg 3, posterior view; **E**, leg 4, posterior view.

**Maxillule** (Fig. 2D,E) Praecoxal arthrite with 9 terminal spines, 1 short anterodistal spine and 4 posterior surface setae; coxal endite and basal endites 1 and 2 with 4 (2 smaller than others), 4, 5 setae

respectively; basis and endopod segments appear to be fused; endopod with 3 (1 small)+2+4 setae; exopod with 10 setae and outer row of spinules on anterior surface; coxal epipodite with 9 setae.

**Maxilla** (Fig. 2F,G) Praecoxal endites 1 and 2 with 5 and 3 setae respectively; coxal endite 1 with 1 long seta, 1 very short seta, and 1 worm-like sensory seta, coxal endite 2 with 1 stout spinulose, claw-like seta, 1 plumose seta, and 1 very short seta; basal endite with 1 long seta, 1 stout spinulose claw-like seta, and 2 tapering setae that appear to be sensory; endopod indistinctly 3-segmented with 1 worm-like and 7 sensory brush-like filaments, 5 of them long and thin, 1 shorter and thin, and 1 much thicker and shorter than others (Fig. 2G).

**Maxilliped** (Fig. 3A) Syncoxa and basis of approximately equal length; syncoxa with 1 (sensory), 2 (plumose), 2 (1 brush-like, 1 stiff with few spinules), 3 setae (proximal-most naked) numbered from proximal to distal, long setae on endites 1 and 2 distal portion has appearance of sensory setae; basis with 3 medial setae (middle seta naked, proximal 2 plumose and close together), and with elongate patch of spinules proximally and short row of small spinules at base of distal-most seta; endopod slightly more than half length of basis, setae short, segment 1 apparently incorporated into basis with 2 setae, free segments 2–6 with 4, 4, 4, 3+1, and 4 setae respectively.

**Swimming legs** **Leg 1** (Fig. 3B) Endopod anterolateral swelling decorated with row of fine spinules, swelling apparently without pores. **Leg 2** (Fig. 3C) Endopod segment 2, posterior surface with 2 semicircular rows of about 4 long strong spines as well as 3 additional small spines in the proximal group. Terminal exopod spine with 19–25 lateral teeth. **Leg 3** (Fig. 3D) Endopod segment 2 with an approximately longitudinal row of 7 strong spines on posterior surface as well as a few minute additional spinules; endopod segment 3 with transverse row of 4 large spines on posterior surface. Terminal exopod spine with 21–25 lateral teeth. **Leg 4** (Fig. 3E) Endopod segment 2 posterior surface with 10 robust spines on inner part of segment and 4 long, fine spines adjacent to inner seta, additional spines (5) extend around outer border onto anterior face of segment; endopod segment 3 covered in fine spinules; exopod segment 2 with proximal row of large soft spinules, inner-most of which appear to have been broken off, distal row of short spines, and patch of inner spinules on posterior surface; exopod segment 3 with elongate patch of small spinules on posterior surface. Terminal exopod spine with 22–26 lateral teeth. **Leg 5** (Fig. 1F,G) Uniramous, symmetrical, coxae separated from intercoxal sclerite with strong, short spines covering

inner surface round onto posterior surface. Basis partially fused to exopod with fusion line hardly visible on anterior face, but well marked on posterior surface, with strong, short spines covering inner surface and longer, flexible spinules on outer distal border round onto distal outer posterior surface. Exopod 1-segmented, with inner distal spine fused to segment, outer distal spine (St) articulated to segment, inner (Si) and outer (Se) articulated spine inserted opposite one another at about midlength, all four spines with double row of lateral spinules that are located slightly on the posterior surface of spines. Posterior surface of exopod covered in long, flexible spinules on outer half of segment and shorter spinules on inner half.

**Male** (Fig. 4–6)

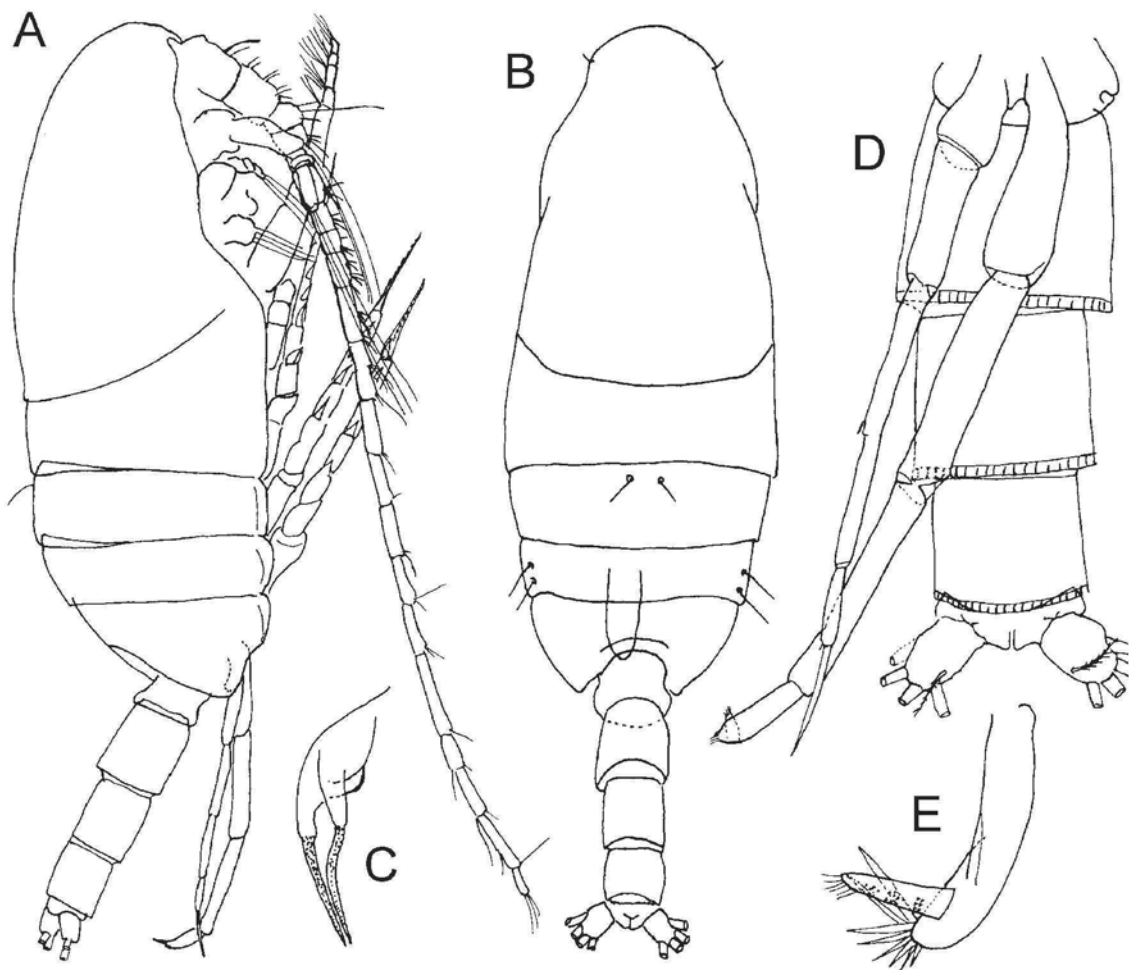
**Body** Rostrum in form of pair of non-articulated, cuticular extensions, distal part of which is similar to aesthetasc (Fig. 1C). Cephalosome separated from pedigerous somite 1; pedigerous somites 4 and 5 fused (Fig. 4A,B). Posterolateral corners of prosome rounded in dorsal and lateral views. Urosome of 5 somites; anal somite small; caudal rami longer than wide, setae I and II absent, seta VII located on ventral surface mostly directly laterally (Fig. 4D).

**Antennule** (Fig. 5A) Extending to caudal rami; 18-segmented on right, armature elements referring to ancestral segments as follows: I-1 + aesthetasc, II–IV-3 + 6 aesthetascs, V-2 + 2 aesthetascs, VI-2 + aesthetasc, VII-2 + 2 aesthetascs, VIII-2 + aesthetasc, IX-2 + 2 aesthetascs, X–XV-7 + 7 aesthetascs, XVI–XVII-2 + 2? aesthetascs, XVIII-1 + aesthetasc?, XIX-1 + aesthetasc?, XX-1 + aesthetasc?, XXI-1 + aesthetasc?, XXII–XXIII-1, XXIV-1 + 1, XXV-1 + 1, XXVI-1 + 1, XXVII–XXVIII-5 + 2 aesthetascs. Segments XII–XIII and XVI–XVII, with fusion line evident. Left antennule 19-segmented with segments XXII and XXIII separate; aesthetascs on segments XIII, XVII, XVIII, XX, XXI inferred from the presence of the basal attachment remnant.

**Antenna** (Fig. 5B) Similar to that of female.

**Mandible** (Fig. 5C) Similar to that of female except there appear to be only 2 setae on basis. Gnathobase short and with atrophied terminal teeth.

**Maxillule** (Fig. 5D) Reduced relative to that of female. Setae on inner endites and endopod not well developed. Praecoxal arthrite with 8 terminal setae; coxal endite small, with 1 seta; basal endites 1 and 2 with 3 and 4 setae respectively; endopod with 2+6 setae; exopod with 10 setae; coxal epipodite with 9 setae.



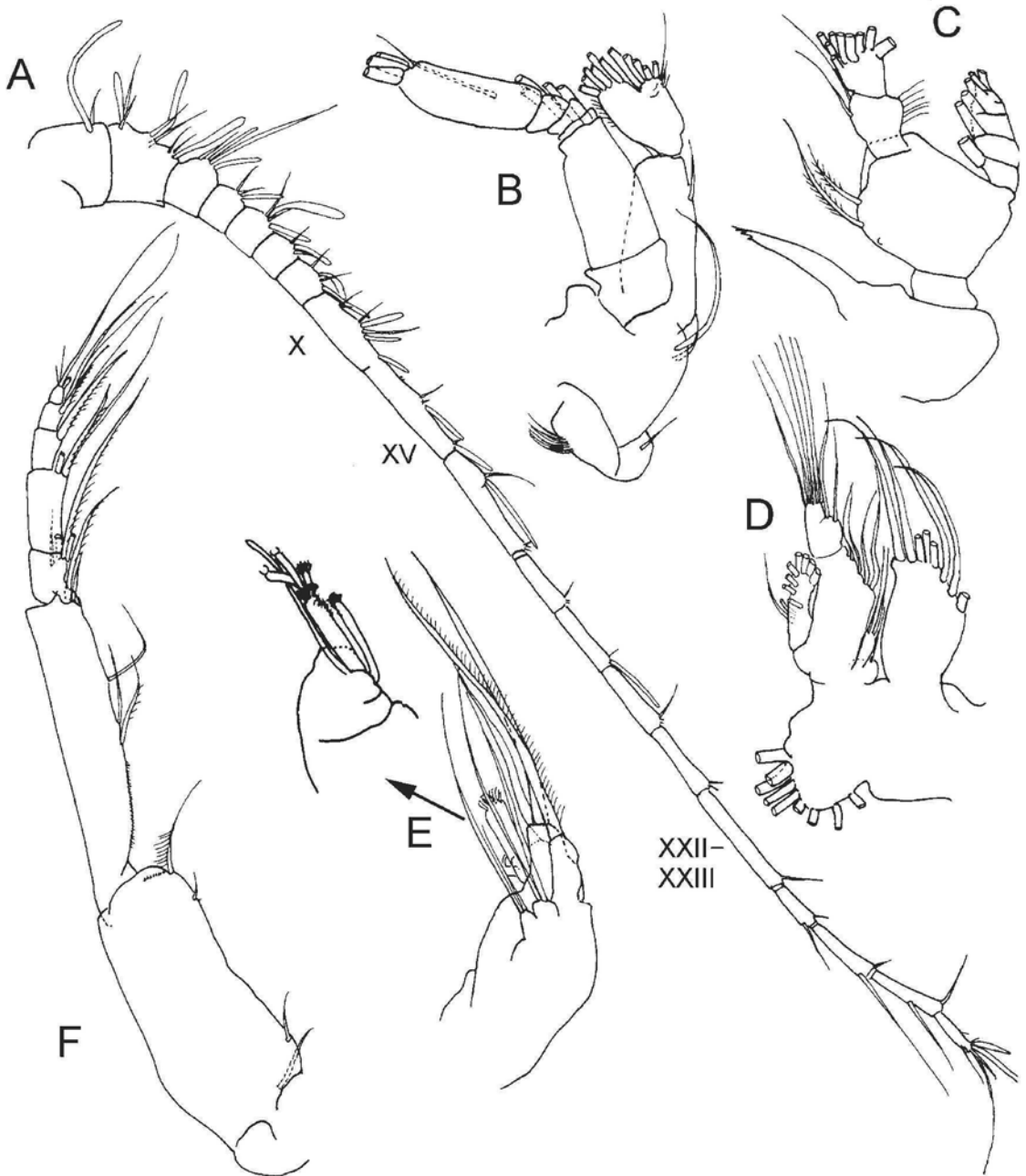
**Fig. 4** *Xanthocalanus longispinus* n. sp. Male illustrated from paratype specimens P1382: **A**, lateral view; **B**, dorsal view; **C**, rostrum; **D**, urosome (flattened) and leg 5 which is not oriented to urosome as in whole animal, ventral view; **E**, leg 5, terminal part of left leg.

**Maxilla** (Fig. 5E) Reduced relative to that of female. Numbers and development of all setae reduced. Praecoxal endite apparently without setae, endite 2 with 2 setae; coxal endite 1 with 2 setae, coxal endite 2 with 1 long seta; basal endite with 2 long setae; endopod with 1 large and 4 smaller brush-like and 1 apparently worm-like sensory setae.

**Maxilliped** (Fig. 5F) Not as robustly developed as in female. Setae not as well-developed especially on syncoxa and basis; brush-like sensory seta on endite 3 of syncoxa absent.

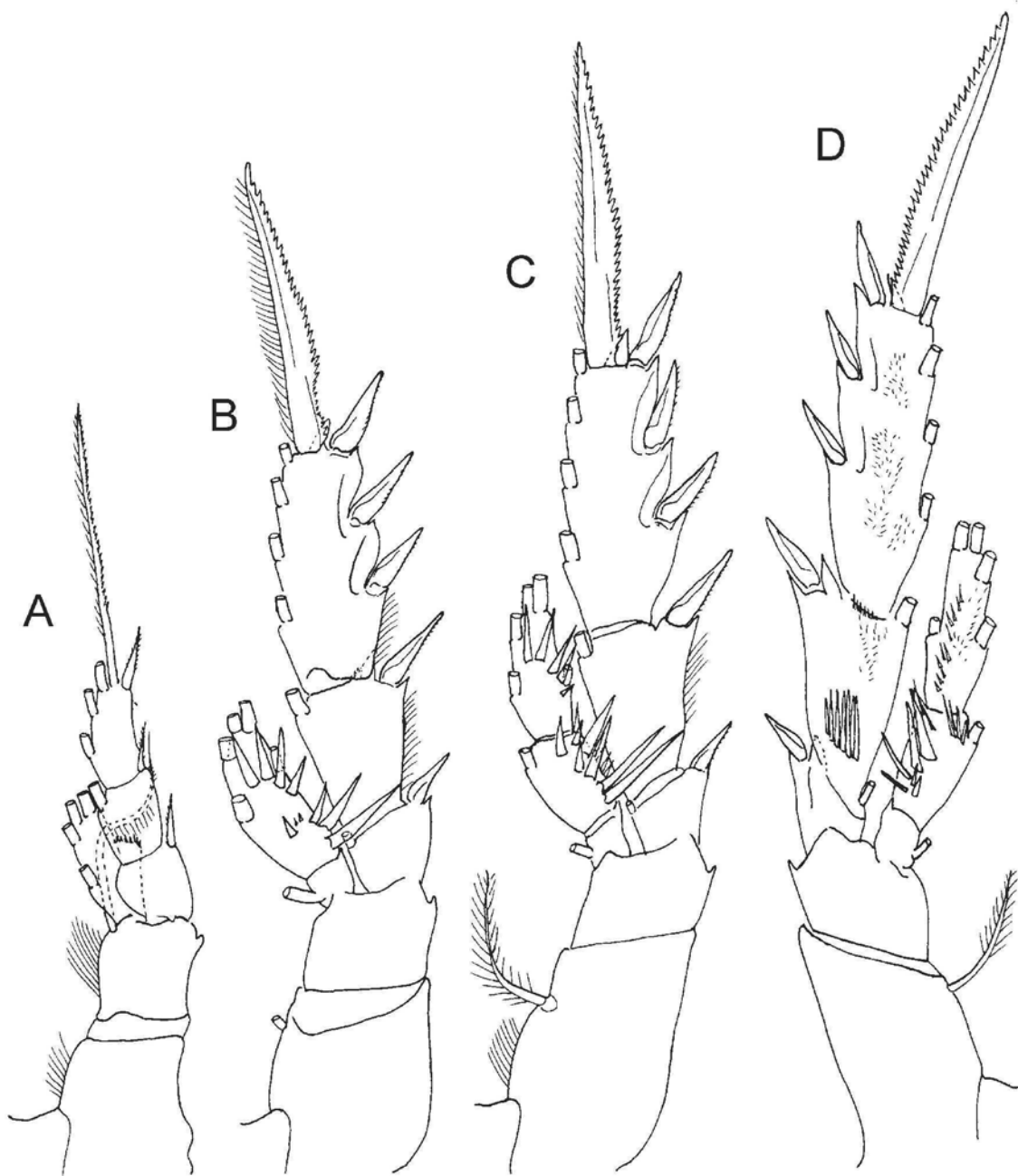
**Swimming legs** (Fig. 6A–D). Generally similar to those of female. **Leg 5** (Fig. 4D,E) Asymmetrical, uniramous on both sides without any sign of

endopods, and extending to the anal somite. Right leg styliform; coxa short, extending to midlength of left coxa; basis almost twice length of coxa and slightly narrower, extending beyond coxa of left leg; exopod segments 1 and 2 fused, narrow, with small seta at distal extent of segment 1, combined segment extends almost to midlength of left exopod segment 1; exopod segment 3 short and bearing a long terminal spine that is 1.7 times length of its segment and a minute outer distal spine. Left leg with elongate coxa and basis that are as broad as widest part of right coxa; basis extends just short of distal extent of right basis; basis extends beyond distal extent of right exopod segment 1; exopod segment 1 elongate with outer distal spinule, extends half way along terminal



**Fig. 5** *Xanthocalanus longispinus* n. sp. Male illustrated from paratype specimens P1382: **A**, right antennule—note segments XXII and XXIII are fused, but separated on left antennule; **B**, antenna; **C**, mandible; **D**, maxillule; **E**, maxilla; **F**, maxilliped.

**Fig. 6** *Xanthocalanus longispinus* n. sp. Male illustrated from paratype specimens P1382: **A**, leg 1, posterior view; **B**, leg 2, posterior view; **C**, leg 3, posterior view; and **D**, leg 4, posterior view. ➤



spine of right leg; exopod segment 2 short, about same length as right exopod segment 3 and with inner distal corner bearing 8 apparently stiff spines that grade in size from outer to inner; exopod segment 3 very short about 1/3 length of segment 2 and decorated by terminal hairs and surface spinules.

#### Etymology

The specific name *longispinus* is derived from the Latin words "longus" meaning long in combination with "spina" meaning a thorn alluding to long terminal spines on exopod of the male left leg 5.

## Remarks

*Xanthocalanus longispinus* n. sp. differs from all other species by the combination of the following characters: female leg 5 with the inner terminal spine completely fused to its segment; the outer spine at midlength on the terminal segment of the female leg 5 is short, not extending as far as the base of the outer terminal articulated spine; the inner border spinules on coxa and basis of the female legs 5 are small and pointed; the outer border soft spinules on basis of female leg 5 are fine and tapering; and the posterior corners of the prosome have a convexly tapering shape, dorsally and ventrally, in lateral view terminated by a small tooth; total length 2.00–2.31 mm (female), 1.70–1.90 mm (male).

Of the 54 species that potentially belong to *Xanthocalanus* only *X. echinatus* Sars, 1925, *X. fallax* Sars, 1925, *X. meteorae* Markhaseva & Schiel, 2003, *X. multispinus* Chen & Zhang, 1965, *X. profundus* Sars, 1907, *X. squamatus* Farran, 1936, specimens identified as *X. pinguis* by Sars (1925) and specimens identified by Bradford et al. (1983) as *X. penicillatus* Tanaka, 1960 have the female leg 5 with the inner terminal spine completely fused to its segment, as does *X. longispinus* n. sp. (Table 1). Amongst these species *Xanthocalanus longispinus* is very similar to *X. fallax* (see below) but in *X. fallax* the outer spine on the terminal segment of the female leg 5 extends almost as far as the tip of the outer terminal articulated spine; the inner border spinules on coxa and basis of the female legs 5 are fewer, stout, with rounded tips; the outer border soft spinules on segment 2 of female leg 5 are fewer and broad; and the posterior corners of the prosome taper in lateral view: concavely on the dorsal border and straight to convexly on the ventral border. The male of *X. fallax* differs from that of *X. longispinus* in that the former has a short right leg 5 that hardly extends beyond the left leg coxa.

Species of *Xanthocalanus* are very difficult to distinguish using male characteristics. Of the males that have been described that are c. 2 mm long or just under and which have leg 5 of nearly equal length (*X. subagilis*, *X. minor*, and *X. echinatus*) the male of *X. longispinus* can be distinguished by the fused pedigerous somites 4 and 5, by the fact that antennule ancestral segments X–XV and XVI–XVII are fused (as well as XXII–XXIII on the right), by leg 5 that do not extend beyond the caudal rami (Fig. 4A), by the series of about 8 stiff spines, graded in size, on the distal border of left leg 5 exopod segment 2; the innermost spine is almost the same length as exopod segment 3, and by the spinulose nature of the surface

**Table 1** Comparison of *Xanthocalanus* females of species with leg 5 terminal inner spine fused to its segment. (bl, brush-like sensory seta; BP, benthopelagic; Gns, genital double somite; P, leg; Pd, pedigerous somite; Se, outer spine (see Fig. 1); Si, inner spine (see Fig. 1); St, terminal spine (see Fig. 1); TL, total length; wl, worm-like sensory seta.)

Species	TL (mm)	Depth (m)	Localities/habitat	P5: length Si relative to Se	P5: insertion Se relative to Si	P5: length Se relative to base St	P5: length Si relative to base St	Pd5 extent along Gns	Pd 4, 5: fusion	Mxp syncoxa seta type
<i>X. echinatus</i> Sars, 1907	2.10	3465	north-east temperate Atlantic/BP	longer	distal	exceeds	far exceeds	<½	separate	?5 bl, ?2 wl
<i>X. fallax</i> Sars, 1921	2.90–3.30	120–615	north-east Atlantic, Norwegian Fjord, Med./BP	subequal	opposite	exceeds	exceeds	½	fused	7 bl, 1 wl
<i>X. meteorae</i> Markhaseva & Schmack-Schiel, 2003	1.2–1.3	460–565	north-east Atlantic, Great Meteor Seamount	subequal	proximal	exceeds	exceeds	½	fused	6 bl, 2 wl
<i>X. multispinus</i> Chen & Zhang, 1965	1.85–1.95	<200	Eastern Sulu Sea?	longer	slightly proximal	equal	far exceeds	>½	fused	?
<i>X. profundus</i> Sars, 1907	6.20	2480–3465	north-east temperate Atlantic/BP	subequal	proximal (variable?)	short	equals	>½	separate	?6 bl, ?2 wl
<i>X. pinguis</i> : Sars, 1925	7.30	5285	north-east temperate Atlantic/BP	subequal	opposite	exceeds	exceeds	<½	separate	?
<i>X. squamatus</i> Farran, 1936	3.20	0–180 over 225	Great Barrier Reef Australia	equal	opposite	equals	equals	>½	fused	? bl, 1 wl
<i>X. longispinus</i> n. sp.	2.00–2.31	299–452	north-east New Zealand/BP	longer	opposite	short	exceeds	>½	fused	7 bl, 1 wl
<i>X. stewarti</i> n. sp.	3.20–3.40	452	north-east New Zealand/BP	longer	opposite	short	almost equal	=½	fused	7 bl, 1 wl



of left exopod segment 3 as well as terminal longer spines.

### *Xanthocalanus stewarti* n. sp.

#### Material examined

**Holotype** Female (adult, not dissected), off south-eastern coast of North Island, New Zealand, 41°04.67'S 176°23.48'S. 13 April 2000, near sea floor, 452 m depth, KAH0005/05 (NIWA H834).

**Paratypes** 2 females (#1 and 2) both dissected, same data as holotype (NIWAP1383).

Descriptions based on paratype specimens. An additional female was taken at the type locality. Total length: holotype 3.50 mm, 3 females 3.2–3.4 mm total length (mean 3.35 mm) from type locality. Types are deposited in the collection of the National Institute of Water and Atmospheric Research.

#### Female (Fig. 7–9)

**Body** Similar to *X. longispinus* n. sp. apart from the following details. Posterolateral corners of prosome obtusely pointed in dorsal and lateral views and covering nearly half of genital double-somite (Fig. 7A,B). Genital double-somite symmetrical, with single ventral genital operculum (Fig. 7C) and pair of seminal receptacles placed in anterior part of somite although details of these could not be observed in lateral view; there is sign that somite covered in scales as attachment scars evident and few dorsal scales, evident in lateral view are present on genital double-somite of one specimen (Fig. 7E). Caudal ramus seta VII small, situated on ventral surface directed lateroposteriorly.

**Antennule** (Fig. 8A) Extending to posterior border of pedigerous somite 5; 24-segmented, extending to posterior border of pedigerous somite 5; armature elements referring to ancestral segments as follows: I-3 (2 setae plumose), II-IV-6 + aesthetasc, V-2 + aesthetasc, VI-2, VII-2 + aesthetasc, VIII-2, IX-2 + aesthetasc, X-XI-4 + aesthetasc, XII-1, XIII-1, XIV-2 + aesthetasc, XV-1, XVI-2 + aesthetasc, XVII-1, XVIII-2, XIX-1, XX-2, XXI-1 + aesthetasc, XXII-1, XXIII-1, XXIV-1 + 1, XXV-1 + 1, XXVI-1 + 1, XXVII-XXVIII-5 + aesthetasc.

**Antenna** (Fig. 8B) With endopod  $\frac{1}{2}$  length of exopod; coxa and basis separate, coxa with 1 plumose seta and tuft of posterior surface hairs, basis with 2 setae; endopod segment 1 with 2 setae, segment 2 with a total of 14 (8 + 6) setae and with outer border lined with small spinules; exopod 6-segmented, segment

2 includes ancestral segment V, segment 1 without seta, segments 2–5 with 1 seta each, segment 6 with 3 terminal setae and 1 seta placed midlength.

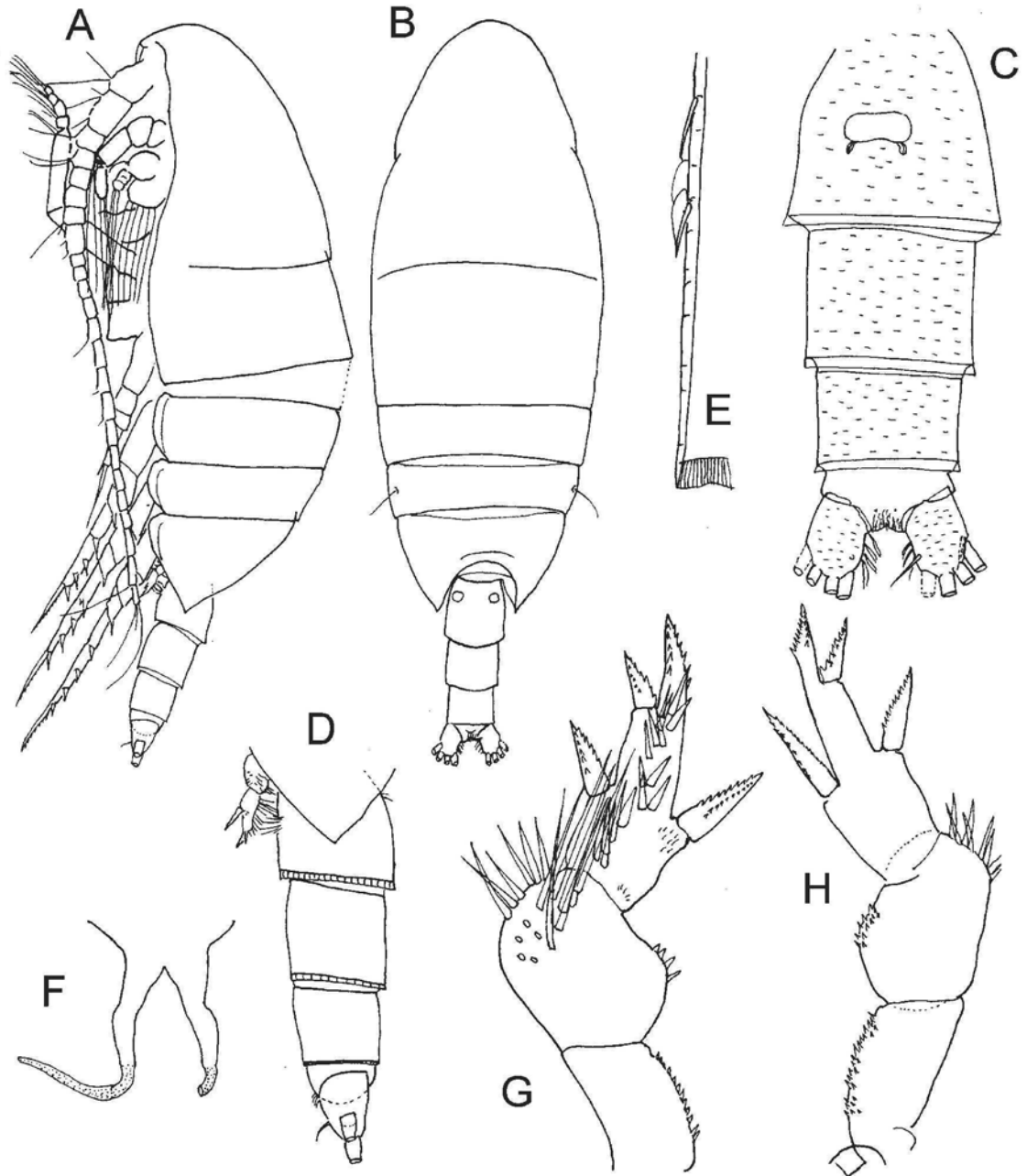
**Mandible** (Fig. 8C) Gnathobase with about 10 ventral teeth and 1 strong setose dorsal seta, anterior and posterior surfaces of cutting edge with rows of spinules; basis with 3 strong setae; endopod segment 1 with 2 unequal setae, segment 2 with 9 distal setae; exopod with 6 setae.

**Maxillule** (Fig. 8D) Praecoxal arthrite with 10 terminal spines and 4 posterior surface setae; coxal endite and basal endites 1 and 2 with 3, 4, 5 setae respectively; basis and endopod segments appear to be fused; endopod with 3+3(1 very small)+4 setae; exopod with 10 setae; coxal epipodite with 9 setae.

**Maxilla** (Fig. 8E,F) Praecoxal endites 1 and 2 with 5 and 3 setae respectively; coxal endite 1 with 1 long and 1 very short setae plus 1 tapering sensory seta, coxal endite 2 with 1 stout spinulose, claw-like seta, 1 plumose seta, and 1 very short seta; basal endite with 1 stout spinulose claw-like seta, and 2 tapering setae that appear to be sensory; endopod indistinctly 3-segmented with 1 worm-like and 7 brush-like (1 much shorter and thicker than others) sensory filaments.

**Maxilliped** (Fig. 9A) Syncoxa and basis of approximately equal length; syncoxa with 1, 1, 2, 3 setae numbered from proximal to distal, endite 3 has a short brush-like sensory seta and a spinulose seta; basis with 3 medial setae and elongate patch of spinules proximally; endopod more than half length of basis, setae short, segment 1 apparently incorporated into basis with 2 setae, free segments 2–6 with 4, 4, 4, 3+1, and 4 setae respectively.

**Swimming legs** (Fig. 9B–E) **Leg 1** (Fig. 9B) Endopod antero-outer swelling decorated with rows of fine spinules, swelling apparently without pores. **Leg 2** (Fig. 9C) Endopod segment 2 posterior surface with 2 curved rows of strong spines of graded size, proximal row of 7 spines, distal row of 6 spines. Terminal exopod spine with 26–27 lateral teeth. **Leg 3** (Fig. 9D) Endopod segment 2 posterior surface with 2 rows of strong spines of graded size, proximal row of 6 spines, distal row of 3 spines; endopod segment 3 with curved row of 8 strong spines and more distal small fine spinules. Terminal exopod spine with 23–24 lateral teeth. **Leg 4** (Fig. 9E) Endopod segment 2 posterior surface with numerous (c. 19) long spines as well as 6 spines along the outer edge, endopod segment 3 with numerous small spinules on posterior surface; exopod segment 2 posterior surface with distal transverse row of long soft spines, row of fine spinules along



**Fig. 7** *Xanthocalanus stewarti* n. sp. Female illustrated from paratype specimens P1383: **A**, lateral view; **B**, dorsal view; **C**, urosome, ventral view (flattened); **D**, urosome, lateral view; **E**, dorsal wall of genital double somite showing scales; **F**, rostrum; **G**, leg 5, anterior view; **H**, leg 5, posterior view.

distal border and small spinules in between; exopod segment 3 posterior surface with 2 patches of small spinules. Terminal exopod spine with 25–26 lateral teeth. **Leg 5** (Fig. 7G,H) Uniramous, symmetrical, coxae separated from intercoxal sclerite, with strong,

short spines along inner border. Basis is widest segment separated from exopod, with strong, short spines along inner distal border and longer, flexible spinules on outer distal border round onto distal outer posterior surface. Exopod 1-segmented, with inner

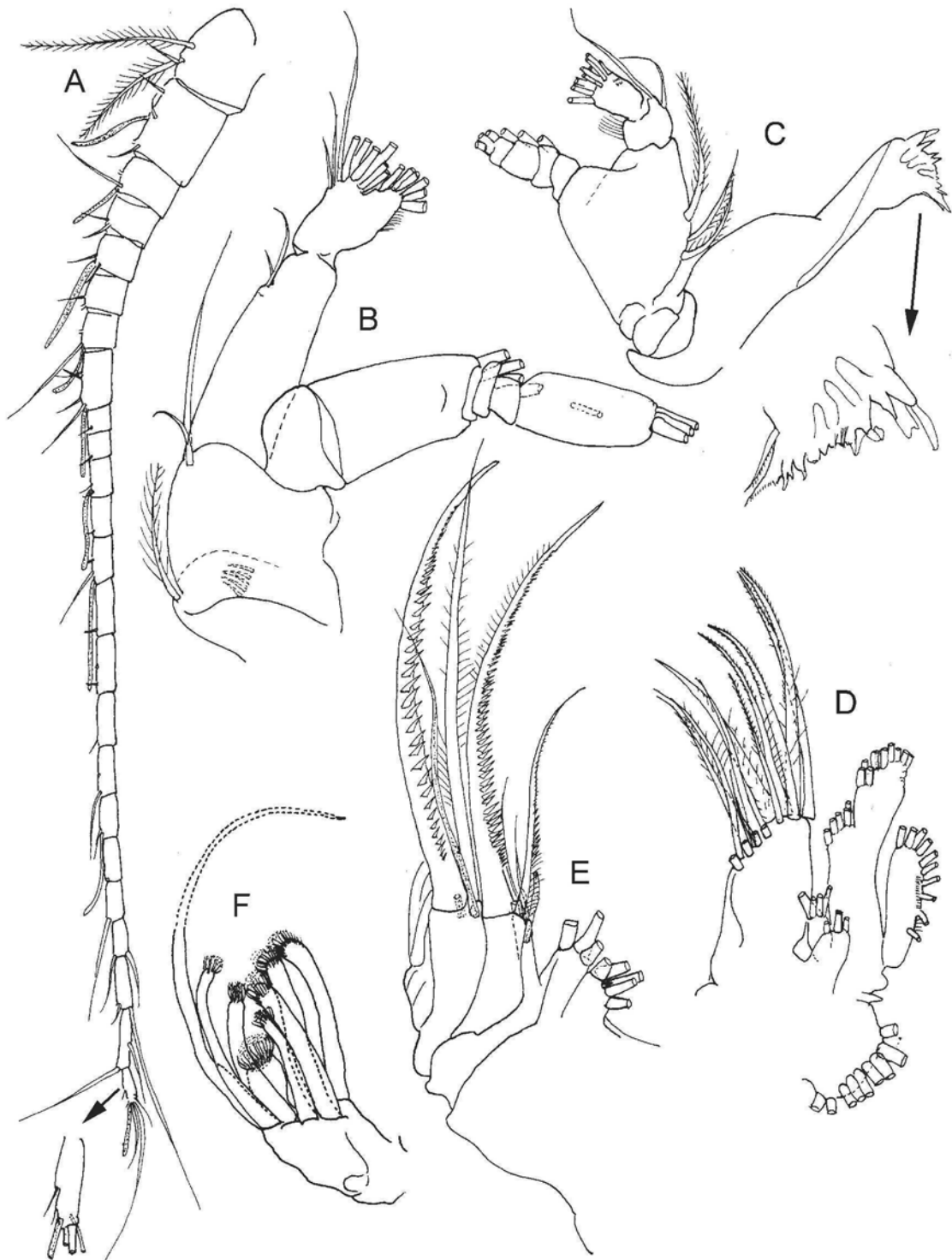
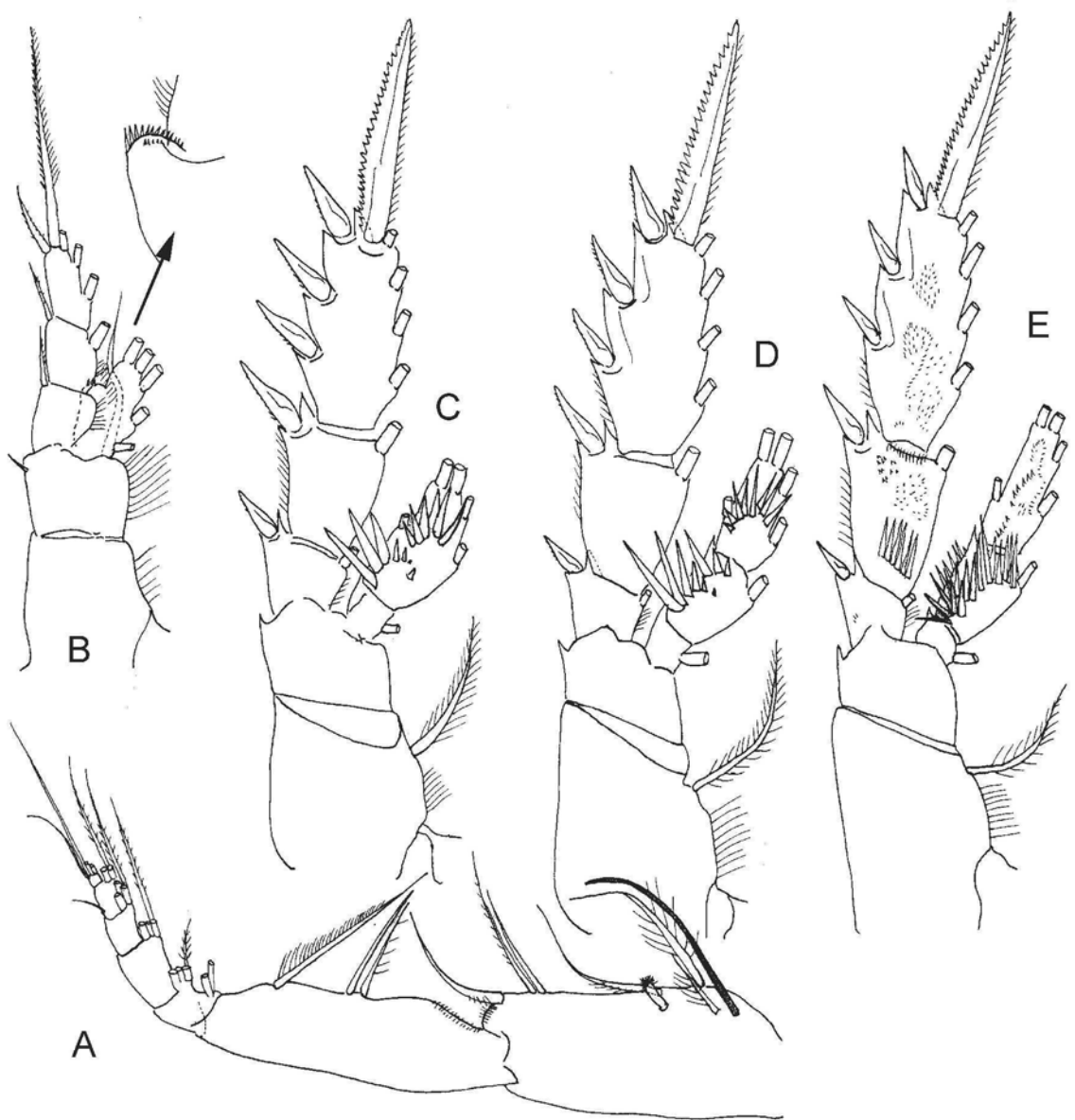


Fig. 8 *Xanthocalanus stewarti* n. sp. Female illustrated from paratype specimens P1383: A, antennule; B, antenna; C, mandible; D, maxillule; E, maxilla; F, maxilla, endopod.



**Fig. 9** *Xanthocalanus stewarti* n. sp. Female illustrated from paratype specimens P1383: A, maxilliped; B, leg 1, posterior view; C, leg 2, posterior view; D, leg 3, posterior view; E, leg 4, posterior view.

distal spine completely fused to segment and directed slightly outwards, outer distal spine articulated to segment, inner and outer articulated spine inserted opposite one another at about midlength, inner spines slightly longer than outer, all four spines with double row of lateral spinules located slightly on posterior surface of spines. Posterior surface of exopod covered in long, flexible spinules on outer half of

segment and few shorter spinules on inner half at base of inner articulated spine and proximally.

#### Etymology

This species is named for Rob Stewart, NIWA, who devised the method of catching benthopelagic biota by attaching a net to the trawl warps of a fishing vessel.

**Remarks**

*Xanthocalanus stewarti* n. sp. differs from all other species because of the combination of the following characters: female leg 5 with the inner terminal spine completely fused to its segment; the terminal segment of the female leg 5 has the outer spine not extending as far as the base of the outer terminal articulated spine and the terminal fused spine is directed slightly outwards (unlike the other species); the inner borders of coxa and basis of female leg 5 with few, very small, sharply pointed teeth and the outer posterodistal spinules of basis are of two lengths; the posterior corners of the prosome in dorsal view extend only as far as the middle of the genital double-somite and have an obtusely triangular shape in lateral view; total length 3.2–3.4 mm (female).

*Xanthocalanus stewarti* n. sp. is most similar to *X. longispinus*, *X. fallax*, *X. squamatus* Farran, 1936 (Table 1), and the specimen identified by Bradford et al. (1983) as *X. penicillatus*. The terminal segment of the female leg 5 has the outer spine not extending as far as the base of the outer terminal articulated spine in *X. longispinus* and *X. squamatus*, but *X. fallax* has this spine extending almost to the tip of the terminal articulated spine. The terminal fused spine is directed distally in *X. longispinus*, *X. squamatus*, and *X. fallax* (not outwards as in *X. stewarti*). The inner borders of the coxa and basis of the female leg 5 of *X. stewarti* have a smaller number of smaller teeth than *X. longispinus*, *X. squamatus*, and *X. fallax* and the outer posterodistal spinules of leg 5 basis of *X. stewarti* are of two lengths, unlike the other three species. The posterior corners of the prosome in dorsal view extend to the middle of genital double-somite in *X. stewarti* whereas, in *X. longispinus*, *X. squamatus*, and *X. fallax*, they extend beyond the middle of the genital double-somite.

The female identified as *X. penicillatus* by Bradford et al. (1983) is probably not Tanaka's (1960) species that has both terminal spines of leg 5 articulated to their segment. It is possible that the New Zealand specimen is *X. stewarti* but this proposition is difficult to corroborate because the outer terminal spine of leg 5 is not drawn as bent outwards and this limb is now distorted on the slide.

***Xanthocalanus fallax* Sars, 1921**

*X. borealis*: Sars, 1902 (part), p. 46, pl. XXXI, XXXII (not *X. borealis* Sars, 1900).

*X. fallax* Sars, 1921, pp. 2–3.—Sars, 1925, pp. 128–129, pl. XXXV, fig. 5–7.—Matthews, 1964, pp. 29–39, fig. 10–12.

**Materials examined**

Fifteen females (total length 3.10–3.30 mm, mean 3.20 mm), light trap at night 19, 20 October 1999, 120 m depth, Raunefjord, Norway outside the University of Bergen, Biological Station, Norway, registered number NIWA 3358.

**Female**

(Fig. 10, 11)

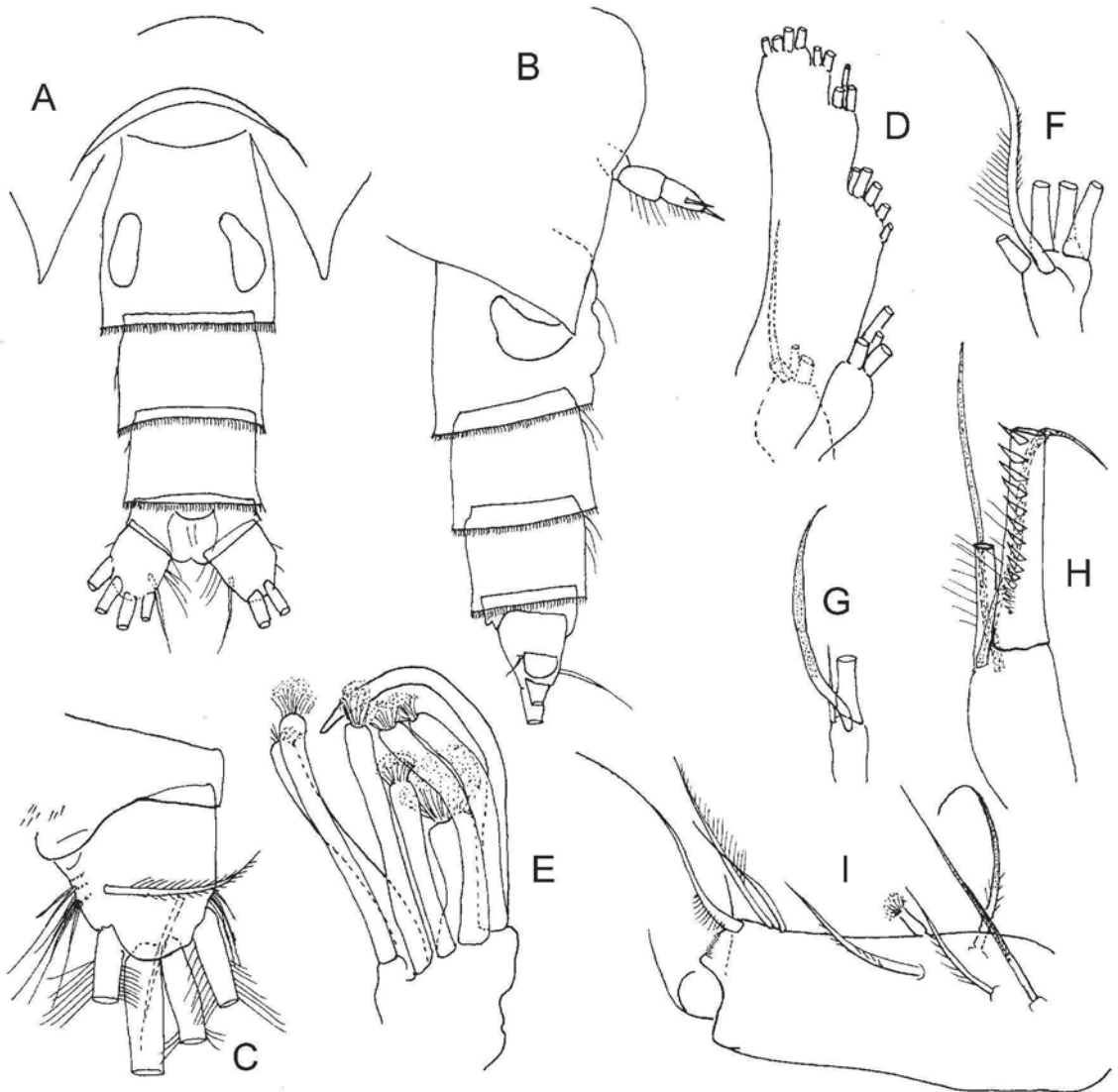
**Body** General form and features as described and illustrated by Sars (1902, as *X. borealis*; 1925 as *X. fallax*) and similar to *X. longispinus* n. sp. but with the following additional details. Cephalosome fused to pedigerous somite 1 with very faint fusion-line evident dorsally; pedigerous somite 3 with large dorsolateral hair on each side; pedigerous somites 4 and 5 fused with fusion line visible only dorsally (Fig. 10A). Surfaces of urosomites (not including anal somite) sparsely covered in very small semicircular thickenings (not figured) that probably represent place of attachment of large scales that were evident in some individuals. Genital double-somite with pair of seminal receptacles, curved in lateral view (Fig. 10B) and with common oval anteroventral genital opening containing visible, paired gonopores; posterior to operculum is transverse fold. Posterior borders of urosomites, excluding anal somite, bordered by hyaline frill. Anal somite not visible in dorsal view, bearing very short hairs on ventral surface in posterior midline. Caudal rami without seta in position I, seta II small, located dorsally near base of seta III, four strong terminal plumose setae in positions III–VI, seta VII small, situated on ventral surface, directed laterally, with 3 transverse rows of spinules around inner border, anterior-most very small, other 2 rows with very small to very long spinules (Fig. 10C).

**Antennule** As in *X. longispinus* n. sp. but extending to posterior border of genital double somite.

**Antenna** Similar to illustration of Sars (1902) but coxa with seta and tuft of posterior surface hairs, endopod segment 1 with 2 setae, segment 2 with a total of 14 (8+6) setae and with outer distal border lined with small spinules; exopod 6-segmented, segment 2 probably includes ancestral segments II–V, segment 1 without seta.

**Mandible** Similar to illustration of Sars (1902) but endopod segment 2 with 9 distal setae.

**Maxillule** (Fig. 10D), **Maxilla** (Fig. 10E–H) and **Maxilliped** (Fig. 10I) As in *X. longispinus* n. sp.

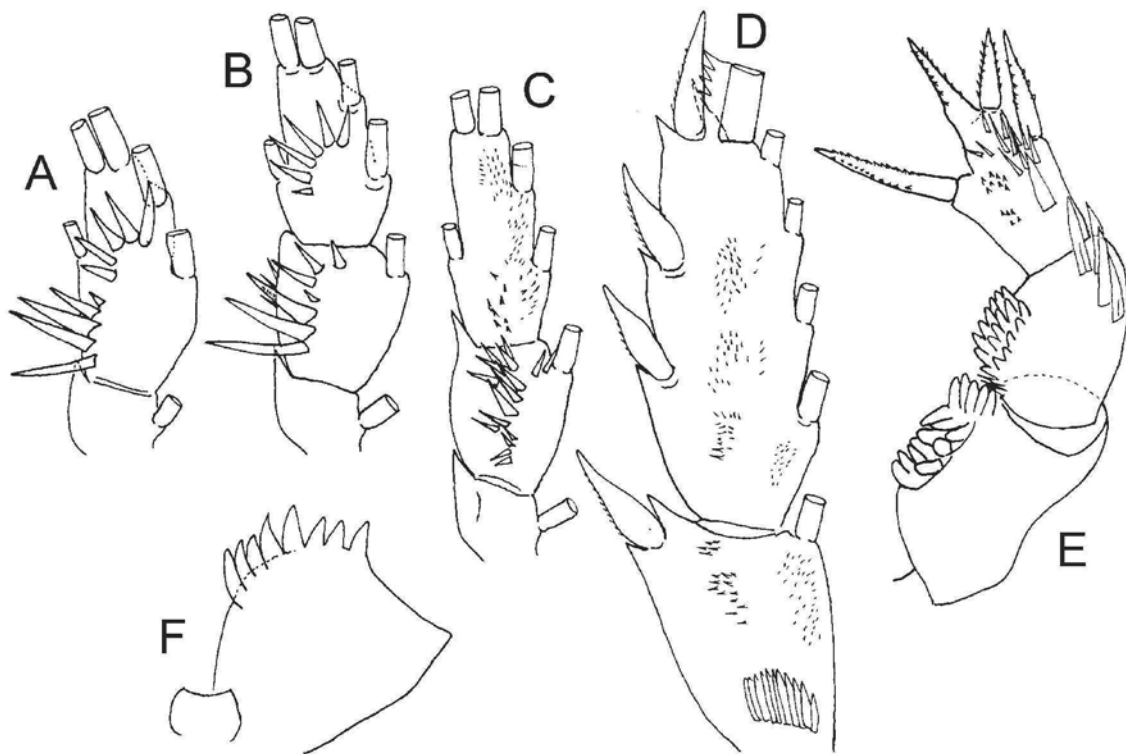


**Fig. 10** *Xanthocalanus fallax* Sars, 1925, female: **A**, urosome, dorsal view; **B**, urosome, lateral view; **C**, caudal ramus, ventral view; **D**, maxillule, coxal endites 1, 2; basal endites and endopod; **E**, maxilla, endopod; **F**, maxilla, praecoxal endite 1; **G**, maxilla, coxal endite 1; **H**, maxilla, basal endite; **I**, maxilliped, syncoxa.

**Swimming legs** **Leg 1** As in *X. longispinus*.

**Leg 2** (Fig. 11A) Endopod segment 2, posterior surface with 2 semicircular rows of about 5 heavy spines, distal-most smallest in the proximal group; distal group with 5–6 spines. Terminal exopod spine with 25–32 lateral teeth. **Leg 3** (Fig. 11B) Endopod segment 2 with an approximately longitudinal row of 6 strong spines on posterior surface as well as 1 small additional spinule; endopod segment 3 with semi-circular row of 6 large spines on posterior surface. Terminal exopod spine with 26–28 lateral

teeth. **Leg 4** (Fig. 11C,D) Endopod segment 2 posterior surface with 15 strong spines on inner part of segment and 4 long, fine spines adjacent to inner seta; endopod segment 3 sparsely covered in spinules, finer distally; exopod segment 2 with proximal row of about 8 large soft spinules, distal row of short spines, and patch of inner spinules on posterior surface; exopod segment 3 with elongate patch of spinules on posterior surface and group of finer spinules on inner proximal border. Terminal exopod spine with 24 lateral teeth. **Leg 5** (Fig.



**Fig. 11** *Xanthocalanus fallax* Sars, 1925, female: **A**, leg 2, endopod; **B**, leg 3, endopod; **C**, leg 4, endopod; **D**, leg 4, exopodal segment 2 and 3; **E**, leg 5, posterior view; **F**, leg 5 coxa another posterior view.

11E,F) Uniramous, symmetrical, coxae separated from intercoxal sclerite, with 7–11 spinules with rounded tips along inner border; appears to be some asymmetry with one side having a single row and other side having part or all of border with more than one row for all or part of border. Basis with several longitudinal rows of strong short teeth covering inner surface and long, wide, flexible spinules on outer distal border and stouter distal outer posterior surface spines. Exopod 1-segmented, inner distal spine fused to segment although fusion boundary evident; outer distal spine articulated to segment, inner and outer articulated spines inserted opposite one another slightly distal to midlength, outer spine extends more than half way along outer terminal articulated spine, all four spines with double row of lateral spinules that are located slightly on the posterior surface of spines. Posterior surface of exopod covered in long, flexible spinules on outer half of segment and shorter spinules on inner half.

#### Remarks

This species has mouthparts that are typical of many species in this genus in that the maxilla has coxal

endite 1 with 1 setae of the sensory type, basal endite with 2 setae of the sensory type, and the endopod has 1 worm-like and 7 brush-like sensory setae, one of which is much wider and shorter than the others. The syncoxa of the maxilliped bears 8 setae arranged proximal to distal 1, 2, 2 (1 of these is short and brush-like), 3 respectively. The male of this species has been partially described by Sars (1902 as *X. borealis*) and Matthews (1964) and has a short right leg 5.

#### *Xanthocalanus minor* Giesbrecht, 1892

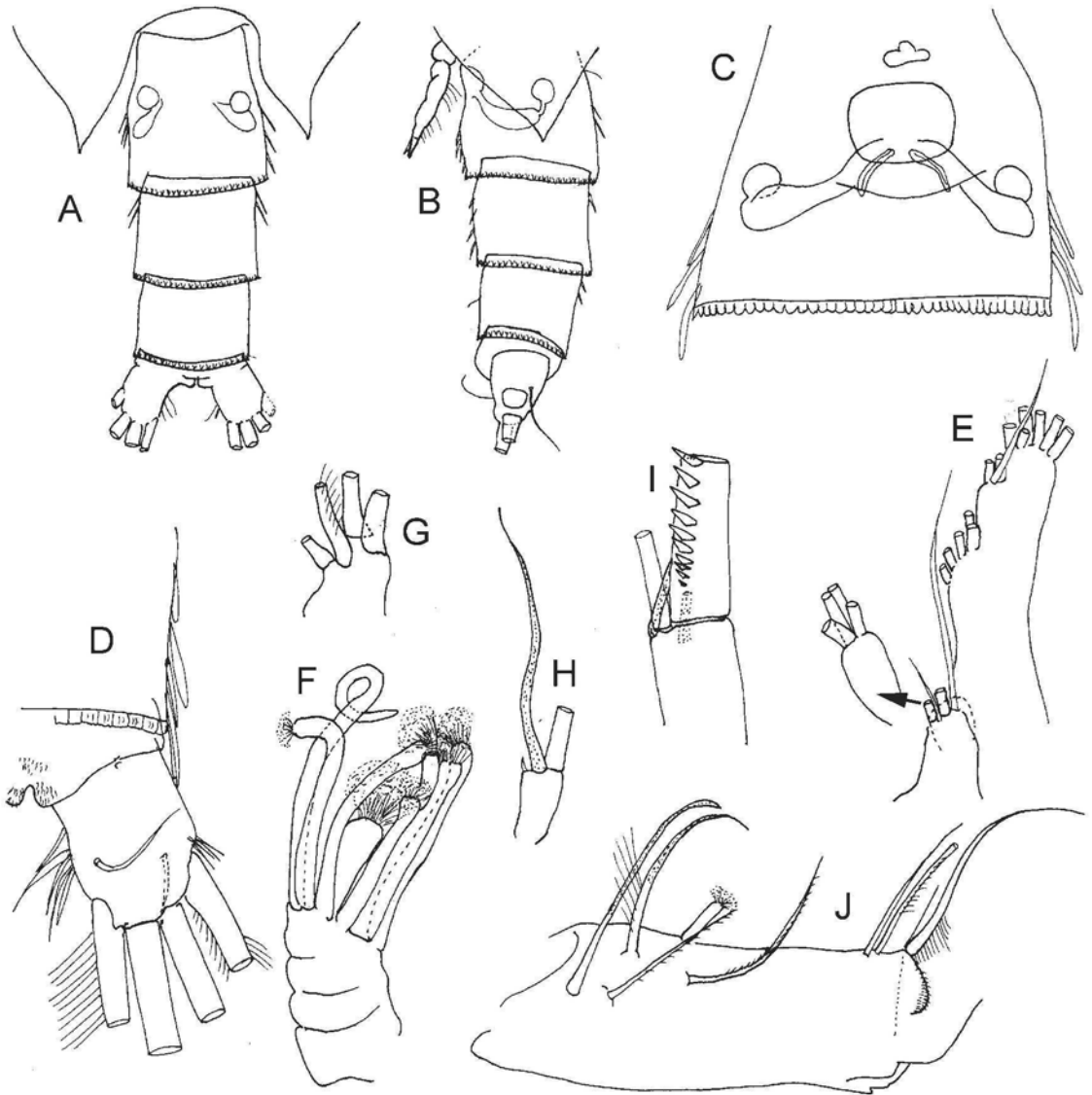
*X. minor* Giesbrecht, 1892, pp. 286–291, pl. 12, fig. 32.—Sars, 1921, pp. 3–4, pl. I.—Matthews, 1964, pp. 40–43, fig. 13.

*X. borealis*: Sars, 1902 (part). pl. XXXII (P5 juv.) (not *X. borealis* Sars, 1900)

#### Materials examined

28 females (total length 2.50–2.95 mm, mean 2.80 mm), taken with a light trap at night 19, 20 October 1999 at 120 m depth in Raunefjord, registered number NIWA 3357.





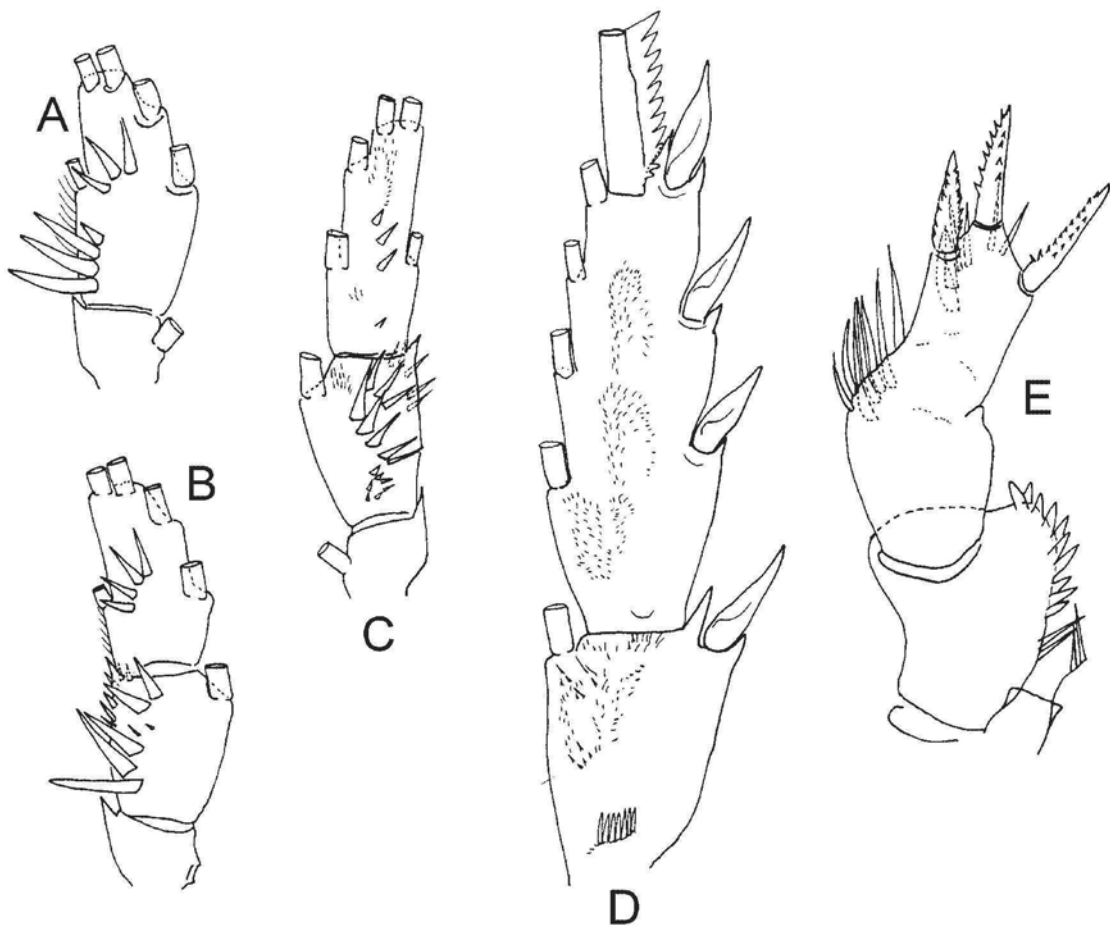
**Fig. 12** *Xanthocalanus minor* Giesbrecht, 1892, female: **A**, urosome, dorsal view; **B**, urosome, lateral view; **C**, genital double-somite, ventral view (flattened); **D**, caudal ramus, ventral view; **E**, maxillule, coxal endites 1, 2; basal endites and endopod; **F**, maxilla, endopod; **G**, maxilla, praecoxal endite 1; **H**, maxilla, coxal endite 1; **I**, maxilla, basal endite; **J**, maxilliped, syncoxa.

### Female

(Fig. 12, 13)

**Body** General form and features as described and illustrated by Sars (1921) but with the following additional details. Cephalosome partially separate from pedigerous somite 1 on dorsal surface and round onto the lateral surface; pedigerous somites 4 and 5 completely fused. Posterolateral corners of prosome extend posteriorly into triangular flaps; borders of posterior prosomal flaps, in lateral view,

slightly more convex in shape than those of *X. fallax*; flaps are pointed in dorsal and lateral views and cover more than half of genital double-somite (Fig. 12A,B). Surfaces of urosomites sparsely covered in very small semicircular thickenings that appear to represent place of attachment of elongate scales that are evident when viewed in profile away from somite although these are clearly easily detached (their shape in planar view could not be determined using



**Fig. 13** *Xanthocalanus minor* Giesbrecht, 1892, female: **A**, leg 2, endopod; **B**, leg 3, endopod; **C**, leg 4, endopod; **D**, leg 4, exopodal segment 2 and 3; **E**, leg 5, anterior view.

light microscope). Genital double-somite with pair of spherical dorsal seminal receptacles connected by narrow neck to more ventral, elongate part (Fig. 12A–C); there is common, square-shaped anteroventral genital opening containing visible, paired gonopores; posterior to operculum is transverse fold (Fig. 12C). Posterior borders of urosomites, except for anal somite, bordered by hyaline frill. Anal somite hardly visible in dorsal view, bearing hairs on ventral surface in posterior midline. Caudal rami without seta in position I, seta II small, located dorsally near base of seta III, four strong terminal plumose setae in positions III–VI, seta VII small, situated on ventral surface, directed laterally (Fig. 12D).

**Antennule** As in *X. longispinus* extending slightly beyond the posterior border of caudal rami.

**Antenna** As in *X. longispinus* but with endopod  $\frac{4}{5}$  length of exopod.

**Mandible, Maxillule, Maxilla and Maxilliped** As in *X. longispinus*.

**Swimming legs** As in *X. longispinus* apart from:  
**Leg 2** (Fig. 13A). Endopod segment 2, posterior surface with 3 large, distal spines and graded series of 3–4 proximal spines (distal one smallest); terminal exopod spines with 25–27 outer edge teeth.  
**Leg 3** (Fig. 13B) Endopod segment 2 with an approximately longitudinal row of 5–7 strong spines on posterior surface as well as 1–2 minute additional spinules, additional spines (5–7) extend around outer border onto anterior face of segment; endopod segment 3 with oblique row of 3–4 large spines on posterior surface; terminal exopod spines with 25–28 outer edge teeth. **Leg 4** (Fig. 13C,D) Endopod

segment 2 posterior surface with 13–15 strong spines on inner part of segment and 7–10 long, fine spines adjacent to inner seta, additional spines (3–5) extend around outer border onto anterior face of segment; endopod segment 3 with row of 4–9 large, centrally-placed spines, more distal fine spinules, and inner proximal fine spinules; exopod segment 2 with proximal row of large soft spinules, distal horizontal row of short spines, and patch of inner distal spinules on posterior surface; exopod segment 3 with elongate patch of small spinules, divided into 3 sections of variable extent, on posterior surface; terminal exopod spines with 26–28 outer edge teeth.

**Leg 5** (Fig. 13E) Uniramous, symmetrical, coxae separated from intercoxal sclerite and with strong, broadly tapering spines lining inner border, proximal spines longest. Basis fused to exopod with fusion line hardly visible, inner surface naked, posterior outer border and around onto posterior surface with long spinules. Exopod 1-segmented, with 3 subequal, articulated spines, inner spine inserted slightly proximal to insertion of outer spine, all three spines with double row of lateral spinules that are located slightly on the posterior surface of spines. Posterior surface of exopod with outer and distal long, flexible spinules.

### Remarks

This species has mouthparts that are typical of many species in this genus in that the maxilla has coxal endite 1 with 1 setae of the sensory type, basal endite with 2 setae of the sensory type, and the endopod has 1 worm-like and 7 brush-like sensory setae, one of which is much wider and shorter than the others. The syncoxa of the maxilliped bears 8 setae arranged proximal to distal 1 (sensory), 2, 2 (1 of these is short and brush-like), 3 respectively. The male of this species has been partially described by Mathews (1964) and has a styliform right leg 5.

### Discussion

More than 50 species have been placed in *Xanthocalanus*, many of which are poorly described. The re-examination of *X. fallax* and *X. minor* shows that assumptions about the setation of the maxilla and maxilliped, derived from earlier descriptions, misled Campaner (1978) when he attempted to split *Xanthocalanus* species into an *agilis* and *minor* group based on apparent differences in number and type of sensory setae on the female maxilla endopod and whether or not the right leg 5 is long and styliform or short (all other characters mentioned overlapped these two groups).

Both *X. fallax* and *X. minor* have setation on the endopod of the maxilla and syncoxa of the maxilliped that are similar even though the type of male leg 5 is different. That is, the endopod of the maxilla has 1 worm-like and 7 brush-like setae (1 of which is shorter and wider than the others), and the syncoxa of the maxilliped bears 8 setae with 1 seta on endite 3 modified as a brush-like sensory seta. In conjunction with these observations, the male of *X. longispinus* from New Zealand, the female of which is very similar to *X. fallax*, has leg 5 very similar to that of *X. minor* (assuming that males have been correctly matched with females). Therefore, the characters that Campaner used to separate his two *Xanthocalanus* groups are not consistently found in members of his groups. Re-examination of *X. fallax* and *X. minor* indicates that the mouthparts (especially the maxilla and maxilliped) of all of Sars' phaennid species should be redescribed.

*Xanthocalanus longispinus* and *X. stewarti* appear to be related to a number of species that have females with the maxilla endopod with 1 worm-like and 7 brush-like sensory setae (one of these is shorter and wider than the others), as well as a worm-like sensory setae on coxal endite 1 and 2 worm-like sensory setae on the basal endite (although many species are probably not well enough described to know how extensive this combination of characters is amongst *Xanthocalanus*); the maxilliped syncoxa with an ordinary seta on endite 1, and at least 1 brush-like sensory seta on endite 3. Species that are known to have these characters are: *X. fallax* Sars, 1925; *X. gracilis* Wolfenden, 1911; *X. harpagatus* Bradford & Wells, 1983; *X. longispinus* n. sp.; *X. marlyae* Campaner, 1978; *Xanthocalanus medius* Tanaka, 1960; *X. minor* Giesbrecht, 1892; *X. penicillatus* Tanaka, 1960; *X. polarsternae* Markhaseva, 1998; *X. quasiprofundus* Vyshkvartzeva, 2002; *X. spinodenticulatus* Markhaseva, 1998; *X. stewarti* n. sp.; *Xanthocalanus* sp. 1 Bradford et al. 1983. These species have female leg 5 with a variety of forms with variable numbers of articulated spines on the terminal segment and fusion of these spines to its segment and types of surface decoration. As yet we do not have complete enough information on which to assess the likelihood that natural species groups occur within this genus.

Males of these species, where known (*X. fallax* Sars, 1925, see Sars, 1902, Matthews 1964; *X. longispinus* n. sp.; *X. minor* Giesbrecht, 1892, see Mathews 1964; *X. polarsternae* Markhaseva, 1998), have varying numbers of ancestral antennule segments X–XVII fused on both sides as well as

XXII–XXIII fused on the right, but the right leg 5 may be styliform or reduced.

The fusion of antennule segments XXII and XXIII on the right is possibly a remnant of the geniculate antennule that is a primitive Calanoid characteristic (e.g., Gurney 1931; Ohtsuka & Huys 2001). In families that have an antennule geniculate between segments XX and XXI, XXII and XXIII are often fused. This characteristic has also been noted in *Tharybis* (Schulz 1981; Bradford-Grieve 2001a) and *Macandrewella* (Ohtsuka et al. 2002). Giesbrecht (1892) notes the fusion of segments XXII and XXIII on the right in *X. agilis*, as does Tanaka (1960) in *X. echinatus* and *X. pectinatus* and Drs Nina Vyshkvartseva and Elena Markhaseva report this characteristic (unpubl. obs. in lit.) for *X. kurilensis* and *X. polarsternae*, respectively. It may be reasonable to assume that other *Xanthocalanus*, described as *Amalophora* by Tanaka (1960), have symmetrical male antennae as he does not mention asymmetry as he does for *X. echinatus* and *X. pectinatus*. Nevertheless, it is tempting to suggest that this characteristic may prove to be more widespread in families with modified setae on their mouthparts than is currently recognised.

### *Brachycalanus* sp.

#### Materials examined

One dissected adult female, off south-eastern coast of North Island, New Zealand, 41°04.67'S 176°23.48'E, 13 April 2000, near sea floor, 452 m depth, KAH0005/05, catalogue number NIWA 3359. Total length: 1 damaged female 2.97 mm. The description is based on the single damaged specimen.

#### Female

(Fig. 14–16)

**Body** Rostrum bifurcate terminating in pair of sensory filaments (Fig. 14E). Cephalosome appears to be separate from pedigerous somite 1; pedigerous somites 4 and 5 appear to be fused (Fig. 14A,C) although in dorsal view there is some sign of a fusion line. Posterolateral corners of prosome extending posteriorly into bluntly triangular flaps and covering about half of genital double-somite. Urosome of 4 free somites (Fig. 14D) and apparently covered in small scale-like spinules (v-shaped scars show the position of these spinules); genital double-somite symmetrical, with single ventral genital operculum and pair of seminal receptacles; with hyaline fringe on posterior border. Urosomites 2 and 3 with posterior hyaline fringes; caudal rami symmetrical,

about twice as long as wide (length measured along the outer border), also covered in scale-like spinules, apparently without seta in position I, seta II located on dorsal surface at base of seta III, four strong terminal plumose setae in positions III–VI, seta VII small, situated on ventral surface directed anteriorly.

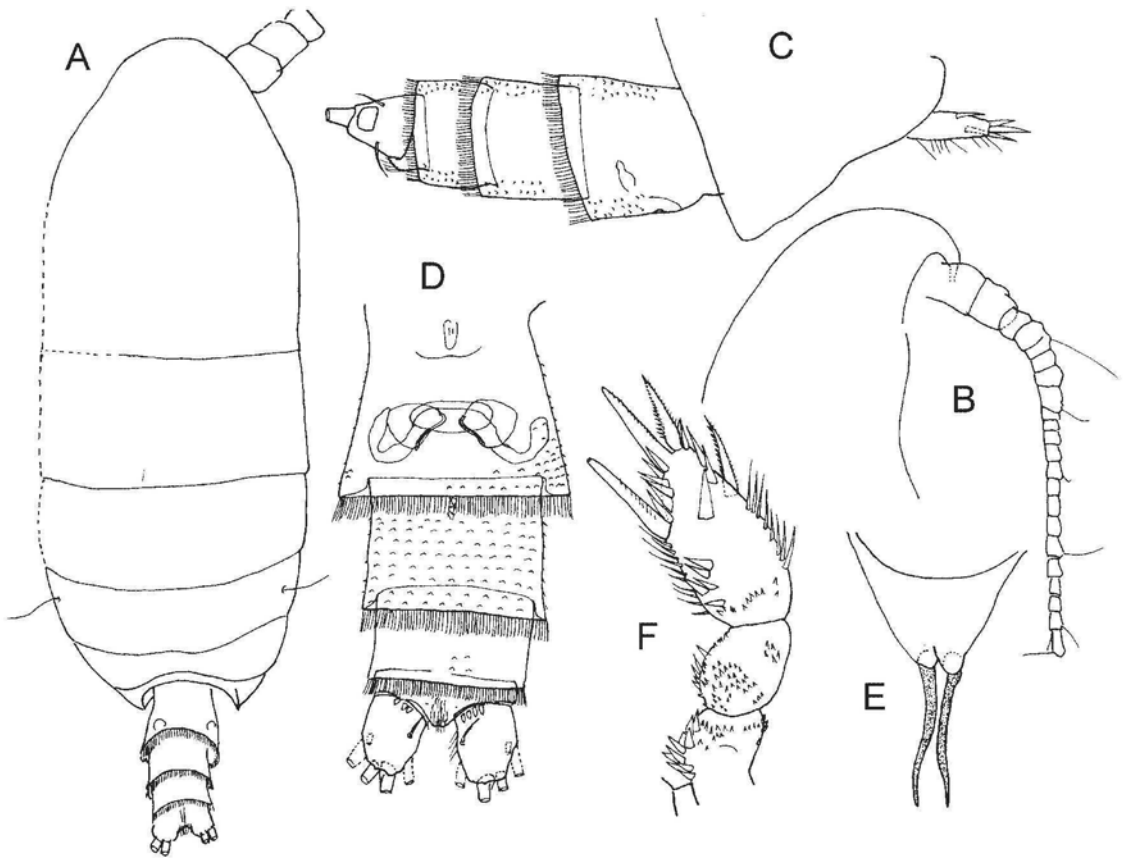
**Antennule** (Fig. 14B, 15A) 24-segmented (but last 2 segments missing on right side and last 16 segments missing on left), extending to beyond posterior border of pedigerous somite 1; armature elements referring to ancestral segments as follows: I-3, II-IV-6 + aesthetasc, V-2 + aesthetasc, VI-2, VII-2? + aesthetasc, VIII-2?, IX-2? + aesthetasc?, X-XI-4? + aesthetasc, XII-1?, XIII-1?, XIV-2 + aesthetasc, XV-1?, XVI-2? + aesthetasc?, XVII-1?, XVIII-2?, XIX-1?, XX-2?, XXI-1? + aesthetasc?, XXII-1?, XXIII-1, XXIV-1 + 1, XXV-1 + 1. Two setae on segment I are plumose; other setae appear of a sensory nature although differing in appearance from aesthetascs. A number of setae are indicated by their position of attachment and are indicated by “?”.

**Antenna** (Fig. 15B) With endopod about 7/10 of exopod; coxa and basis separate, coxa with seta and tuft of posterior surface hairs, basis with 2 setae; endopod segment 1 with 2 setae, segment 2 with a total of 15 (8 + (6+1 very small)) setae and with outer distal border lined with small spinules; exopod 7-segmented, segment 2 includes ancestral segment IV, segment 1 without seta, segment 2 with minute seta and covered on inner distal surface with short minute spinules, segments 3–6 with 1 large seta each, segment 7 with 3 terminal setae and 1 seta at midlength.

**Mandible** (Fig. 15C) Gnathobase with 1 strong setose dorsal seta and undetermined number of teeth, largest tooth ventral, basis with 2 strong short setae and 1 small more distally placed seta; endopod segment 1 with 1 long seta and 1 short spine-like seta, segment 2 with 9 distal setae and horizontal row of small spinules on outer border; exopod with 6 setae.

**Maxillule** (Fig. 15D) Praecoaxal arthritis with 10 terminal spines and 4 posterior surface setae; coxal endite and basal endites 1 and 2 with 3, 5, 5 setae respectively; basis and endopod segments more or less fused; endopod with 3+3+5 setae; exopod with 10 setae and outer row of anterior surface spinules; coxal epipodite with 9 setae.

**Maxilla** (Fig. 15E) Praecoaxal endites 1 and 2 with 5 and 4 setae respectively; endites 1 and 2 of coxa with 3 setae each, basal endite 1 with 1 seta heavy and claw-like; basal endite 2 of basis with 4 setae, 1



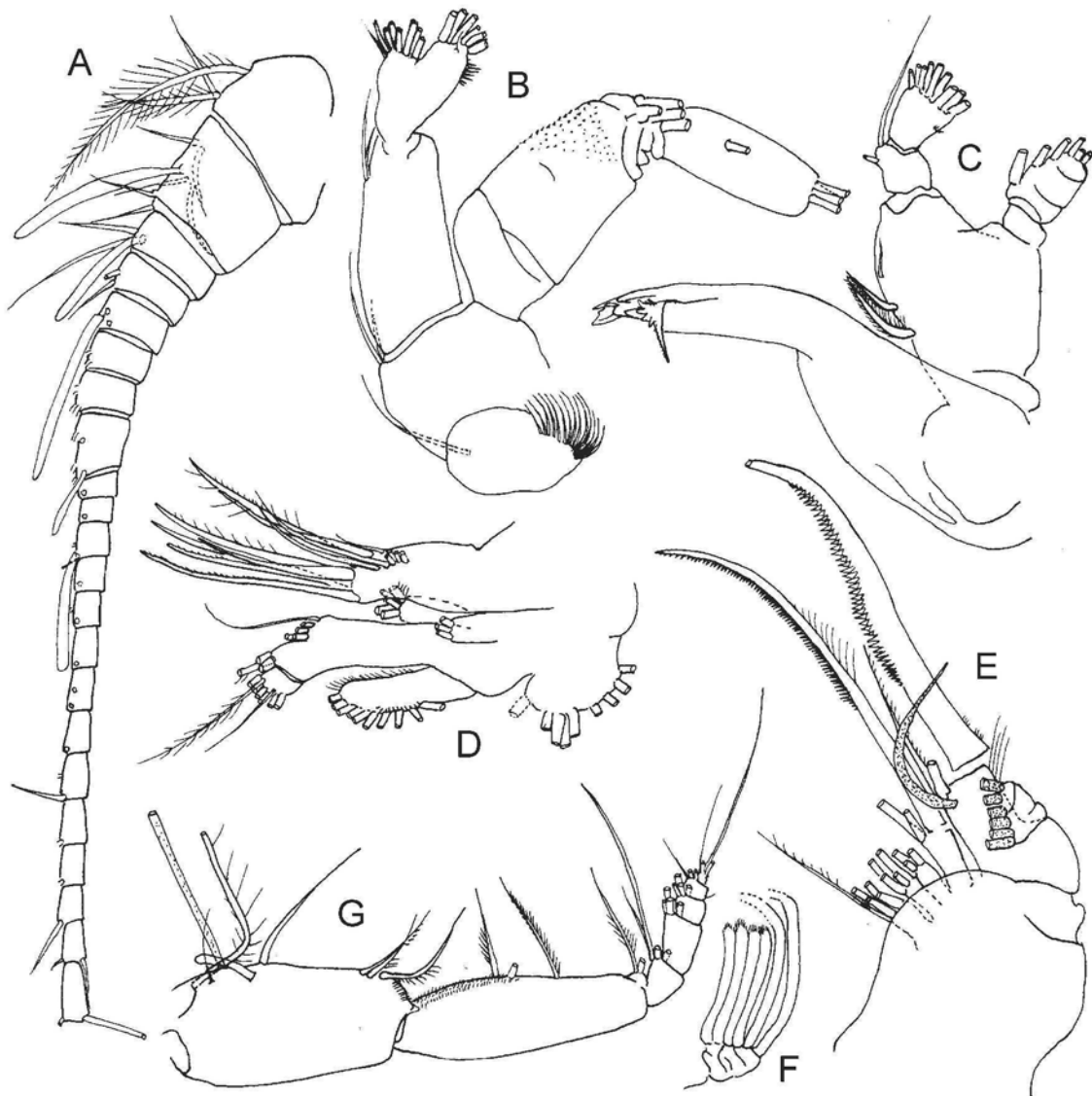
**Fig. 14** *Brachycalanus* sp. female: **A**, dorsal view; **B**, head, lateral view; **C**, urosome, lateral view; **D**, urosome, ventral view, flattened; **E**, rostrum; **F**, leg 5, posterior view.

seta very heavy and claw-like, 1 seta modified as sensory seta; endopod setation not seen clearly because of included detritus overlying sensory setae, with 2 longer and 4 apparently shorter (brush-like?) sensory setae (Fig. 15F).

**Maxilliped** (Fig. 15G) Syncoxa shorter than basis, thickened; syncoxa with 1 (proximally plumose), 2 (1 sensory, 1 small and naked), 2 (1 very delicate and sensory—probably brush-like, 1 naked), 3 (plumose) setae; basis with 3 medial setae (middle 1 naked, proximal 2 setae grouped together) and with wedge-shaped row of small, inner edge spinules extending from proximal to just beyond second medial seta; endopod just over half length of basis, setae short, segment 1 apparently incorporated into basis with 2 setae, free segments 2–6 with 4, 4, 3, 3+1, and 4 setae respectively.

**Swimming legs** (Fig. 16A–H) Segmentation and disposition of spines and setae are presumed to be

as in the genus but in legs 2–4 endopod and exopod segments 2 and 3 are missing. **Leg 1** (Fig. 16A,B) Coxa anterior surface decorated with minute spinules. Basis with 1 outer distal spinule, inner distal border produced posteriorly into large rounded process bearing 5 prominent teeth, anterior surface decorated with minute spinules. Endopod antero-outer swelling decorated with row of fine spinules. Exopod segments decorated with minute spinules on anterior surface. **Leg 2** (Fig. 16C,D) Coxa posterior surface decorated with minute spinules, anterior surface decorated with minute spinules and proximo-outer transverse row of large scale-like spinules. Basis posterior surface decorated with minute spinules and larger, scale-like spinules on outer and distal border (many of these appear to be missing—determined by the scar-like marks on the surface), anterior surface also covered with minute spinules and an undetermined number of scale-like

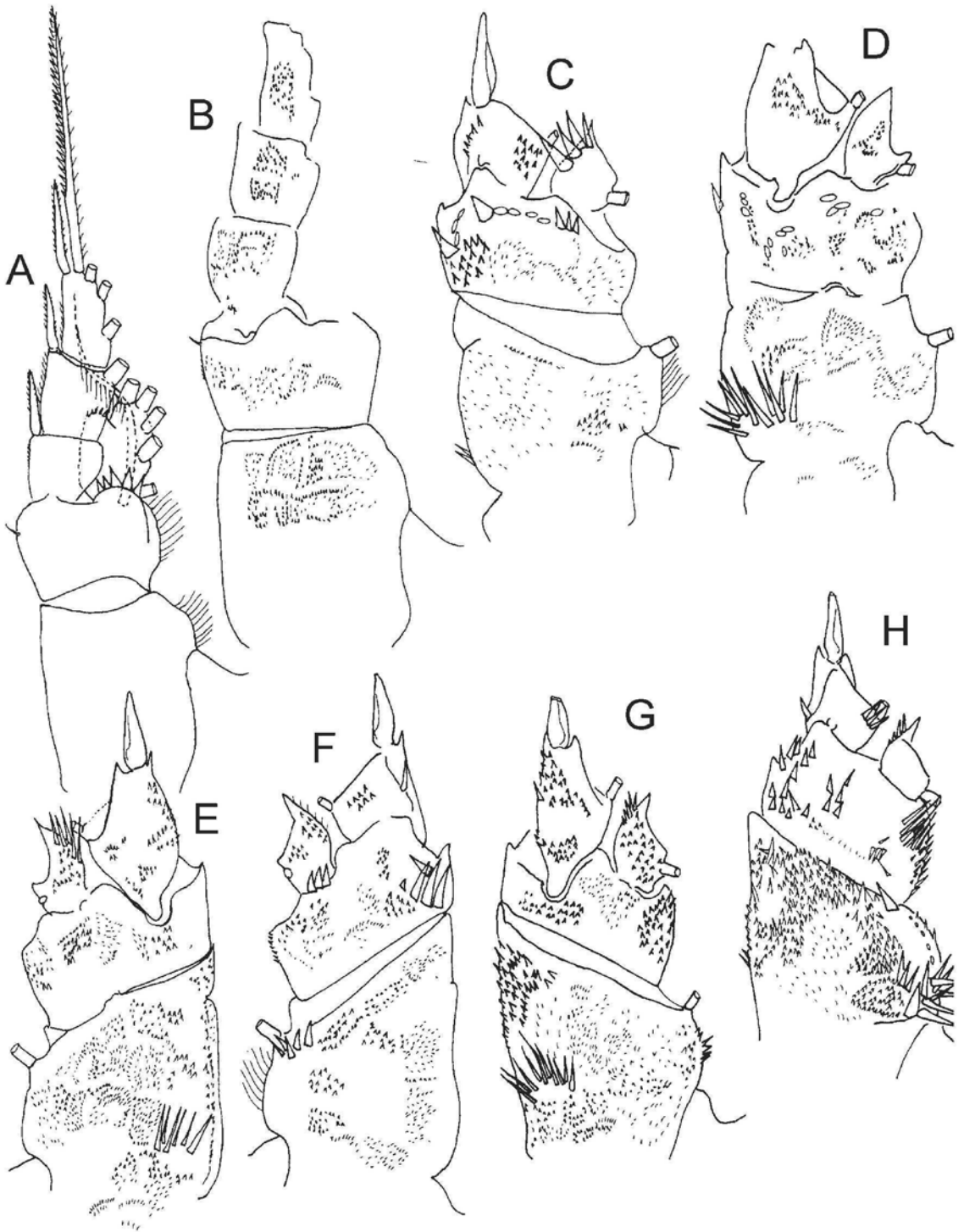


**Fig. 15** *Brachycalanus* sp. female: A, antennule; B, antenna; C, mandible; D, maxillule; E, maxilla; F, maxilla, endopod; G, maxilliped.

spines. Endopod segment 1 posterior surface with longitudinal row of 4 long spines on outer border of segment, anterior surface with minute spinules. Exopod segment 1 with minute posterior and anterior surface spinules. **Leg 3** (Fig. 16E,F) Coxa decorated on anterior and posterior surfaces with minute spinules, and at base of inner seta there are 5 larger scale-like spinules on posterior surface and transverse row of long spinules on proximal outer anterior surface. Basis decorated on anterior and posterior surfaces with minute spinules, and larger

scale-like spinules on posterior surface at base of endopod and near outer border. Endopod segment 1 decorated with minute spinules on anterior and posterior surfaces and long spinules on outer anterior surface. Exopod segment 1 decorated with minute spinules on anterior and posterior surfaces and scale-like spinules on outer posterior surface. **Leg 4** (Fig. 16G,H) Coxa decorated with minute (although larger than on other legs) spinules on anterior and posterior surfaces, with large scale-like spinules on inner posterior surface, and transverse row of long spinules





**Fig. 16** *Brachycalanus* sp. female: A, leg 1, posterior view; B, leg 1, posterior view; C, leg 2, posterior view; D, leg 2, anterior view; E, leg 3, anterior view; F, leg 3, posterior view; G, leg 4, anterior view; H, leg 4, posterior view.



**Table 2** Comparison of females of all *Brachycalanus* species. (B, basis; C, coxa; P, leg; Se, outer spine; Si, inner spine; St, terminal spine.)

Species	Size (mm)	Depth (m)	Distribution	P5: insertion of Si and Se	P5: length Si relative to base St	P5: length Se relative to base St	P5 inner St articulation	P1 B: distal border	Other references
<i>B. atlanticus</i> (Wolfenden, 1904)	3.95	550	West coast of Ireland	opposite at midlength	exceeds	shorter than	yes	?	
<i>B. atlanticus</i> : Farran, 1905	2.0–2.5	365	Atlantic slope off Ireland	opposite at midlength	shorter than	shorter than	yes	without protrusion or spinules	
<i>B. bjornbergae</i> Campaner, 1978	1.60–2.00	72–150	continental shelf, Brazil	not opposite: Si proximal to Se	exceeds	exceeds	yes	without protrusion or spinules	
<i>B. brodskyi</i> Ferrari & Markhaseva, 2000	4.0	2945–3010 1–5 m above bottom	eastern tropical Pacific, volcano 7	not opposite: Si distal to Se	exceeds	shorter than	yes	semicircular row fine spinules	
<i>B. flemingeri</i> Ferrari & Markhaseva (2000)	2.01–2.41	2600–2800	off Kona, Hawaii	not opposite: Si distal to Se	exceeds	exceeds	yes	with protrusion	
<i>B. ordinarius</i> (Grice, 1972)	2.92–3.40	992–1000	north-west Atlantic slope	opposite, slightly distal to midlength	exceeds	exceeds	yes	without protrusion or spinules	Ferrari & Markhaseva (2000)
<i>B. rothlisbergi</i> Othman & Greenwood, 1988	1.57–1.68	0–<70	Gulf of Carpentaria, Australia	opposite, slightly distal to midlength	exceeds	equal to	yes	without protrusion or spinules	
<i>Brachycalanus</i> sp.	2.97	452	continental slope east of New Zealand	opposite, slightly distal to midlength	exceeds	exceeds	no	with protrusion + 5 large teeth	This paper

on anterior proximal part of segment. Basis decorated with minute spinules on anterior surface and scale-like spinules on posterior surface; many of these seem to have been detached. Endopod segment 1 decorated with minute spinules on anterior surface and long distal outer spinules. Exopod segment 1 decorated with minute spinules on anterior surface and long spinules at base on inner distal seta on posterior surface. **Leg 5** (Fig. 14F) Uniramous, symmetrical, coxae separated by intercoxal sclerite, decorated with minute spinules on anterior and posterior surfaces, inner spines very robust. Basis about as broad as long, decorated with minute spines on anterior and posterior surfaces, inner spines heaviest. Exopod formed from a single segment about twice as long as wide (not including the terminal spines), outer and inner spines articulated to segment and inserted opposite one another just distal to midlength, inner distal spine completely fused to its segment, outer distal spine articulated to the segment, all spines lined with small spinules, posterior surface of segment with numerous scale-like spinules although many of these appear to be missing, anterior surface decorated with minute spinules.

## Remarks

The genus *Brachycalanus* includes *B. atlanticus* (Wolfenden, 1904); *B. bjornbergae* Campaner, 1978; *B. brodskyi* Ferrari & Markhaseva, 2000; *B. flemingeri* Ferrari & Markhaseva, 2000; *B. ordinarius* (Grice, 1972); *B. rothlisbergi* Othman & Greenwood, 1988 (Table 2). The present damaged female specimen is most similar to *B. ordinarius* in size but differs from all the previously described species in that leg 1 distal posterior surface of the basis has very conspicuous terminal spines on a rounded posterior projection and leg 5 has the inner terminal spine completely fused to the segment. Because of the damaged state of this specimen and the consequent inability to observe morphological details that would contribute to our knowledge of the genus, it has not been named.

## ACKNOWLEDGMENTS

Thanks to Rob Stewart (NIWA Wellington) who worked out how to obtain samples from a trawler and Dr Martin Cryer who made sure the samples were collected. Specimens of *X. fallax* and *X. minor* were

kindly made available by Dr Audun Fosshagen, University of Bergen, Norway. I am grateful to Dr Niel Bruce, Dr Susumu Ohtsuka, Dr Elena Markhaseva, and Dr Knud Schulz whose critiques helped to improve the manuscript. This work was supported by the New Zealand Foundation for Research, Science and Technology contract C01X0219.

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