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PSEUDOCALANUS ACUSPES (CRUSTACEA: COPEPODA) FROM THE WHITE SEA

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ABSTRACT

The presence of *Pseudocalanus acuspes* in the White Sea is confirmed. In this northern Sea *P. acuspes* coexists with its congener *P. minutus*. The morphological characters proposed by Frost (1989) as distinguishing for *P. minutus* and *P. acuspes* apply well for the White Sea specimens. A key diagnostic character is P4 coxopod to basipod ratio, which is more than 1.5 in *P. minutus* and less than 1.5 in *P. acuspes*. Additional characters are: size of spiniform processes on postero-ventral margins of pedigerous somites 2 and 3, prosome to urosome ratio, and shape of cephalon in anterior lateral view. In females morphology of oral parts does not help in distinguishing between species, but is helpful for males.

Key words: Copepoda, *P. minutus*, *P. acuspes*, the White Sea

PSEUDOCALANUS ACUSPES (CRUSTACEA: COPEPODA) ИЗ БЕЛОГО МОРЯ

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РЕЗЮМЕ

Подтверждено присутствие *Pseudocalanus acuspes* в Белом море. В этом северном море сосуществуют *P. acuspes* и *P. minutus*. Признаки, предложенные Фростом (Frost 1989) для различения *P. minutus* and *P. acuspes* хорошо применимы для беломорских видов. Ключевым диагностическим признаком является отношение длины коксоподита к базиподиту P4, которое больше 1.5 у *P. minutus* и меньше 1.5 у *P. acuspes*. В качестве дополнительных таксономических признаков служат: размеры шипиков на постеровентральном крае педигеров 2 и 3, соотношение длины просомы к уросоме и форма передней части цефалона при взгляде сбоку. У самок строение ротовых частей практически идентично и не может помочь в определении видов, в то время как у самцов отмечаются различия в вооружении.

Ключевые слова: Copepoda, *P. minutus*, *P. acuspes*, the White Sea

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INTRODUCTION

Pseudocalanus Boeck, 1873 is widely distributed in the seas of the northern hemisphere. The genus was reviewed by Frost (1989) and now includes seven species. Species of this genus are common, abundant, often dominant in the zooplankton communities, show high densities and biomass and are used in the experiments on feeding, salinity adaptations and in the various research on the biology of marine Calanoida.

Pseudocalanus is a typical component of the White Sea pelagic communities. Papers on zooplankton published earlier than 1989 refer *P. elongatus* (Boeck, 1865) for the White Sea (e.g., Prygunkova 1974, 1979, 1985). After Frost's revision (Frost 1989), species inhabiting the White Sea have been considered *P. minutus* (Krøyer, 1845) and the only species of the genus to exist in this sea (Berger and Kosobokova 2001; Berger et al. 2003; Kosobokova et al. 2003; Pertsova and Kosobokova 1996, 2002, 2003; Primakov 2002; Kutcheva 2005; Primakov et al. 2010). Just once, without discussion, another species *P. acuspes* (Giesbrecht, 1881) was mentioned in the compiled table on the zooplankton abundance (Kosobokova and Pertsova 2005). However, researchers, dealing with the zooplankton samples from the White Sea, have permanent confusion in the identification of *Pseudocalanus* to species level, and it was considered necessary to revise taxonomic status of its representatives in this sea.

Original and later taxonomic descriptions of *Pseudocalanus* species (e.g., Krøyer 1845, 1848; Giesbrecht 1882; Sars 1901, 1903) are not enough detailed for any of species of the genus. That is why the complete taxonomic re-description of the White Sea *Pseudocalanus* has been fulfilled.

METHODS AND TERMINOLOGY

Adult specimens for this study were sorted from the samples collected by Juday net (mouth opening 37 cm, mesh size 168 μm) in July–August, 2007 in the Chupa Inlet of the Kandalaksha Bay of the White Sea at the Decade Station (66°19.5′N, 33°39.4′E, depth 63m) where the long-term series of sampling have been fulfilled since 1957 at the White Sea Biological Station of the Zoological Institute RAS. Specimens were fixed in 96% ethanol and later stained by adding a solution of chlorazol black E dissolved in 70% ethanol/30% water. Oral parts and swimming legs were dissected and figures were made in glycerin using a *camera lucida*. Measurements were done according Frost (1989) for about 60 females of each species, 10 males of *P. acuspes*, and 3 males of *P. minutus*.

The following abbreviations are used in the descriptions: Pr, prosome; Ur, urosome; P1–P5, swimming legs 1 to 5; c, coxopod; b, basipod. Free segments of the antennule are designated by Arabic numerals, ancestral segments by Roman numerals; one seta and one aesthetask on a segment of the antennule are designated as: 1s + 1ae. Further, the segmentation of maxilla follows Ferrari and Ivanenko (2008) and the syncoxa of the maxilliped is considered to have three praecoxal endites and one coxal endite (Ferrari and Markhaseva 2000a, b; Ferrari and Ivanenko 2001).

SYSTEMATICS

Order Calanoida G.O. Sars, 1903

Family Clausocalanidae Giesbrecht, 1893

Genus *Pseudocalanus* Boeck, 1873

***Pseudocalanus acuspes* (Giesbrecht, 1881)**
(Figs 1–6)

Description. *Adult female*. Total length 1.05–1.81 mm; prosome 2.06–2.30 times as long as urosome. Rostrum (Fig. 1, 2B) as 2 filaments. Cephalosome and pediger 1, and pedigers 4 and 5 fused; posterior corners as rounded lobes (Fig. 1, 2A). Postero-ventral margins of pedigers 2 and 3 in lateral view with very small, or reduced spiniform processes (marked by arrow on Fig. 2C–F). Genital double-somite symmetrical, spermathecae clearly visible in lateral view (Fig. 1, 2G–I). Caudal rami (Fig. 2G–H) with 4 terminal plus 1 small dorsolateral and 1 small ventral setae each.

Antennule (Fig. 2J) reaching to about middle of second-third urosomal somite, of 24 free segments; armature as follows: I – 3s, II–IV – 6s + 1ae, V – 2s + 1ae, VI – 2s, VII – 2s + 1 ae, VIII – 2s, IX – 2s; X–XI – 4s + 1ae, XII to XIII – 1s each; XIV – 2s + 1ae, XV – 1s, XVI – 2s + 1ae, XVII to XIX – 1s each, XX – 2s, XXI – 1s + 1ae, XXII to XXIII – 1s each, XXIV to XXVI – 2s each, XXVII–XXVIII with 4s + 1ae.

Antenna (Fig. 3A), coxa with 1 seta; basis with 2 setae; endopodal segment 1 with 2 setae, endopodal segment 2 with 15 setae; exopod incompletely 8–segmented with 1–1, 1–1, 1, 1, 1, 1, 1 and 3 setae.

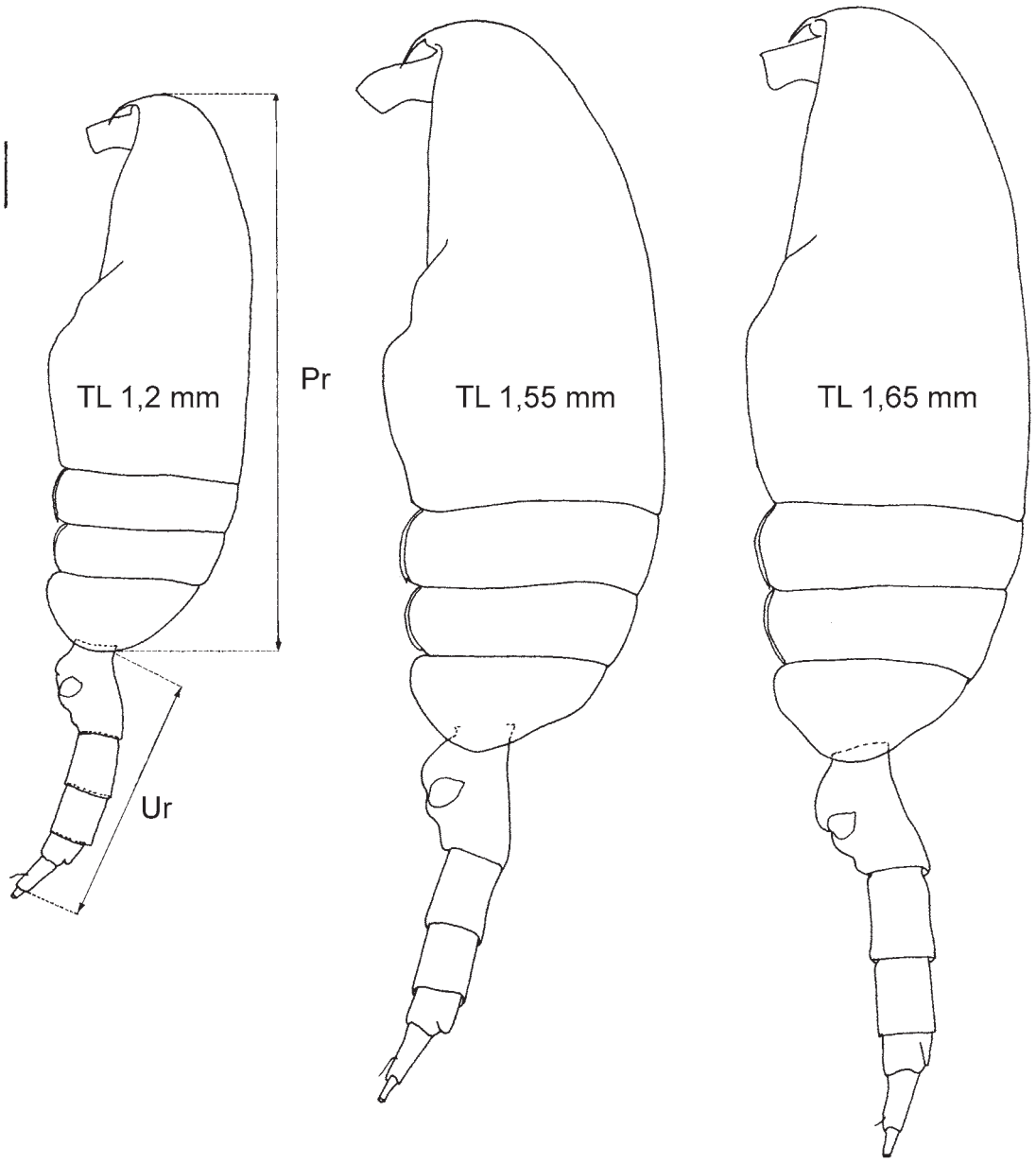

Fig. 1. *Pseudocalanus acuspes* (Giesbrecht, 1881), female, habitus, lateral. *Scale bar*: 0.1 mm.

Mandible (Fig. 3B), gnathobase cutting edge with about 8 teeth; exopod of five segments with 1, 1, 1, 1 and 2 setae; endopod segment 1 with 4 setae, endopod segment 2 with 11 setae; basis with 4 setae.

Maxillule (Fig. 3C), praecoxal arthrite with 9 terminal spines, 4 posterior setae and 1 anterior setae; coxal endite with 3 setae, coxal epipodite with 9 setae; proximal basal endite with 4 setae, distal basal endite with 5 setae; endopod with 16–17 setae, exopod with 11 setae.

Maxilla (Fig. 3D), praecoxal endite bearing 5 setae, coxal (former considered as distal praecoxal endite) with 3 setae; basal endites (considered as coxal endites) with 3 setae each; lobe of proximal endopodal segment (considered as proximal basal endite) with 4 setae. Endopod with 5 plus 1 setae.

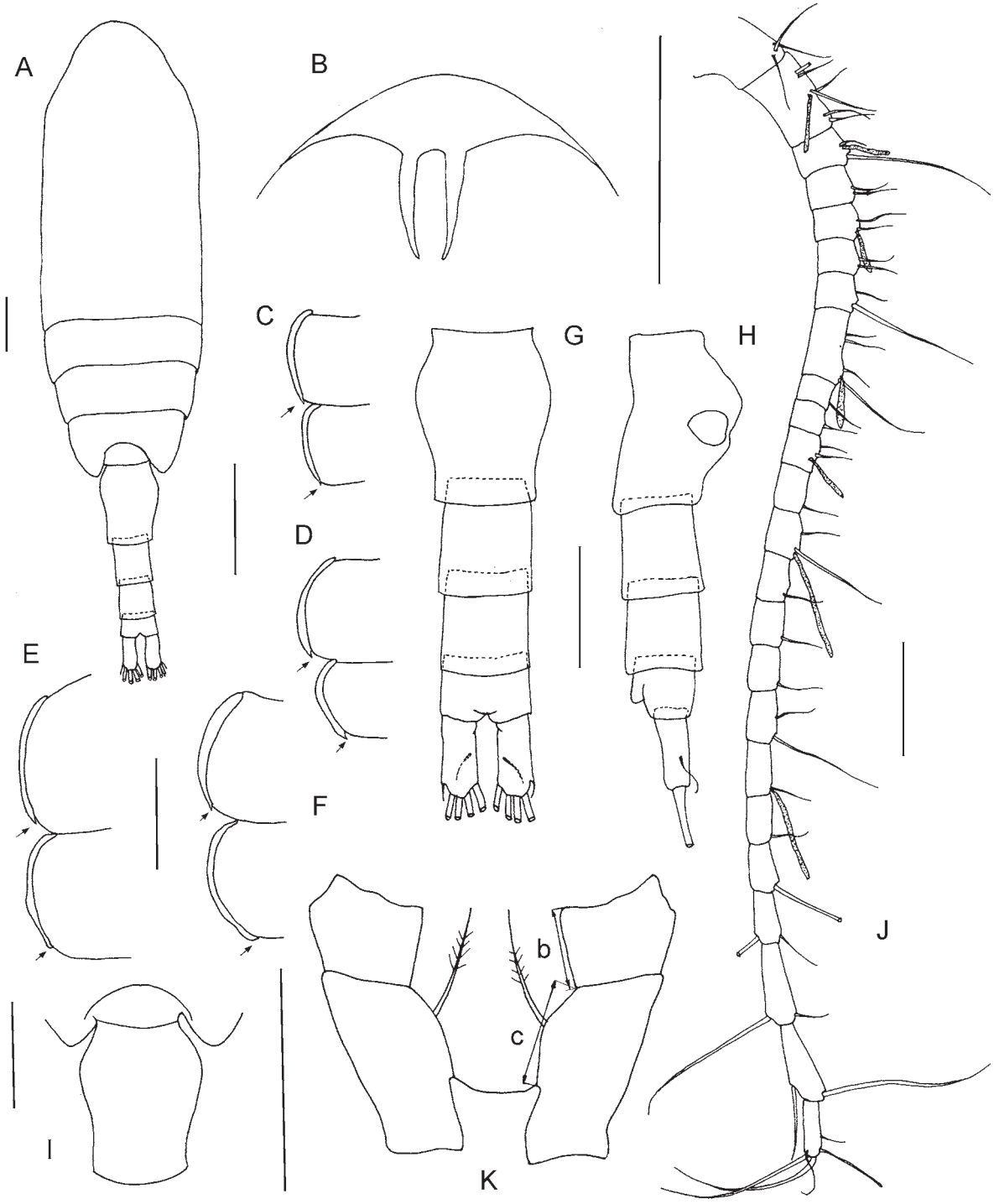

Fig. 2. *Pseudocalanus acuspes* (Giesbrecht, 1881), female: A – habitus, dorsal; B – rostrum, ventral; C – F – postero-ventral margins of pedigers 2 and 3, arrows mark spiniform processes; G – urosome, dorsal; H – urosome, lateral; I – posterior prosome and genital double-somite, dorsal; J – antennule; K – P4 coxo- and basipod (protopod), arrows show measurements for their length. *Scale bar*: 0.1 mm.

Fig. 3. *Pseudocalanus acuspes* (Giesbrecht, 1881), female: A – antenna, B – mandible; C – maxillule; D – maxillae; E – maxilliped. *Scale bar*: 0.1 mm.

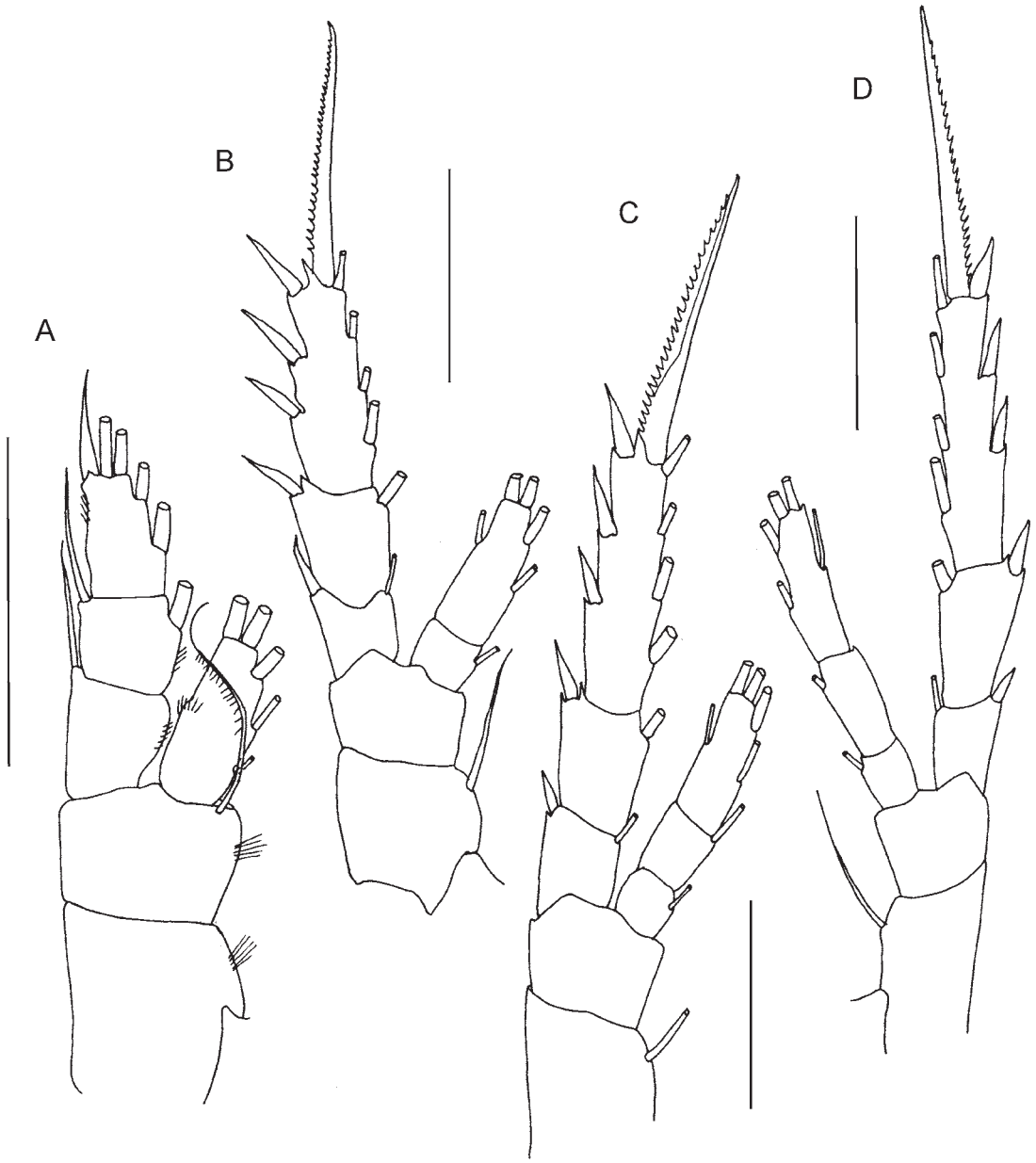

Fig. 4. *Pseudocalanus acuspes* (Giesbrecht, 1881), female: A – P1; B – P2; C – P3; D – P4. *Scale bar*: 0.1 mm.

Maxilliped (Fig. 3E), syncoxa with 1 sclerotized seta on proximal praecoxal endite, 2 sclerotized setae on middle endite, and 3 setae on distal praecoxal endite, coxal endite with 3 setae. Basis with 3 medial setae plus 2 setae distally of incorporated endopod segment 1; endopod of five free segments with 4, 2, 2, 2+1 and 4 setae.

P1 (Fig. 4A), basis with curved medial distal seta; endopod one-segmented with 3 medial and 2 terminal setae; lateral lobe poorly developed; exopod three-segmented, segment 1 with lateral spine, segment 2 with lateral spine and medial seta, segment 3 with lateral spine, 3 medial setae and terminal spine.

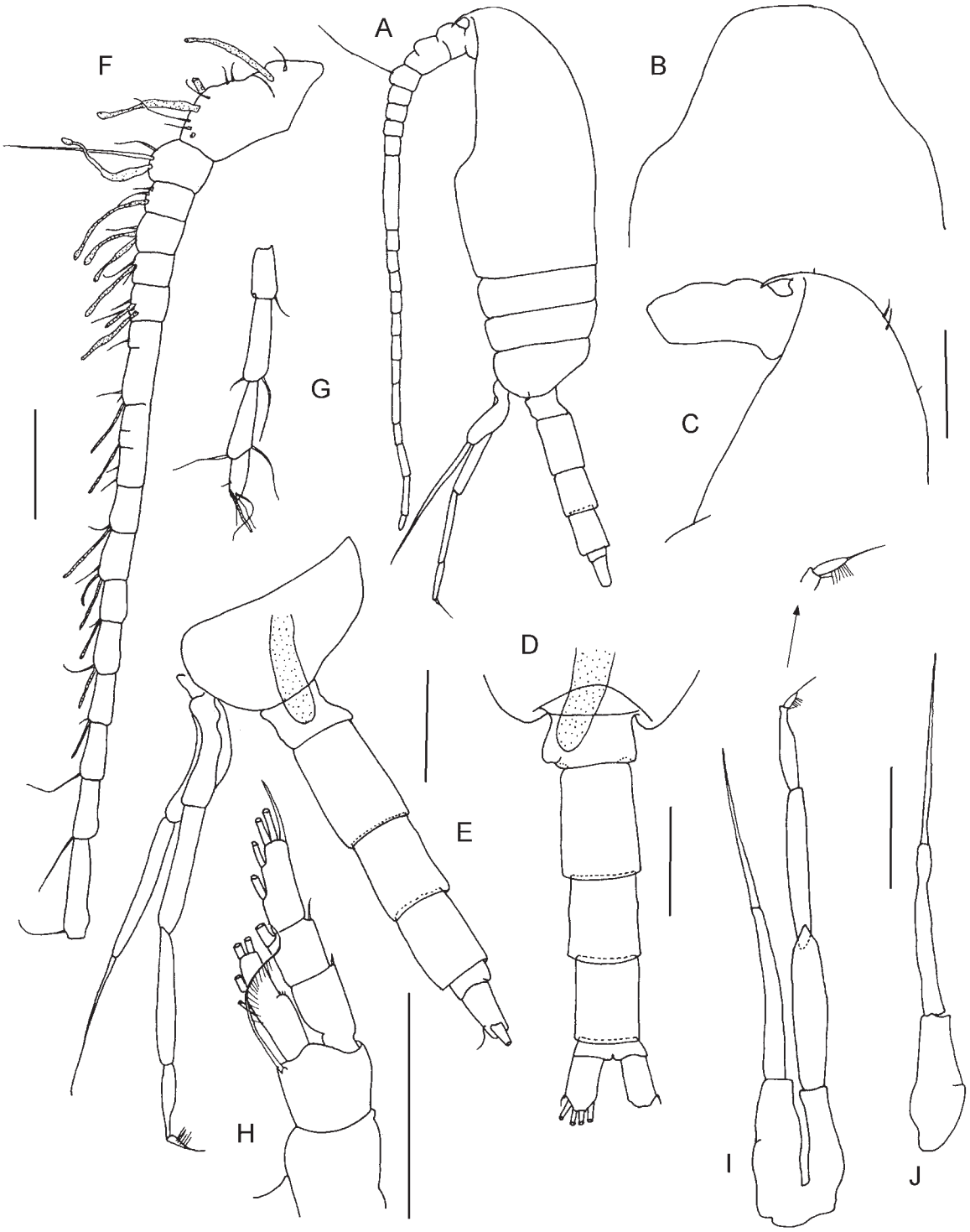

Fig. 5. *Pseudocalanus acuspes* (Giesbrecht, 1881), male: A – habitus, lateral; B – cephalon, dorsal; C – cephalon and rostrum, lateral; D – posterior prosome and urosome, dorsal; E – posterior prosome and urosome, P5, lateral; F – antennulle, ancestral segments I – XXII–XXIII; G – antennulle, ancestral segments XXIV–XXVIII; H – P1; I – P5, J – P5 right. *Scale bar*: G, 0.1 mm.

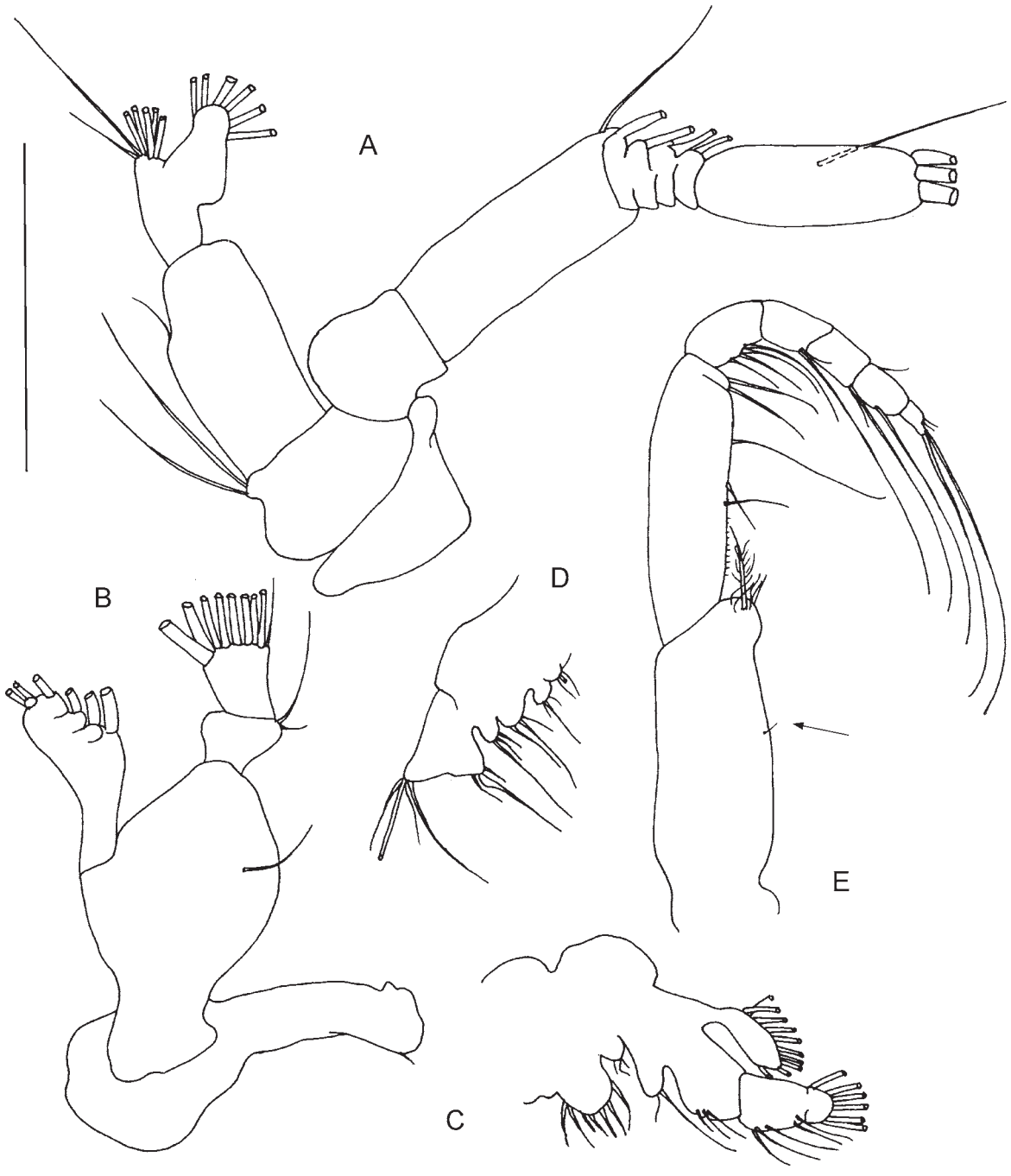

Fig. 6. *Pseudocalanus acuspes* (Giesbrecht, 1881), male: A – antenna; B – mandible; C – maxillule; D – maxilla; E – maxilliped. *Scale bar*: 0.1 mm.

P2 to P4 biramous with 3-segmented exopods, endopod 2-segmented in leg 2 and 3-segmented in legs 3 to 4 (Fig. 4B–D). P4 (Figs 2K, 4D), coxopod to basipod ratio less than 1.5 (1.20–1.45, in one specimen 1.50).

Adult male. Total length 0.95–1.15 mm, prosome 1.90–2.13 times as long as urosome. Rostrum (Fig. 5C) as in female. Cephalosome (Fig. 5A–B) and pediger 1, and pedigers 4 and 5 fused; posterior corners as rounded lobes (Fig. 5A, E). Caudal rami (Fig. 5D–E) with 4 terminal plus one small dorsolateral and ventral setae.

Antennule reaching to anterior third of urosomal somite, right and left symmetrical, of 23 segments (Fig. 5F–G), armature as follows: I – 1s + 1ae, II–IV – 5s + 2ae +1?, V – 2s + 1ae, VI – 2s + 1ae, VII – 1s + 2ae, VIII – 2s + 1ae, IX – 2s + 2ae; X – 1s, XI – 2s + 1ae (X and XI incompletely fused), XII – 0, XIII – 1ae; XIV – 2s (XII and XIV incompletely fused), XV – 1s + 1ae, XVI – 2s + 1ae, XVII – 1s + 1ae, XVIII – 1s + 1ae, XIX – 1s + 1ae, XX – 1s, XXI – 1s, XXII –XXIII – 1s, XXIV – 1s +1?, XXV–XXVI – 2s each, XXVII–XXVIII 4s + 1ae.

Antenna (Fig. 6A), coxa without seta; basis with 2 setae; endopodal segment 1 with 1 seta, endopodal segment 2 with 13 setae; exopod 8-segmented with 0–0, 0–1, 1, 1, 1, 1, 1 and 3 setae.

Mandible (Fig. 6B), gnathobase cutting edge with reduced teeth; exopod of five segments with 1, 1, 1, 1 and 2 setae; endopod segment 1 with 2 setae, endopod segment 2 with 9 setae; basis with 1 seta.

Maxillule (Fig. 6C), praecoxal arthrite with 7 terminal setae; coxal endite with 3 setae, coxal epipodite without setae; proximal basal endite with 2 setae, distal basal endite with 3 setae; endopod with 11 setae, exopod with 9–10 setae, all setae rudimentary.

Maxilla (Fig. 6D), praecoxal endite bearing 3 setae, coxal (former considered as distal praecoxal endite) with 3 setae; basal endites (considered as coxal endites) with 3 setae each; lobe of proximal endopodal segment (considered as proximal basal endite) with 3 setae. Endopod with 4 setae.

Maxilliped (Fig. 6E), syncoxa without setae on proximal praecoxal and middle endites, and 1 reduced seta on distal praecoxal endite (marked by arrow on Fig. 6E), coxal endite with 1 seta. Basis with 3 medial setae plus 2 setae distally of incorporated endopod segment 1; endopod of five free segments with 4, 2, 2, 1+1 and 4 setae (of them 2 rudimetrary).

P1 to P4 as in female.

P5 (Fig. 5A, E, I, J) uniramous, nearly as long as urososme. Right leg protopod of coxo- and basipod nearly completely fused, exopod 2-segmented. Left leg longer than right, with protopod nearly twice as long as left; exopod 3-segmented, terminal segment with spine and lateral spinules.

***Pseudocalanus minutus* (Krøyer, 1845)**
(Figs 7–9)

Description. *Adult female*. Total length 1.29–1.85 mm; prosome 2.20–2.72 times as long as urosome. Rostrum (Figs 7, 8A) as 2 filaments. Cephalosome and pediger 1, and pedigers 4 and 5 fused; posterior corners as rounded lobes (Figs 7, 8G–J). Posteroventral margins of pedigers 2 and 3 in lateral view usually with long spiniform processes rarely of small size or reduced (marked by arrow on Fig. 8B–F). Genital double-somite symmetrical, spermathecae well visible in lateral view (Fig. 8J). Caudal rami (Fig. 8G) with four terminal plus one small dorsolateral and one small ventral setae each.

Antennule reaching to about urosomal somites 3–4, of 24 free segments; armature as in *P. acuspes*.

Antenna, mandible, maxillule, maxilla, maxilliped and swimming legs P1–P3 as in *P. acuspes*.

Coxo- to basipod P4 length ratio is > 1.5 (1.51–1.86).

Adult male. Total length 1.25–1.30 mm, prosome 2.20 times as long as urosome. Rostrum (Fig. 9B) as in female. Cephalosome and pediger 1, and pedigers 4 and 5 fused; posterior corners as rounded lobes (Fig. 9C). Caudal rami (Fig. 9C–D) with 4 terminal plus one small dorsolateral and ventral setae.

Antennule reaching to the middle of urosomal somite 3, right and left symmetrical, of 23 segments, armature as follows: I – 1s + 1?, II–IV – 6s + 2ae, V – 2s + 1ae, VI – 2s + 1ae, VII – 1s + 2ae, VIII – 1s + 1ae, IX – 2s + 2ae; X–XI – 2s + 2ae (fused) +2?, XII – 0, XIII – 1?; XIV – 2s (segments XII, XIII and XIV fused), XV – 1?, XVI – 2s + 1ae (1 seta curved), XVII – 1s + 1ae, XVIII – 1s + 1ae, XIX – 1?, XX – 1?, XXI – 1s, XXII –XXIII – 1s, XXIV – 2s + 1ae, XXV– 2s, XXVI–XXVIII –broken.

Antenna as in *P. acuspes*.

Mandible, seta on the basis not observed, in other details identical to *P. acuspes*.

Maxillule, coxal endite with 1 seta, in other details identical to *P. acuspes*.

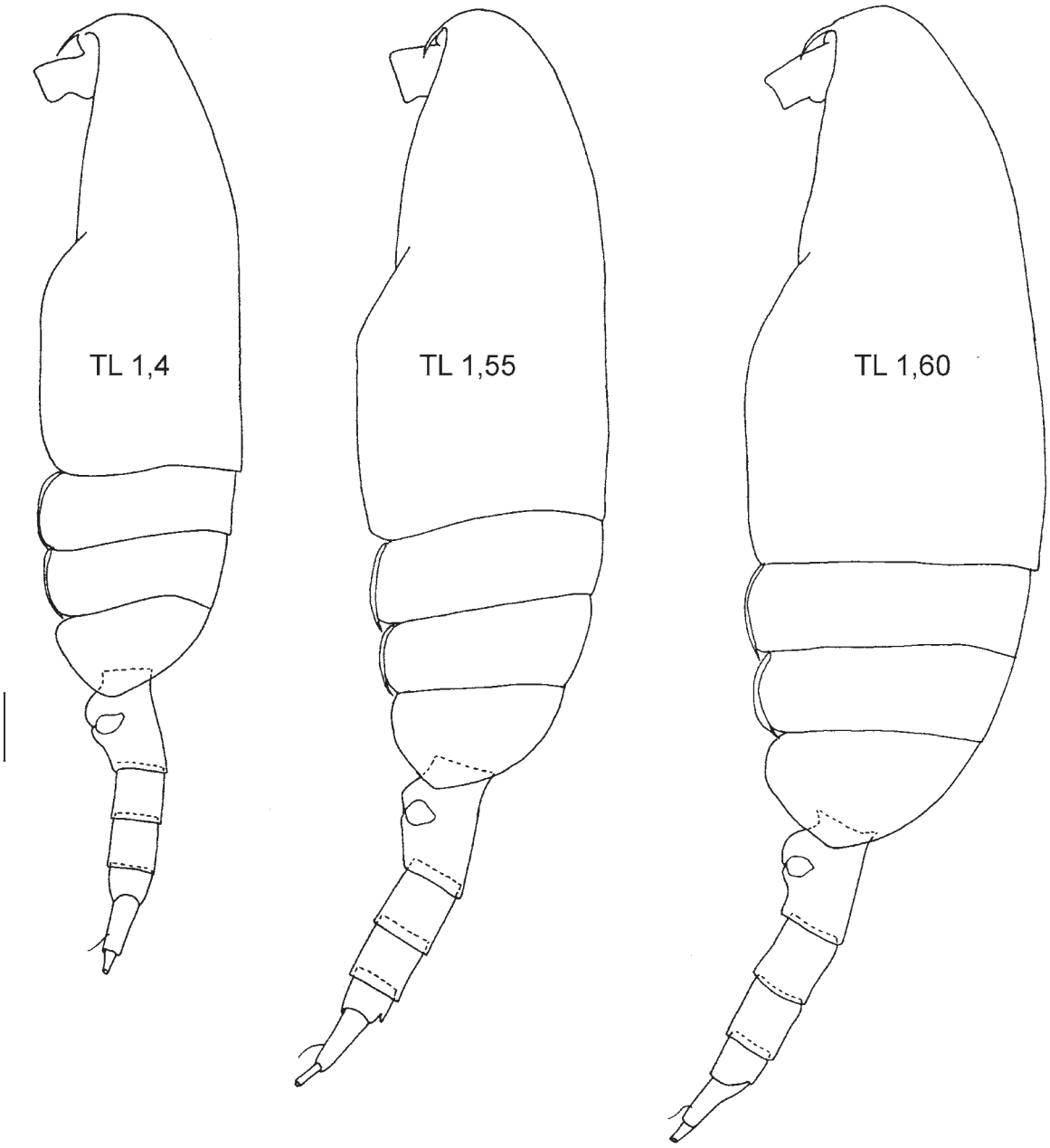

Fig. 7. *Pseudocalanus minutus* (Krøyer, 1845), female: habitus, lateral. *Scale bar*: 0.1 mm.

Maxilla, lobe of proximal endopodal segment (considered as proximal basal endite) with 2 setae; endopod with 5 setae, in other details identical to *P. acuspes*.

Maxilliped (Fig. 9E), syncoxa with 1 seta on proximal praecoxal endite, 1 seta on middle endite, in other details identical to *P. acuspes*.

P1 to P4 as in females.

P5 (Fig. 9C), as in *P. acuspes*.

DISCUSSION

Based on morphological analysis of adult females and males of *Pseudocalanus*, two species, *P. minutus*

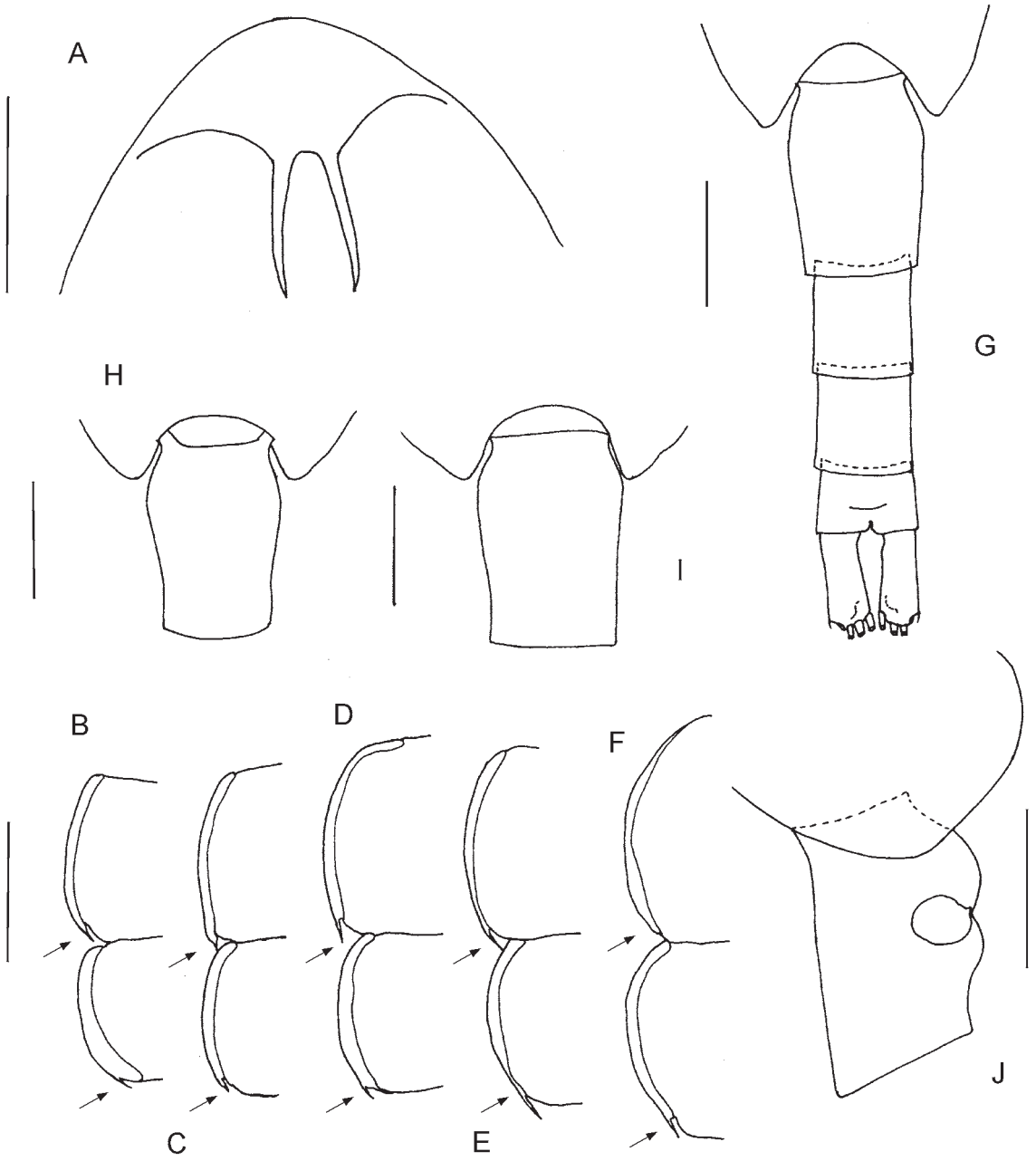

Fig. 8. *Pseudocalanus minutus* (Krøyer, 1845), female: A – rostrum, ventral; B – F postero-ventral margins of pedigers 2 and 3, arrows mark spiniform processes; G – posterior prosome and urosome, dorsal; H–I, – posterior prosome and genital double somite, dorsal; J – posterior prosome and genital double-somite, lateral. *Scale bar*: 0.1 mm.

and *P. acuspes* coexist in the Chupa Inlet of the White Sea. This is the first documented report of *P. acuspes* in the White Sea. A key character to distinguish adults of *P. minutus* from *P. acuspes* is the length ratio of coxo- to basipod P4 length (Frost 1989: 529), which is > 1.5 in *P. minutus* and < 1.5 in *P. acuspes* (Figs 2K, 4D). This character is diagnostic and can be well applied to distinguish between *P. acuspes* and

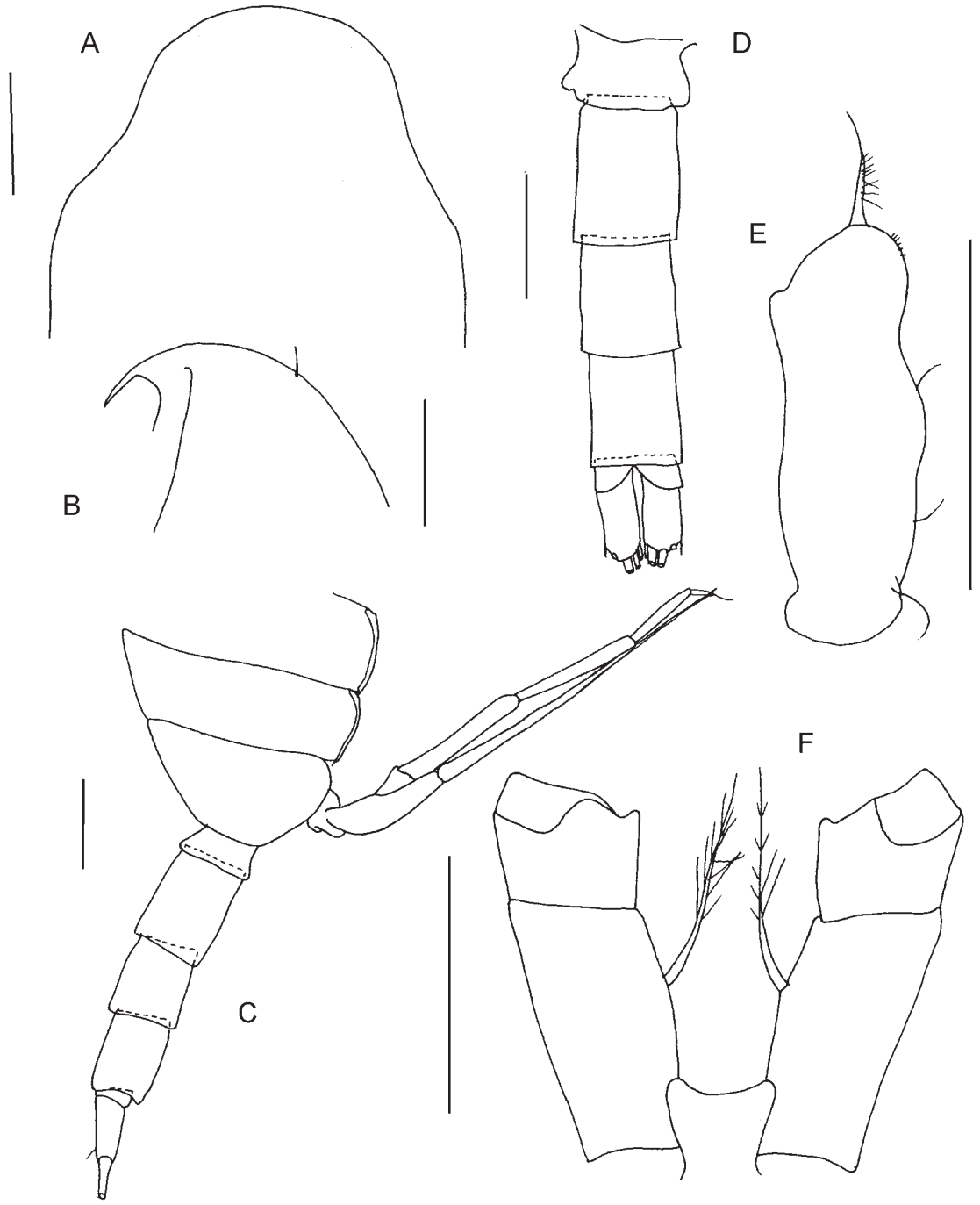

Fig. 9. *Pseudocalanus minutus* (Krøyer, 1845), male: A – cephalon, dorsal; B – cephalon and rostrum, lateral; C – pedigers 2–5, urosome and P5, lateral; D – urosome, dorsal; E – maxilliped syncoxa; F – P4 coxo- and basipod (protopod). *Scale bar*: 0.1 mm.

P. minutus in the White Sea. Some other characters, mentioned by Frost (1989: 530, 537), can be helpful in identification, but for the case of the White Sea *Pseudocalanus* populations have been considered just additional to key character, because they vary and, sometimes, overlap. These are the following characters: 1) in *P. acuspes* cephalosome in lateral view is flat anterior of rostrum (Fig. 1), than protruding and angular in *P. minutus* (Fig. 7); 2) spiniform processes on the postero-ventral margins of pedigers 2 and 3 usually smaller in size (if not reduced) in *P. acuspes* (Fig. 2C–F) compared to *P. minutus* (Fig. 8B, D–E); however, spiniform processes can be also small, or absent in *P. minutus* (Fig. 8C, F); 3) in *P. acuspes* females urosome tend to be longer, relative to prosome (prosome to urosome ratio is 2.06–2.30) than in females of *P. minutus* (2.20–2.72); and 4) in some female specimens of *P. acuspes* lateral swellings of the genital double somite (dorsal view, Fig. 2G) look more pronounced, than in *P. minutus* (Fig. 8H–I).

These differences for males are: 1) in *P. acuspes* seta on mandible basis present (not observed *P. minutus*); 2) in *P. acuspes* maxillule coxal endite with three setae (one seta in *P. minutus*); 3) in *P. acuspes* maxillae lobe of proximal endopodal segment (considered as proximal basal endite) with three and endopod with four setae (two and five setae respectively in *P. minutus*); 4) in *P. acuspes* maxilliped syncoxa without setae on proximal and middle praecoxal endites, (one seta on each of endites in *P. minutus*).

Given the evidence for coexistence of two species of *Pseudocalanus* in the White Sea, the life cycles and seasonal patterns of abundance of *Pseudocalanus* should be reexamined. Combination of morphological and molecular studies could be useful for this purpose.

Recently molecular method was applied to verify the identification of *P. acuspes* and *P. minutus* from Svalbard waters (Guðmundsdottir 2008) and to confirm *P. acuspes* as the single species present in the Baltic Sea (Holmborn et al. 2011). The further study of *P. acuspes* and *P. minutus* inter- and intraspecific variability from the different localities of their distributional range supported by the molecular research can be considered necessary.

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