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ON SPECIES OF THE GENUS *THERMOCYCLOPS* (COPEPODA: CYCLOPIDAE) OCCURRING IN NORTHERN QUEENSLAND, AUSTRALIA

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Abstract.— The paper reports on the occurrence of five *Thermocyclops* species in urban subterranean habitats in North Queensland, Australia: *T. crucis* **sp. nov.**, *T. pseudoperculifer* **sp. nov.**, *T. rylovi* (Smirnov), *T. crassus* (Fischer), and *T. decipiens* (Kiefer). Females and males of *T. operculifer* (Kiefer), a supposedly close relative of the Australian taxon *T. pseudoperculifer*, is redescribed based on the holotype (Lombok) and non-type material (Sulawesi) from Indonesia. *Thermocyclops crucis* **sp. nov.** and *T. pseudoperculifer* **sp. nov.** (tropical coast of Queensland) share the caudally spinulose ornamentation of P2–P4 couplers and bare P1 coupler with *T. operculifer* (Indonesia: Lombok, Sulawesi) and *T. uenoi* (Japan: Kyushu, Tomogashima Island). Diagnostic values of the morphological characters used to define the '*schmeili*-group' sensu Mirabdullayev and Fiers, to which both new Australian taxa might be allocated, are discussed. Finding of *T. rylovi* known so far from East Africa, Central and South Asia, in a semiarid inland locality in Queensland, is the first record of the species in Australia. Descriptions and illustrations of the diagnostic characters of *T. crassus* and *T. decipiens* are provided, and the morphology of the Australian specimens is compared with that in the European and Southeast Asian representatives. An identification key to all *Thermocyclops* species occurring in Australia is added.

Key words.— Copepoda, Cyclopidae, *Thermocyclops*, taxonomy, *operculifer*-group, Australia.

INTRODUCTION

In 1997–2000, B. H. Kay and his colleagues (Queensland Institute of Medical Research and University of Queensland Tropical Health Program, Brisbane) investigated the application of predator cyclopids (*Mesocyclops*) in the biological control of disease-bearing *Aedes* and *Ochlerotatus* in urban pipeline systems where mosquitoes may find refuge in cool and dry periods (Kay *et al.* 2000, 2002). As a result of the extensive sampling that included a survey for copepods in subterranean urban habitats on the tropical coast and semiarid inland region of North Queensland, a few interesting cyclopid taxa, new for science or the fauna of Australia, have been discovered (Hołyńska and Brown 2003). The *Thermocyclops* species here described were also found during this project.

The genus *Thermocyclops* comprises 52 known (sub)species (Mirabdullayev *et al.* 2003, Silva and Matsumura-Tundisi 2005). In the latest monograph of the World fauna, Mirabdullayev *et al.* (2003) pointed to some widely distributed taxa (e.g., *T. tenuis*, *T. inopinus*, *T. crassus*, *T. schmeili*, *T. oblongatus*), which probably are complexes of species with more restricted distribution. In about $^1/_4$ of *Thermocyclops* taxa the available descriptions are old and incomplete, data on the morphology of the cephalothoracic appendages and surface ornamentation of the natatory legs, other than

leg 4, are missing or incorrect. A series of redescriptional papers (Mirabdullayev and Fiers 2001, Mirabdullayev and Ueda 2001, Mirabdullayev 2006), on poorly known Asian representatives of the genus, recently started filling up these gaps. Significant increase in the number of species can be expected as morphological criteria used for delimitation of the taxa will be extended to microcharacters of the antennule, mouthparts, and natatory legs. Baribwegure and Dumont (1999, 2003) and Baribwegure *et al.* (2001) compared the integumental pore signature in 8 African and 1 Palaearctic *Thermocyclops* species. Although this approach is distinguished by the relatively large number of characters available for phylogenetic analysis, the low number of the taxa (8) where the pore pattern is fully mapped sets limit to interpretation of these data for the moment. The genus is known as one of the most common and important components of the lake plankton in the tropical and temperate belts, yet many of the species successful in large lakes are actually eurytopic (Reid 1989), and several others, like members of the *schmeili*-group sensu Mirabdullayev and Fiers (2001), seem to be benthic and occur in small ponds, puddles, wells, caves, shallow lakes and ricefields.

Knowledge of the Australian cyclopids is still fragmentary. Recent investigations concentrate on the western and southern parts, the northern and eastern tropical region have received less attention (Holyńska and Brown 2003, Morton 1985, 1990, Tait *et al.* 1984, Timms and Morton 1988). In most cyclopid genera a comprehensive taxonomic revision and rigorous phylogenetic analyses are still lacking, what makes understanding of the history of the Australian fauna very difficult. A recent analysis (Holyńska 2006) of the evolutionary relationships within *Mesocyclops* (a prevailingly tropical group, and supposedly close relative of *Thermocyclops*) suggests multiple invasions of the continent and close interrelationship between the Australian and South and East Asian fauna.

Very little is known of the *Thermocyclops* fauna of Australia, only two species, *T. decipiens* (Kiefer, 1929) and *T. crassus* (Fischer, 1853), have been reported so far (Tait *et al.* 1984, Timms and Morton 1988). Of the 5 *Thermocyclops* species found in urban environment and here described, 2 are new for science and 1 is new for the continent. As Australian representatives of *T. decipiens* and *T. crassus* have never been characterized in detail, and taxonomy of these two widely distributed taxa is not fully understood, both species are described and illustrated in the article. Great resemblance of one of the new Australian species to T. *operculifer* (Kiefer, 1930), which is known from several yet not fully congruent descriptions, made emendation of the diagnosis of this latter taxon necessary too.

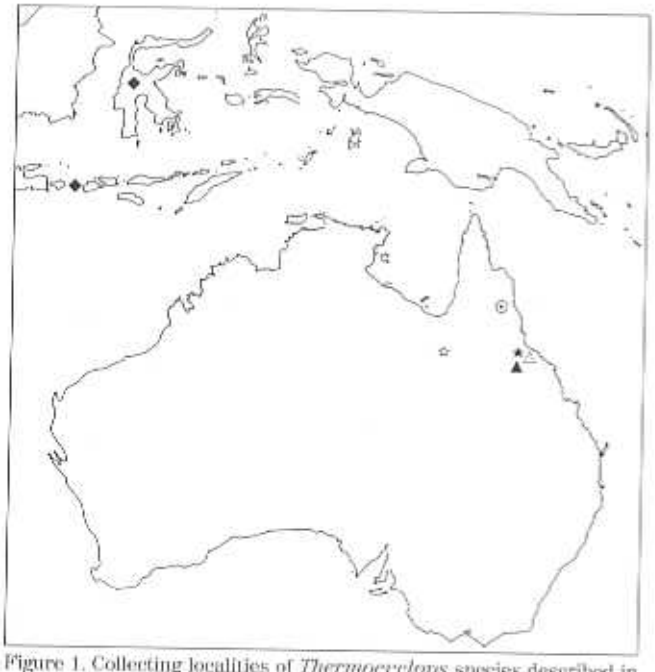

Figure 1. Collecting localities of *Thermocyclops* species described in the paper. ◆ – *T. operculifer*; ⊙ – *T. pseudooperculifer* sp. nov.; ▲ – *T. crucis* sp. nov.; ★ – *T. crassus*; △ – *T. decipiens*; ☆ – *T. rylovi*.

Material and methods

Locality data are given at the descriptions of the particular species and shown also on the map (Fig. 1). Specimens were observed and measured in glycerin, with bright-field and differential interference contrast optics. Drawings were made using a camera lucida attached to an Olympus BX 50 compound microscope. Telescoping body segments were measured separately. The length of pediger 4 was measured as the distance between its anteriormost and posteriormost points. The width of the third endopodal segment of leg 4, the genital double-somite, and the cephalothorax were measured across their widest parts.

Abbreviations: P1–P4 – swimming leg 1 to leg 4; exp – exopodite; enp – endopodite;

SMNK – Staatliches Museum für Naturkunde Karlsruhe;

MIZ – Museum and Institute of Zoology PAS, Warsaw.

Taxonomy

Thermocyclops crucis sp. nov.

Type material. Holotype (♀, T-76, Stagpole/Claude, 30 Jan. 1999, service manhole) and two paratypes (♀♀, T-88, Lara/Albert, 21 Jan. 1998, service manhole) from Townsville (19°16'S, 146°49'E) Queensland, Australia. The holotype and one paratype

are deposited in the Queensland Museum, Brisbane, one paratype (MIZ60426) is placed at the Museum and Institute of Zoology, Warsaw. All specimens are dissected and mounted on two slides each.

Etymology. The species is named after the Southern Cross, the most famous constellation of the Australian starry sky.

Diagnosis (female). *Thermocyclops crucis* differs from its congeners in the following combination of characters: couplers of P1–P4 bearing spiny distal protuberances; couplers caudally spinulose on P2–P4; antennule short, 17-segmented, hyaline membrane on terminal segment proximally not extending beyond implantation of medial seta of segment 17; second endopodal segment of antenna armed with 8 setae; genital double-somite and succeeding two urosomites with transverse ridges; genital double-somite about as long as wide; anal operculum weakly developed; caudal ramus elongate, 4.1–4.7 times as long as wide, medial margin without hairs; medialmost terminal caudal seta short, 1.2–1.3 times as long as lateralmost terminal caudal seta; no spinules at implantation of lateral and lateralmost terminal caudal setae; medial expansion of basipodite of P1 with proximal spinules and distal hairs, those on P2–P4 with spinules; medial spine of P1 basipodite not reaching distal margin of second endopodal segment, without longer setules on proximal half; apical spines of P4enp3 subequal.

Description. Female. Body slender (Fig. 3A), length 765–950 µm (765 µm in holotype); cephalothorax width/genital double-somite width: 2.3–2.4.

Pediger 5 (Figs 5D, 6D) with tiny spinules on laterodorsal surface, two medial and two posteriolateral hair-sensilla on dorsal surface; posteriolateral angle slightly protruding. Dorsally open pseudosomite present between pediger 5 and genital double-somite. Genital double-somite (Fig. 5C) about as long as wide, ornamented with ridges formed by confluent cuticular pits. Ridges transverse and parallel on posterior part of genital double-somite and succeeding two urosomites, yet medially ascendant in region of seminal receptacle. Lateral arms of seminal receptacle wide and short, slightly curving backward. Posterior margin of anal somite with few (5–5 in holotype) robust spinules on ventral surface, and with fine medial spinules on dorsal surface (Fig. 6E). Anal operculum (Fig. 6E) weakly developed, without teeth. Caudal ramus (Fig. 6E) 4.1–4.7 (4.1 in holotype) times as long as wide, without hairs on medial margin. No spinules at implantation of lateral and lateralmost terminal caudal setae. Relative length of terminal caudal setae from medialmost to lateralmost: 1.2–1.3; 4.5–4.8; 4.0–4.2; 1.0. Dorsal caudal seta (Fig. 6E) shorter than lateralmost terminal seta; tip of inner median terminal caudal seta straight, seta 0.6–0.8 (0.78 in holotype) times as long as urosome (Fig. 3A).

Antennule 17-segmented (Fig. 3B, C), reaching posterior margin of cephalothorax to middle of pediger 2. In holotype, articulation between segments 5 and 6 incomplete, suture line missing on anterior surface. Armature formula as common in genus: 8, 4, 2, 6, 4, 1+spine, 2, 1, 1, 0, 1, 1+aesthetasc, 0, 1, 2, 2+aesthetasc, 7+aesthetasc. Last two antennular segments (Fig. 3C) bearing hyaline membrane, that on segment 17 extending only to implantation of medial seta, without notch. Aesthetases on segments 12 and 16 reaching distal margin of segment 14 and 17, respectively. Lateral (shorter) seta on segment 15 relatively long (Fig. 3C), reaching well beyond half of segment 16. Antennule adorned with cuticular pits on posterior surface, and spinules on anterior surface of first segment.

Antenna (Fig. 3D) armed with 3 setae on coxobasis and 1, 8, 7 setae on endopodal segments 1–3, respectively. Exopodite seta reaching beyond distal margin of third endopodal segment. Caudal ornamentation of coxobasis (Fig. 3D) complex, composed of transverse row of tiny spinules along suture line between basipodite and coxopodite, long spinules on lateral margin near base, group next to former spinules, tiny spinules arranged in wavy line proximally to longitudinal row of longer spinules, field of tiny spinules near implantation of medial setae, oblique field proximally to former group, and few small spinules on medial margin near base. Short oblique row about half of segment next to medial margin sometimes present. Spinule pattern on frontal surface of coxobasis (Fig. 4D) composed of few long spinules arranged in row or group in proximal half of segment near lateral margin, and transverse row of tiny spinules proximal to former group.

Lateral protuberances of labrum with small teeth (Fig. 4F). Paragnath (Fig. 4F) with 4 large dorsal teeth (setae) perpendicular to paragnath axis, 2 longitudinal rows of long hairs on ventral surface, those nearer the medial margin shorter, row of dorsal spinules mediodistally, and group of long hairs on mediodistal lobe. Mandible (Fig. 4E) with palp bearing two long and one short setae, no spinule ornamentation near palp. Maxillule (Fig. 4C) with 11 elements on arthrite, palp with 3 apical and 1 proximal setae, lateral lobe of palp with 3 setae; no ornamentation on palp discerned. Maxilla (Fig. 4B) with syncoxopodite (praecoxal-coxal suture present on caudal surface), basipodite and two-segmented endopodite. Armature formula: 5 (syncoxopodite with three endites, 2, 1 and 2 setae each), 2, 2 3. Longitudinal field of small spinules present on frontal surface of coxopodite. Maxilliped (Fig. 4A) with syncoxopodite, basipodite and two-segmented endopodite, armature formula 3, 2, 1, 3. Group of large spinules present on frontal surface of syncoxopodite at height of proximalmost seta. Basipodite and first endopodal segment with long spinules on frontal

surface near medial margin. Caudal spinules on basipodite arranged in 2 groups.

Armature of swimming legs as in Table 1. Medial spine of P1 basipodite (Fig. 5A) spiny and robust reaching 1/3 to 2/3 of second endopodal segment. Medial expansions of P1 basipodite (Fig. 5A) with medial spinules and hairs, those on P2–P4 (Figs 5B, 6A, B) bearing only distal spinules on caudal surface. Group of tiny spinules on caudal surface of medial expansion of basipodite present on P3–P4 (Fig. 6A, B). Couplers of P1–P4 (Figs 5A, B, 6A–C, F, G) bearing semicircular, spiny distal protuberances. P2–P4 couplers spinulose on caudal surface (Figs 5B, 6A, B). In paratype T-88-1 caudal spinules also present on P1, but resctricted to left side of coupler. P3 and P4 couplers bearing spinules also on frontal surface (Fig. 6F, G), P1 coupler frontally spinulose (Fig. 5A) in 2 of 3 specimens [holotype and paratype T-88-1]. Ornamentation of P4 coxopodite varies between specimens (Fig. 6B, C): Oblique row of tiny spinules joining row along distal margin present in holotype, restricted to one side in paratype T-88-2 (MIZ60426), and absent on coxopodites of both sides in paratype T-88-1. Group near medial margin present in paratypes (Fig. 6C), and on coxopodite of right side in holotype. P4 enp3 (Fig. 6B) 2.2–2.4 times as long as wide, terminal spines subequal, medial spine 0.72–0.75 times as long as segment. Segmentation and setation of P5 (Fig. 6D) typical of genus, relative length of medial spine, apical and lateral setae, 1.36:1.04:1.0 (holotype).

Male: unknown.

Comments. For discussion of taxonomical relationships of *T. crucis* see description of *T. pseudoperculifer*.

Thermocyclops operculifer (Kiefer, 1930)

Mesocyclops (Thermocyclops) operculifer Kiefer, 1930: 187–189, Figs 5–10.

Type material. Holotype*: '*Mesocyclops operculifer* ♀ n. sp. Kiefer 10.11.29; Lombok Segare Anak Exp. Rensch': SMNK: 1285 (A1–P4) SMNK: 1286 (urosome), re-mounted in glycerin.

* There is no direct indication on the slides that this specimen was designated by Kiefer as holotype, nevertheless it is the only specimen of *Thermocyclops operculifer* deposited in the Kiefer-Collection (Franke 1989), and its collecting data fully agree with those provided in the original description.

Examined material. Indonesia, Sulawesi, 45 km SSE Palu, Salua village 1°15'S, 119°57'E, R. & M. Holynski 15 May 1989: roadside ditch 'A', 4 ♀♀, 3 ♂♂ (MIZ60427–433); puddles, 1 ♀ (MIZ60434).

Diagnosis, female (emended). Couplers of P1–P4 bearing spiny distal protuberances; caudal surface of P2–P4 couplers spinulose. Antennule 17-segmented, reaching middle to distal margin of pediger 2; hyaline membrane on terminal segment proximally not extending beyond implantation of medial seta of segment 17. Second endopodal segment of antenna armed with 8 or 9 setae. Genital double-somite about as long as wide, with ridges medially ascendant in region of seminal receptacle. Two oval fields of small shallow cuticular pits near copulatory pore. Lateral arms of seminal receptacle elongate, curved backward. Anal operculum strongly developed, semicircular, without teeth. Caudal ramus 3.5–4.1 times as long as wide, without medial hairs. Of terminal caudal setae, medialmost 1.5–1.8 times as long as lateralmost; longest terminal seta 0.8–1.0 times as long as urosome; no spinules at implantation of lateral and lateralmost terminal caudal setae. Medial expansion of basipodites of P1–P3 with apical hairs, that of P4 bearing apical spinules. Medial spine on P1 basipodite not reaching distal margin of second endopodal segment, with longer setules on proximal half. Of apical spines of P4enp3 medial one 1.7–2.1 times as long as lateral.

Redescription. Female. Body length 770–810 µm [holotype ca. 800 µm, measured by Kiefer (1930)]; cephalothorax width/genital double-somite width: 2.2–2.4 (Sulawesi).

Pediger 5 without ornamentation in holotype, tiny lateral spinules present in one (MIZ60429) of four specimens from Sulawesi. Two medial and two posteriolateral hair-sensilla present on dorsal surface; posteriolateral angle acute. Genital double-somite (Fig. 7A, D) as long as wide or slightly shorter. Urosomites ornamented with conspicuous ridges discernible even at low magnification, and scattered cuticular pits. Ridges transverse and parallel on posterior part of genital double-somite and succeeding two urosomites, but medially ascendant in region of seminal receptacle. Small shallow cuticular pits arranged in two oval fields near copulatory pore (Fig. 7A, D). Lateral arms of seminal receptacle (Fig. 7D) elongate, curved backward. Posterior margin of anal somite with many large spinules on ventral surface (Fig. 7C), and with fine medial spinules on dorsal surface (Fig. 7B, E). Anal operculum (Fig. 7B, E) strongly developed, semicircular, and without teeth.

Table 1. Armature of leg 1–4 in *Thermocyclops crucis* sp. nov. Spines are denoted by Roman, setae by Arabic numerals. The armature on the lateral margin of any segment is given first, followed by the elements on the apical and medial margins.

	Coxa	Basis	Exopodite	Endopodite
Leg 1	0-1	1-I	I-1; I-1; I-I,2-2	0-1; 0-2; 1-I,1-3
Leg 2	0-1	1-0	I-1; I-1; II-I,1-3	0-1; 0-2; 1-I,1-3
Leg 3	0-1	1-0	I-1; I-1; II-I,1-3	0-1; 0-2; 1-I,1-3
Leg 4	0-1	1-0	I-1; I-1; II-I,1-3	0-1; 0-2; 1-II-2

Caudal ramus (Fig. 7E) 3.5–4.1 times as long as wide (Sulawesi), without hairs on medial margin. As a result of long-term conservation, rami somewhat flattened in the holotype; in the original description the length/ width proportion is referred to as 'more than 3'. No spinules at implantation of lateral and lateralmost terminal caudal setae. Relative length of terminal caudal setae from medialmost to lateralmost: 1.5–1.8; 5.3–6.6; 4.5–5.0; 1.0 [1.5, 5.3, 4.5; 1.0 in holotype]. Dorsal and lateralmost terminal seta subequal (Fig. 7C, E), tip of longest (inner median) terminal caudal seta (Fig. 7A) straight, seta 0.8–1.0 times as long as urosome.

Antennule (Fig. 8A–D) 17-segmented, reaching middle to distal margin of pediger 2. Armature as in *T. crucis*. Two terminal segments (Fig. 8D) with hyaline membrane, membrane on segment 17 proximally not extending beyond implantation of medial seta, without notch. Aesthetases on segments 12 and 16 reaching distal margin of segment 14 and 17, respectively (Fig. 8C, D). Lateral seta on segment 15 (Fig. 8D) relatively long, reaching beyond middle of segment 16. Antennule adorned with cuticular pits on posterior surface, and spinules on anterior surface of segment 1. Antenna armed with 3 setae on coxobasis and 1, 8 or 9, and 7 setae on endopodal segments 1–3, respectively (verified on specimens from Sulawesi). Setae are missing on the second endopodal segment of the holotype; from position of the setae present and trace of insertion of the lost setae, 9-setae state can be inferred. Exopodite seta reaching beyond distal margin of terminal endopodal segment. Caudal ornamentation of coxobasis (Fig. 9D) similar to *T. crucis*, yet spinules in group next to lateral spinules near base long (Figs 8E, 9D, arrowed), and additional group of tiny spinules present at height of exopodite seta. On frontal surface (Fig. 8E), long spinules arranged in group or row in proximal half of segment near lateral margin, and proximally to former group transverse row of spinules present. Transverse row of fine spinules along presumed border of coxo- and basipodite of compound segment; spinules also present along proximal margin of compound segment.

Lateral protuberances of labrum with teeth (Fig. 9E), distal fringe hairs arranged in group, epistoma except for shallow cuticular pits without ornament. Paragnaths (Fig. 9E) like in *T. crucis*. Mandible with palp bearing 2 long and one short setae (verified in females from Sulawesi), no ornamentation near palp. Maxillule (Sulawesi) (Fig. 9C) with armature common in family, maxillular palp with few small spinules. Maxilla (Fig. 9A) with syncoxopodite, basipodite, and 2-segmented endopodite; armature formula: 5 (syncoxopodite with three endites, 2, 1 and 2 setae, respectively), 2, 2 3. Syncoxopodite adorned with tiny spinules. Maxilliped (Fig. 9B) with syncoxopodite, basipodite and two-segmented endopodite, armature formula 3, 2, 1, 3. Group of large spinules present on frontal surface of syncoxopodite at height of proximalmost seta. Caudal spinules on basipodite arranged in 2 groups.

P1–P4 (Fig. 10A–D) 3-segmented, armature formula as in table 1. Medial spine of P1 basipodite (Fig. 10A) robust, not reaching distal margin of enp2. Few longer setules present on proximal half of spine. Medial expansion of basipodites of P1–P3 with hairs (Fig. 10A–C), those of P4 bearing distal spinules on caudal surface (Fig. 10D). Distal protuberances of P1–P4 couplers (Fig. 10D–G) rounded, spinulose. Couplers frontally bare, caudally with robust spinules on P2–P4, no ornamentation on P1 coupler. Caudal ornamentation of P4 coxopodite (Fig. 10D) composed of: many (18–25) long thin spinules along distal margin, spinules arranged in group or row at laterodistal angle, row of many small spinules near proximal margin, and groups of tiny spinules in lateral part of segment. P4 enp3 (Fig. 10D) 2.1–2.5 [2.1 in holotype] times as long as wide, of apical spines medial one 1.7–2.1 times as long as lateral; medial spine ca. as long as segment. Segmentation and setation of P5 (Fig. 7D) typical of genus; relative length of medial spine, apical and lateral setae: 1.5–2.0; 1.0–1.4, 1.0.

Male (Sulawesi; only those characters are mentioned, which differ from the corresponding states in female). Body length 590–640 µm. Pediger 5 without ornamentation (Fig. 7F). Wide slit pore (Fig. 7F) present on ventral anterior part of genital somite. Posterior margin of anal somite (Fig. 7G) with continuous row of robust spinules. Caudal ramus (Fig. 7G) 2.9–3.7 times as long as wide, spinules present at implantation of lateralmost terminal caudal setae. Relative length of terminal caudal setae from medialmost to lateralmost: 1.6–1.8; 8.4–9.4; 5.5–6.5; 1.0. Tip of longest terminal caudal seta sometimes curved, seta 1.0–1.2 times as long as urosome. Dorsal caudal seta 1.5–1.7 times as long as lateralmost terminal seta.

Antennule 16-segmented, with compound terminal segment, armature formula: 8+3 aesthetases, 4, 2, 2+aesthetase, 2, 2, 2, 2, 1+spine+aesthetase, 2, 2, 2, 2+aesthetase, 2, 1+aesthetase, [5, 7+aesthetase]. Plate-like structures (1 large on segment 14, and 2 smaller on segment 15) and short conical elements (one on segment 14 and 15 each) at distal geniculation. Second endopodal segment of antenna armed with 6 setae. Caudal ornamentation of P4 coxopodite (Fig. 11D) reduced in comparison to that in female: number of spinules in row along distal margin less, spinules on lateral part missing or few. P4enp3 (Fig. 11D) 2.4–2.7 times as long as wide, of apical spines medial one 1.5–1.7 times as long as lateral, medial spine slightly shorter than segment. Relative length of medial spine, apical and lateral setae of P5 (Fig. 7F): 1.3–1.4, 1.0, 1.0. P6 flaps with spinules in pattern shown in Fig. 7F. Length proportion of P6 setae from medialmost to lateralmost: 0.68–0.76, 0.32–0.39, 1.0.

Comments. For discussion of taxonomical relationships of *T. operculifer* see description of *T. pseudoperculifer*.

Thermocyclops pseudoperculifer sp. nov.

Type material. Holotype (♀) and 1 paratype (♀) collected in Port Douglas (16°28'S, 145°28'E) Queensland, Australia, 4 Mar. 1999, PD-14, Nautilus/Mitre St. service manhole. Holotype is deposited in Queensland Museum, Brisbane, paratype (MIZ60435) is placed at Museum and Institute of Zoology, Warsaw. Types are dissected and mounted on two slides each.

Etymology. Specific name refers to the resemblance of the species to *Thermocyclops operculifer*.

Diagnosis (female). Couplers of P1–P4 bearing spiny distal protuberances; caudal surface of P2–P4 couplers spinulose. Antennule 17-segmented, reaching middle to distal margin of pediger 2; hyaline membrane on terminal segment proximally not extending beyond implantation of medial seta of segment 17. Second endopodal segment of antenna armed with 8 or 9 setae. Genital double-somite about as long as wide, with fine hardly discernible transverse ridges. Two oval fields of small cuticular pits absent near copulatory pore. Lateral arms of seminal receptacle elongate, curved backward. Anal operculum quadrangular, without teeth. Caudal ramus 3.3–3.4 times as long as wide, no medial hairs. Of terminal caudal setae, medialmost 1.1–1.2 times as long as lateralmost; longest terminal seta 0.7 times as long as urosome; no spinules at implantation of lateral and lateralmost terminal caudal setae. Medial expansion of basipodites of P1–P3 with apical hairs, those of P4 bearing tiny apical spinules. Medial spine on P1 basipodite not reaching distal margin of second endopodal segment, with longer setules on proximal half. Of apical spines of P4enp3 medial one 1.4 times as long as lateral.

Description. Female. Body length 860–910 μm; cephalothorax width/genital double-somite width: 2.4.

Pediger 5 (Fig. 12D, E) without lateral hairs or spinules; two medial and two posteriolateral hair-sensilla present on dorsal surface, posteriolateral angle acute. Genital double-somite (Fig. 12E) as long as wide. Transverse ridges on genital double-somite and succeeding two urosomites hardly discernible. Oval fields of cuticular pits absent near copulatory pore. Lateral arms of seminal receptacle elongate, curved backward. Ventral posterior margin of anal somite with intermittent row of spinules, medial spinules (7) larger than more lateral ones (8 or 9). Spinules fine and small on dorsal surface, and absent laterally (Fig. 12C). Anal operculum (Fig. 12C) not so strongly developed as in *T. operculifer*, quadrangular, without teeth. Caudal ramus (Fig. 12B, C) 3.3–3.4 times as long as wide, without hairs on medial margin. No spinules at implantation of lateral and lateralmost terminal caudal setae. Relative length of terminal caudal setae from medialmost to lateralmost: 1.1–1.2; 4.7–4.8; 3.8–3.9, 1.0. Dorsal caudal seta about 0.8 times as long as lateralmost terminal caudal seta; tip of longest (inner median) terminal caudal seta straight (holotype) or slightly curved (paratype), seta 0.7 times as long as urosome.

Antennule 17-segmented, reaching middle to distal margin of pediger 2. Armature as in *T. crucis*. Segments 16–17 (Fig. 13B) with hyaline membrane, membrane on segment 17 proximally not extending beyond implantation of medial seta, without notch. Aesthetasc on segment 12 reaching distal margin of segment 14, aesthetasc on segment 16 (Fig. 13B) extending to distal margin of segment 17 or slightly shorter. Lateral seta on segment 15 (Fig. 13B) reaching beyond middle of segment 16. Antennule adorned with cuticular pits on posterior surface of more proximal segments (1, 2, 4, 5) and spinules on anterior surface of segment 1. Antenna armed with 3 setae on coxobasis and 1, 8 or 9 (9 in holotype), and 7 setae on endopodal segments 1–3, respectively. Number of setae on second endopodal segment differs on the antennae of left and right side in paratype. Exopodite seta reaching beyond distal margin of terminal endopodal segment. Caudal ornamentation of coxobasis similar to that of *T. operculifer*, but spinules in group next to lateral spinules near base smaller (Fig. 13A, arrowed). Tiny spinules at height of exopodite seta present in holotype, but probably absent in paratype (Fig. 13A). Frontal surface of coxobasis (Fig. 13D) bearing group of long spinules near lateral margin, small spinules proximally to former group, and transverse row of fine spinules; spinules also present along proximal margin of compound segment.

Lateral protuberances of labrum with teeth (Fig. 13C). Except for long distal fringe hairs arranged in two groups, and 2–3 medial teeth in between, no other ornamentation on ventral surface of labrum, epistoma bare. Structure of paragnaths as in *T. crucis*. Mandible (Fig. 14A) with palp bearing two long and one short setae, no ornamentation near palp. Setation of maxillule (Fig. 13E) as in *T. crucis*, maxillular palp with tiny spinules. Maxilla (Fig. 14C) with syncoxopodite (articulation between precoxopodite and coxopodite retained on caudal surface), basipodite, and 2-segmented endopodite; armature formula: 5 (syncoxopodite with three endites, 2, 1 and 2 setae, respectively), 2, 2 3. Frontal surface ornamentation of syncoxopodite could not be verified. Maxilliped (Fig. 14B) with syncoxopodite, basipodite and two-segmented endopodite, armature formula 3, 2, 1, 3. Group of large spinules present on frontal surface of syncoxopodite at height of proximalmost seta. Caudal spinules on basipodite arranged in 2 groups.

P1–P4 3-segmented, armature formula as in table 1. Medial spine of P1 (Fig. 14D) basipodite robust, not reaching distal margin of enp2. Few longer setules present on proximal half of spine. Medial expansion of basipodites of P1–P3 with hairs, those of P4 (Fig. 14E) bearing tiny distal spinules on caudal surface. Distal protuberances of P1–P4 couplers rounded, spinulose. Couplers frontally bare, caudally with robust spinules on P2–P4, no ornamentation on P1 coupler. P4 coxopodite (Fig. 14E) caudally adorned with many (18–20) spinules along distal margin, oblique row at laterodistal angle, and row of tiny spinules near proximal margin; no spinules in lateral part. P4enp3 (Fig. 14E) 2.3–2.4 times as long as wide, of apical spines medial one 1.4 times as long as lateral, medial spine ca. 0.9 times as long as segment. Segmentation and setation of P5 (Fig. 12E) typical of genus; relative length of medial spine, apical and lateral setae (holotype): 1.4:1.3:1.0.

Comments. Mirabdullayev and Fiers (2001) delimited a large species group, often referred to as '*schmeili*-group', by the spinulose ornamentation of P4 coupler, short genital double-somite, relatively small difference in the length of the medial and lateral apical spines of P4enp3 (medial/lateral < 2), and the relatively short medialmost terminal caudal seta. The group so defined, included taxa from Africa and Madagascar [*T. schmeili* (Poppe et Mrázek), *T. ouadanei* Van de Velde, *T. hastatus* Kiefer, *T. vizarae* (Fryer), *T. crenulatus* Brehm], Western Asia [*T. tinctus* Lindberg], South and East Asia [*T. marmagoensis* (Sewell), *T. conspicuus* (Lindberg), *T. orientalis* Dussart and Fernando, *T. ianthinus* (Harada), *T. kawamurai* (Kikuchi), *T. uenoi* Itô], the Indo-West Pacific region [*T. operculifer* (Kiefer), *T. philippinensis* (Marsh)], and one European species from a cave in Jugoslavia [*T. dalmaticus* Petkovski]. *Thermocyclops dumonti*, described by Baribwegure and Mirabdullayev from southern China (Yunnan) in 2003, has been affiliated to this group as well. Both new species, *T. crucis* and *T. pseudoperculifer*, show the character combination diagnostic of the '*schmeili*-group', yet their relationships to other taxa still remain problematic. A monograph recently published on the World fauna (Mirabdullayev *et al.* 2003) has greatly improved our understanding of the taxonomy of the genus, nevertheless recognition of natural groups is still hampered by the incomplete descriptions of many *Thermocyclops* taxa.

There are also problems with the group criteria proposed by Mirabdullayev and Fiers (2001). Not all species listed above have the whole set of the distinguishing characters of the *schmeili*-group: P4 coupler is pilose in *T. schmeili* and *T. crenulatus*, and bare in *T. dalmaticus* and *T. vizarae* (Mirabdullayev *et al.* 2003, Hołyńska 2006). On the other hand, *T. antillensis* Herbst [Antilles], showing also 3 of 4 features of the *schmeili*-group, was not mentioned by the authors as a member of the group. Frequent occurrence of the short medialmost (inner) terminal caudal seta (char. A) and slight difference in the length of the apical spines of P4enp3 (char. B) among species that do not belong to the '*schmeili*-group' and highly differ in both zoogeographic distribution and morphology, may indicate that both characters are ancestral in *Thermocyclops*. [**char. A** present in: *T. hooki* Löffler – Kenya, *T. parvus* Reid – Florida, *T. minutus* (Lowndes) – South America, *T. inopinus* (Kiefer) – Africa, *T. dybowskii* (Landé) – Palearctics, *T. pachysetosus* Lindberg – Africa, *T. consimilis* (Kiefer) – Africa; **char. B** present in: *T. trichophorus* (Kiefer) – Java, *T. hooki* – Kenya, *T. inversus* Kiefer – Central and South America, *T. brehmi* (Kiefer) – South America, *T. dybowskii* – Palaearctics]. The short (length equals to width) genital double-somite is not a unique feature of the *schmeili*-group either, this character state is also present in *T. trichophorus*.

The caudal ornamentation of P1–P4 couplers seems to be more helpful in search for the close relatives of the new Australian *Thermocyclops* taxa. From

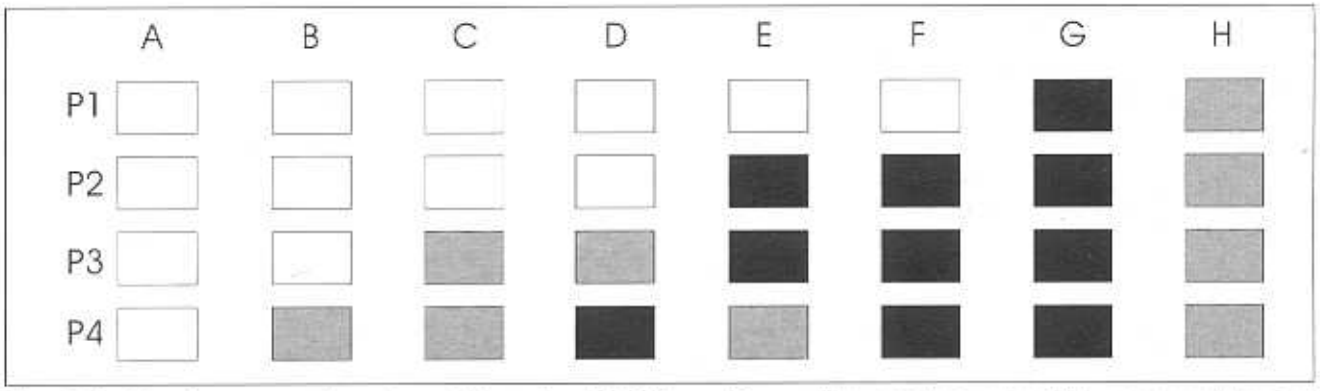

Figure 2. Caudal surface ornamentation patterns of the couplers of P1–P4 observed in some *Thermocyclops* species: white – no ornamentation, grey – hairs present, black – spinules present; P1–P4: natatorial legs 1–4. (A) *T. dybowskii*; (B) *T. crassus*, *T. rylovi* (Australia, Uzbekistan); (C) *T. rylovi* (Uzbekistan); (D) *T. hastatus*, *T. antillensis*; (E) *T. decipiens*; (F) *T. operculifer*-group; (G) *T. tinctus*, *T. kawamurai*; (H) *T. crenulatus*.

distribution of the surface ornamentation characters among the serially homologous structures in *Mesocyclops*, it could be inferred that presence of hairs/spinules on the homologous segments of particular legs are not independent traits, they together constitute a unit (Holyńska 2006): if, for instance, P2 coupler is ornamented, the couplers of P3 and P4 are ornamented too. This same holds in *Thermocyclops* (Fig. 2) as long as presence of ornamentation of any kind on P1–P4 couplers, disregarding its appearance (hairs or spinules), is concerned. As to the types of the ornamentation, their patterns on the legs observed in different *Thermocyclops* species (Fig. 2) indicate that there are only two blocks, P4 and P1–P3, whose ornamentation (hairs or spinules) are independent from each other: if spinules or hairs appear on P1 coupler, couplers of P2 and P3 are spinulose or hairy too; yet when P3 coupler is spinulose, P4 coupler can be either spinulose or pilose. A smaller group, comprising *T. crucis*, *T. pseudoperculifer*, *T. operculifer* (Lombok, Sulawesi) and *T. uenoi* (Japan: Kyushu, Tomogashima Island) are defined here by three characters: (1) caudal surface ornamentation present on P2–P4 and absent on P1 coupler; (2) ornamentation of P2–P3 couplers spinulose; and (3) ornamentation of P4 coupler spinulose too. The *operculifer*-group may also include other taxa from the Philippines [*T. philippinensis*], South [*T. conspicuus*, *T. orientalis*] and East Asia [*T. ianthinus*, *T. dumonti*]; all of them have spinulose P4 coupler, but surface ornamentation of the couplers of P1–P3 is still unknown in these species. Outgroup comparisons unfortunately do not help in unambiguous polarization of the character states: couplers (P4) are spinulose in *Megacyclops*, they can be spinulose or pilose in *Dia-* and *Acanthocyclops*, yet hairy ornamentation appears in *Cyclops* and some *Mesocyclops*.

Close relationship between *T. uenoi* and *T. operculifer* has already been referred to by Mirabdullayev and Ueda (2001). *Thermocyclops uenoi* can be distingushed from other members of the *operculifer*-group by the medially pilose caudal ramus. *Thermocyclops crucis* differs in having subequal apical spines on the third endopodal segment of P4, and apical spinules on the medial expansion of P2–P3 basipodites (hairs present on P2–P3 basipodites in *T. uenoi* *T. operculifer* and *T. pseudoperculifer*). *Thermocyclops operculifer* and *T. pseudoperculifer* share the robust medial spine of P1 basipodite with long setules on proximal half. *Thermocyclops pseudoperculifer* differs from *T. operculifer* in: anal operculum is less developed and rectangular (strong and semicircular in *T. operculifer*); transverse ridges on the urosomites are hardly discernible (conspicuous in *T. operculifer*); two oval fields of small shallow cuticular pits near copulatory pore, present in *T. operculifer*, are absent; medialmost and lateralmost terminal caudal setae are subequal (medialmost seta 1.5–1.8 times as long as lateralmost in *T. operculifer*); of the apical spines of P4enp3, medial one is 1.4 times as long as lateral (medial 1.7–2.1 times as long as lateral in *T. operculifer*). '*Thermocyclops operculifer*' from Gilbert Islands (Lindberg 1954), provided that Lindberg's illustrations are correct, differs form both *T. operculifer* and *T. pseudoperculifer* in hairy ornamentation of the medial expansion of the P4 basipodite, and concave lateral rim of the anal operculum. *Thermocyclops operculifer aberrans*, described from the shallow Lake Sap in Cambodia (Lindberg 1952), also has a combination of characters that does not fit those either in *T. operculifer* or in *T. pseudoperculifer* (body length: 650–655 µm; medialmost terminal caudal seta 1.1 times as long as lateralmost seta; longest terminal caudal seta 6.2–6.3 times as long as lateralmost terminal caudal seta; anal operculum semicircular, but not so strongly developed as in *T. operculifer*; medial apical spine on P4enp3 1.6 times as long as lateral spine). Illustrations of *T. operculifer* occurring in Java (Defaye *et al.* 1987) and North Vietnam (Mirabdullayev *et al.* 2003) show forms that resemble *T. pseudoperculifer* rather than *T. operculifer*. The two females of *T. pseudoperculifer* available from Queensland, do not allow to estimate the intraspecific variation of some diagnostic morphometric traits (relative length of the longest terminal caudal seta, body length, length ratio of the apical spines of P4enp3), and further investigations may reveal *T. pseudoperculifer* to be conspecific with *Thermocyclops operculifer aberrans* and the Javanese and Vietnamese forms. Nonetheless, it is better to describe *Thermocyclops* from Port Douglas as a new species in detail, than sink it in the name of a poorly known taxon, *T. operculifer aberrans*.

Thermocyclops rylovi (Smirnov, 1928)

Mesocyclops rylovi Smirnov, 1928: 17–21; Smirnov 1929: 38–42, Figs 1–5; *Mesocyclops* (*Thermocyclops*) *Rylovi*: Kiefer 1929a: 85; *Thermocyclops rylovi*: Kiefer 1978: 213–214, Fig. 92A; Mirabdullayev *et al.* 2003: 269–271, Fig. 127.

Thermocyclops neglectus prolatus Kiefer, 1952: 71, Figs 56, 58, 59, Table VI, XI – synonymized by Mirabdullayev *et al.* 2003.

Material examined. Australia, Queensland, Cloncurry 20°42'S, 140°30'E, CL-64, Scarr/King St., pit, 23 Feb. 1999, 3 ♀♀ (2 ♀♀, MIZ60436–437, dissected; 1 ♀, MIZ60438, in alcohol). Uzbekistan, fishpond near Qarshi 38°45'N 65°40'E, I. Mirabdullayev Jun. 1989, 5 ♀♀, 1 ♂ (MIZ60439–444).

Description. Female (Australia) (Fig. 15A). Body length 830 µm; cephalothorax width/genital double-somite width: 2.5.

Pediger 5 (Fig. 15B–D) with lateral hairs, and small spinules on lateroventral surface. Two medial and two

posteriolateral hair-sensilla, and one median and two anteriolateral pores on dorsal surface. Genital double-somite (Fig. 15G) 1.1–1.2 times as long as wide, with transverse ridges formed by confluent cuticular pits present also on succeeding two urosomites. Lateral arms of seminal receptacle slightly curving backwards. Ventral posterior margin of anal somite (Fig. 15E) with few larger spinules medially and tiny spinules laterally. Spinules fine and small on dorsal surface (Fig. 15F). Anal operculum (Fig. 15F) without teeth. Caudal ramus (Fig. 15E, F) 3.4–3.5 times as long as wide, adorned with spinules, yet no medial hairs. No spinules at implantation of lateral and lateralmost terminal caudal setae. Relative length of terminal caudal setae from medialmost to lateralmost: 2.4; 4.3–4.5; 3.8–3.9, 1.0. Dorsal caudal seta 1.0–1.1 times as long as lateralmost terminal caudal seta; tip of longest terminal caudal seta straight or slightly curved, seta 0.7 times as long as urosome.

Antennule reaching middle of pediger 2, with armature same as in other *Thermocyclops* species described above. Aesthetasc on segment 12 (Fig. 17C) reaching distal $^1/_3$ to distal margin of segment 14, that on segment 16 (Fig. 17G) reaching distal $^1/_3$ of segment 17. Hyaline membrane on terminal segment (Fig. 17G) proximally not extending beyond insertion of medial seta, without notches. Lateral seta on segment 15 (Fig. 17C, G) reaching slightly beyond half of segment 16. Antennule with cuticular pits on posterior surface of more proximal segments (1, 2, 4), and short row of spinules on anterior surface of segment 1. Antenna (Fig. 16A) armed with 3 setae on coxobasis and 1, 9 and 7 setae on endopodal segments 1–3, respectively. Exopodite seta reaching beyond distal margin of terminal endopodal segment. Caudal ornamentation of coxobasis (Fig. 16A): robust spinules in longitudinal and oblique rows near lateral margin; group of tiny spinules between oblique and longitudinal rows (common in *Thermocyclops*), absent here; small spinules near implantation of medial setae; oblique field proximally to insertion of medial setae, next to medial margin; few spinules in row proximal to oblique field; and few spinules on medial margin near base. Frontal surface of coxobasis (Fig. 16C) adorned with 10 spinules arranged in longitudinal row in proximal half of segment near lateral margin, transverse row of tiny spinules proximal to former group; few tiny lateral spinules near insertion of exopodite seta; and short median row near base of segment. Armature of mouthparts (Figs 16D, 17A, B) as in other *Thermocyclops* species described above. No spinule ornamentation near palp of mandible (Fig. 16D). Maxillular palp (Fig. 16D) and frontal surface of maxillar syncoxopodite (Fig. 17A) bearing small spinules. Syncoxopodite of maxilliped (Fig. 17B) with group of large spinules at height of insertion proximalmost seta, small spinules laterally to former group, and tiny spinules distally to insertion of median seta of segment.

Armature of swimming legs as in table 1. Medial spine of P1 (Fig. 18A) basipodite spinulose and reaching distal margin of second endopodal segment. Medial expansion of P1–P3 (Fig. 18A, C, D) basipodite with hairs, those of P4 (Fig. 18B) with distal spinules on caudal surface. P1–P4 couplers (Fig. 18B–E) bearing semicircular, spiny distal protuberances. Low distal protuberances of P4 coupler (Figs 17F, 18B) with few (3–4) conspicuously large teeth. Caudal ornamentation: coupler pilose on P4, and bare on P1–P3; frontal ornamentation: couplers pilose on P1–P2 or P1–P3, and bare on P4. Caudal ornamentation of P4 coxopodite (Fig. 18B) composed of: 9 robust spinules along distal margin, oblique row at laterodistal angle, median row of robust spinules near proximal margin, and transverse rows in proximolateral part of segment. P4enp3 (Fig. 18B) relatively long, 3.0–3.4 times as long as wide, of apical spines medial one 1.7–1.8 times as long as lateral, medial spine ca. 0.9 times as long as segment. Segmentation and setation of P5 (Fig. 15C) typical of genus; relative length of medial spine, apical and lateral setae: 2.5–2.7; 1.7–2.4; 1.0.

Comments. Smirnov described *T. rylovi* from the Caucasus (Tbilisi, Makhachkala) in 1928, yet a later German version (1929) of the original description is most often referred to in the taxonomic literature. Occurrence of this species was reported on from Central Asia (Mirabdullayev and Kuzmetov 1997, Mirabdullayev *et al.* 2003), Iran (Lindberg 1936, 1942), Afghanistan (Lindberg 1959), Pakistan (Defaye *et al.* 1987), India (Lindberg 1935, Defaye *et al.* 1987), and Thailand (Mirabdullayev *et al.* 2003). Mirabdullayev *et al.* (2003) established the synonymy of *T. neglectus prolatus* Kiefer, 1952 with *T. rylovi*, so distributional area of the latter taxon extends as far as East Africa (Uganda, and Ethiopia). The species can be encountered in ponds, puddles, wells, cisterns, and muddy creeks (Lindberg 1942). Numerous observations on the biotopes of *T. rylovi* in Central Asia (Mirabdullayev *et al.* 2003) and Iran (Lindberg 1942) indicate great salinity tolerance of *T. rylovi*, a biological trait shared by many freshwater copepods (Pinder *et al.* 2005) that can facilitate range extension into arid/semiarid regions, and might also be a precondition of living in ephemeral waters. Finding of *T. rylovi* in a relatively dry inland locality in North Queensland is the first record of the species in Australia.

Comparison of the specimens found in Australia and Uzbekistan revealed differences in the features of the distal protuberances of P4 coupler and caudal ornamentation of the antennal coxobasis. The distal protuberances of P4 coupler are lower, bearing few conspicuously large spinules in the Queensland specimens (Figs 17F, 18B *vs.* Fig. 17D, E). Lindberg's

observations on Iranian populations (1942) however showed both the height of the protuberances and number and size of the spinules on the protuberances as intraspecifically highly variable characters. The spinule pattern on caudal surface of the antennal coxobasis in two dissected Queensland females differ from those in the specimens from Uzbekistan in the presence of a group of small spinules near the implantation of medial setae, and in the absence of the tiny spinules between the oblique and longitudinal rows of robust spinules (Fig. 16A *vs.* Fig. 16B, arrowed). Unfortunately no data are available on these characters in other Asian populations of *T. rylovi*. Taking into consideration the morphological plasticity of the species documented in some features, and concordance of other characters in the Australian and Uzbekistan specimens, the differences in the antennal coxobasis ornamentation are assumed here to be non-diagnostic.

Thermocyclops crassus (Fischer, 1853)

Cyclops crassus Fischer, 1853: 92–93, Pl. III Fig. 29; *Mesocyclops crassus*: Sars 1914 [1913–1918]: 61–62, Pl. 37; *Mesocyclops (Thermocyclops) crassus*: Rylov 1948: 305–308, Fig. 77; *Thermocyclops crassus*: Dussart 1969: 210–213, Fig. 108; Mirabdullayev *et al.* 2003: 265–267, Fig. 125.

Material examined. Australia, Queensland, Townsville 19°16'S, 146°49'E, 57 Railway Avenue, service manhole, 9 Feb. 1998, 2 ♀♀ (MIZ60445–446). Indonesia, Borneo, Mahakam Valley, Sebulu 0°17'S, 116° 58'E, swamp along Mahakam River [2/a], M. and R. Hołyński 30 May 1989, 1 ♀ (Author's collection deposited in MIZ). Hungary, Békés County, Szarvas 46°52'N, 20°33'E, Fisheries Research Institute (HAKI), 'Belső Telep' fispond B-6, M. Hołyńska 29 May 1992, 1 ♀ (Author's collection deposited in MIZ). Belgium, Hamme 51°06' N 04°08'E, A. Capart 1945, 1 ♀ (Author's collection deposited in MIZ).

Description. Female (Australia). Body length 850–870 µm; cephalothorax width/genital double-somite width: 2.5–2.7.

Pediger 5 with small lateral spinules. Genital double-somite 1.1–1.2 times as long as wide, without ridges or cuticular pits. Lateral arms of seminal receptacle (Fig. 19D) short and wide, perpendicular to body axis. Ventral posterior margin of anal somite with 5–7 larger spinules medially and tiny spinules laterally. Anal operculum weakly developed, no teeth. Caudal rami short, 2.2–2.3 times as long as wide, without medial hairs. No spinules at implantation of lateral and lateralmost terminal caudal setae. Lateral seta implanted at distal 1/3 of caudal ramus. Medialmost and outer median terminal caudal setae 2.8–3.1 and 3.8–4.1 times as long as lateralmost terminal caudal seta, respectively [longest seta (inner median) broken off].

Antennule 17-segmented, armature formula as in *T. crucis*. Hyaline membrane (Fig. 19A) present on two terminal segments, that on segment 17 proximally extending to implantation of medial seta. Aesthetases (Fig. 19A) on segments 12 and 16 reaching distal margin of segment 14 and 17, respectively. Lateral seta on segment 15 short, not reaching half of segment 16. Segment 1 adorned with cuticular pits posteriorly and proximal row of spinule on anterior surface, no surface ornamentation on other segments. Antenna (Fig. 19B) bearing 3 setae on coxobasis, and 1, 9, 7 setae on endopodal segments 1–3, respectively. Exopod seta reaching beyond third endopodal segment. Caudal ornamentation pattern of coxobasis (Fig. 19B) similar to those in other *Thermocyclops* species, yet spinules very small. With exception of oblique row near base and longitudinal row near lateral margin, other groups hardly discernible. Few tiny lateral spinules near insertion of exopodite seta observed in 1 of 2 females. Segmentation and setation of mouthparts as in other species here described. Mandible without ornamentation near palp, maxillular palp (Fig. 20A) apically spinulose. Frontal surface of maxillar syncoxopodite bare. Syncoxopodite of maxilliped (Fig. 20B) adorned with large spinules at height of insertion of proximalmost seta, and groups of small spinules distally and proximally to large spinules. Spinules on caudal surface of basipodite of maxilliped arranged in 2 groups.

Medial spine of P1 (Fig. 20D) basipodite reaching beyond distal margin of enp2, with few longer setules on proximal half. Field of small spinules present on frontal surface of first endopodal segment of P1, near lateral margin. Medial expansion of basipodites of P1–P4 (Fig. 20D, E) pilose, hairs on P4 (Fig. 20E) shorter than those on other legs. Distal protuberances of P1–P4 couplers (Fig. 20 D, E) rounded and spinulose. P1–P3 couplers bare on frontal and caudal surfaces, P4 coupler pilose on caudal surface and bare frontally. Caudal ornamentation of P4 coxopodite (Fig. 20E) composed of: long thin spinules (14–16) along distal margin, oblique row at laterodistal angle, median row of small spinules near proximal margin, and oblique rows of small spinules in lateral part. P4enp3 2.7–2.9 times as long as wide, of apical spines medial one 1.7–1.8 times as long as lateral, medial spine 0.8–0.9 times as long as segment. Relative length of medial spine, apical and lateral setae of P5: 2.5:2.3:1.0.

Comments. The single difference found in the microcharacters of the females from Queensland, Borneo, Hungary and Belgium, was the presence of distinctly longer spinules on the frontal surface of the first endopodal segment of P1 on the Hungarian specimen (Fig. 20C *vs.* Fig. 20D). These spinules are tiny on the Belgian and Australian females, which suggests the long-spinule state to be an individual or local variant rather than diagnostic feature of a (sub)species. Morphometric

traits of the Queensland specimens are also within the range of the intraspecific variation (Mirabdullayev *et al.* 2003).

Thermocyclops crassus lives in whole Eurasia and is also known from few localities in the northern, tropical part of Australia. Isolated New World records in northeastern U.S.A. (Vermont), Costa Rica, Nicaragua and Mexico (Tabasco) indicate recent introduction of the species (Gutiérrez-Aguirre and Suárez-Morales 2000). In northern Australia it has been reported from Arnhem Land and the tropical coast of Queensland (from Cairns to Townsville region) (Tait *et al.* 1984, Timms and Morton 1988). According to Timms and Morton (1988), *T. crassus* is 'widespread in temperate Australia' and its area reaches as far as southern Australia.

Thermocyclops decipiens (Kiefer, 1929)

Mesocyclops (Thermocyclops) decipiens Kiefer, 1929b: 316, Fig. 12; *Thermocyclops decipiens*: Mirabdullayev *et al.*, 2003: 257, 260, Fig. 121.

Material examined. Australia, Queensland, Townsville 19°16'S, 146°49'E, Abbott St. 31, service manhole, 2 Feb. 1999, 1 ♀ (MIZ60447). Philippines, Luzon, Pugad Lawin, 14°40'S, 121°01'E, Dasma Cavite, C. Reyes 4 Jun. 2002: pond 2, 2 ♀♀ (MIZ60448–449); pond 3, 1 ♀, 1 ♂ (MIZ60450–451). Indonesia, Borneo, Mahakam River, 14 km point, 25 Dec. 1975, Mizuno Coll.: 839, 1 ♀ (MIZ60452); Java, Lake Telagwarna, near Chibodus, 17 Dec, 1975, Mizuno Coll.: 901, 1 ♀ (MIZ60453).

Description. Female (Australia). Body length 970 µm; cephalothorax width/genital double-somite width: 2.8.

Pediger 5 (Fig. 21A) with lateral spinules. Genital double-somite (Fig. 21A) 1.3 times as long as wide. No transverse ridges or cuticular pits on urosomites. Lateral arms of seminal receptacle perpendicular to body axis. Posterior margin of anal somite with 5-5 larger medial spinules on ventral surface, and 4-4 larger medial spinules on dorsal surface. Operculum weakly developed, without teeth. Caudal ramus (Fig. 21A) 2.4 times as long as wide without medial hairs. No spinules at implantation of lateral and lateralmost terminal caudal setae. Lateral seta implanted ca. 64% of length of ramus. Relative length of terminal caudal setae from medialmost to lateralmost: 3.2:4.3:3.7:1.0. Longest (inner median) terminal caudal seta 0.7 times as long as urosome; tip of seta straight (Fig. 21A). Dorsal seta about as long as lateralmost terminal caudal seta.

Antennule 17-segmented, armature formula as in *T. crucis*. Hyaline membrane (Fig. 21C) present on two terminal segments, that on segment 17 proximally extending to implantation of medial seta, no notch. Aesthetase on segment 12 (Fig. 21B) reaching distal margin of segment 14. Aesthetase on segment 16 (Fig. 21C) ending in short thread-like structure, and not reaching half of segment 17. Lateral seta on segment 15 (Fig. 21B) short, not reaching half of succeeding segment. Row of spinules present on anterior surface of first antennular segment. Antenna furnished with 3 setae on coxobasis, 1, 9, and 7 setae on endopodal segment 1–3, respectively. Caudal ornamentation of antennal coxobasis (Fig. 21D): spinules in longitudinal row near lateral margin and oblique row near base, robust; group of spinules present between longitudinal and oblique rows; oblique field of small spinules present proximally to insertion of medial setae. On frontal surface of coxobasis, few spinules (8) arranged in longitudinal row near lateral margin, and transverse row of tiny spinules next to longitudinal row.

Segmentation and armature of mouthparts as in other species here described. Mandible without ornamentation near palp, maxillular palp spinulose. Syncoxopodite of maxilla (Fig. 21E) frontally ornamented with distal triangular field of tiny spinules, and proximal group next to longitudinal crest of praecoxopodite. Syncoxopodite of maxilliped (Fig. 21F) with large spinules at height of insertion of proximalmost seta, and groups of small spinules distally to large spinules. Spinules on caudal surface of maxilliped basipodite arranged in 2 groups.

Medial spine of P1 basipodite (Fig. 22A) reaching distal margin of enp2, without longer setules on proximal half. Medial expansions of basipodites of P1–P3 (Fig. 22 A–C) pilose, those of P4 (Fig. 22D) with small distal spinules on caudal surface. Distal protuberances of P1–P4 couplers (Fig. 22A–D) rounded and spinulose. Protuberances of P4 coupler conspicuously high. P1 coupler caudally bare, yet group of short hairs present on frontal surface. P2–P3 couplers caudally spinulose, and frontally bearing few short hairs on proximal half of couplers. P4 coupler with long hairs on caudal surface, and 1-1 group of spinules on frontal surface. Caudal ornamentation of P4 coxopodite (Fig. 22D) composed of: relatively few (10) robust spinules along distal margin; oblique row at laterodistal angle; oblique median row of small spinules near proximal margin, and tiny spinules proximally to this row; short transverse row in middle length of segment. P4enp3 3.1 times as long as wide, of apical spines medial one 2.5 times as long as lateral, medial spine about as long as segment. Medial spine of P5 longer than apical and lateral setae.

Comments. Mirabdullayev (in Mirabdullayev *et al.* 2003) gave an illustration of the caudal surface ornamentation of the antennal coxobasis in the African (Kinshasa) type specimen of *T. decipiens*. The ornamentation pattern is similar to that found in the female from Townsville, except for the oblique field of spinules below the insertion of the medial setae, which is absent in the type. This group, common in *Thermocyclops*

and also present on the Australian *T. decipiens* female, appears on the antennal coxobasis in the specimens examined from Luzon, Borneo and Java, but the spinules are extremely tiny and very easy to overlook. It is possible, that size reduction might result in full disappearance of this group of spinules in some populations of *T. decipiens*. The single difference observed between the Southeast Asian and Australian females is the peculiar shape of the aesthetasc on segment 16 in the Townsville specimen. In the females from Indonesia and Philippines the aesthetasc is gradually narrowing (seta-like) and longer, reaching distal fourth to distal margin of segment 17. More observation is needed to verify the diagnostic value of this character.

Thermocyclops decipiens is a Pantropical zooplankter, widely distributed in tropical Australia (Tait *et al.* 1984; Timms and Morton 1988).

Key to species of *Thermocyclops* occurring in Australia

T. pseudoperculifer can be easily confounded with *T. operculifer*, therefore, although it has not been reported from Australia yet, *T. operculifer* is also added to the key.

1. Caudal surface of P4 coupler with spinules (Fig. 10D); medialmost terminal caudal seta < 2 times as long as lateralmost terminal caudal seta (Fig. 7E) 2
–. Caudal surface of P4 coupler with hairs (Fig. 17F); medialmost terminal caudal seta >2 times as long as lateralmost terminal caudal seta (Fig. 15F) ... 4
2. Apical spines of P4 enp3 subequal (Fig. 6B); medial expansion of P1 basipodite with medial hairs and spinules (Fig. 5A), those of P2 and P3 basipodites (Figs 5B, 6A) with distal spinules on caudal surface ..... *T. crucis*
–. Of apical spines of P4 enp3 medial spine conspicuously (>1.2) longer than lateral (Fig. 10D); medial expansions of P1–P3 basipodites with distal hairs (Fig. 10A–C) 3
3. Anal operculum strongly developed, semicircular (Fig. 7E): urosomites with distinct tranverse cuticular ridges, two oval fields of small shallow cuticular pits present near copulatory pore (Fig. 7A, D); medialmost terminal caudal seta 1.5–1.8 times as long as lateralmost terminal caudal seta (Fig. 7E); of apical spines of P4enp3, medial one is 1.7–2.1 times as long as lateral (Fig. 10D) .... *T. operculifer*
–. Anal operculum moderately developed, rectangular (Fig. 12C); tranverse cuticular ridges hardly discernible on urosomites, two oval fields of small shallow cuticular pits absent near copulatory pore (Fig. 12A, E); medialmost terminal caudal seta 1.1–1.2 times as long as lateralmost terminal caudal seta (Fig. 12B); of apical spines of P4enp3, medial one is 1.4 times as long as lateral (Fig. 14E) .... *T. pseudoperculifer*
4. Caudal surface of P2 and P3 couplers and frontal surface of P4 coupler with spinules (Fig. 22B–D) ..... *T. decipiens*
–. Caudal surface of P2 and P3 couplers without ornamentation or sometimes with hairs, frontal surface of P4 coupler bare 5
5. Caudal rami 2.9–3.7 times as long as wide (Fig. 15E); tip of inner median (longest) terminal caudal seta straight or slightly curved (Fig. 15A); frontal surface of P1–P3 couplers with hairs ... *T. rylovi*
–. Caudal rami 2.0–2.9 times as long as wide; tip of longest terminal caudal seta curling; frontal surface of P1–P3 couplers without ornamentation .... *T. crassus*

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Figure 3. *Thermocyclops crucis* sp. nov., female. (A) Habitus, dorsal. (B–C) antennule, anterior: (B) segments 1–14; (C) segments 14–17; (D) antenna, caudal. (A–C) holotype, (D) paratype T-88-2 (MIZ60426). Scales: A: 100 μm, B–D: 50 μm.

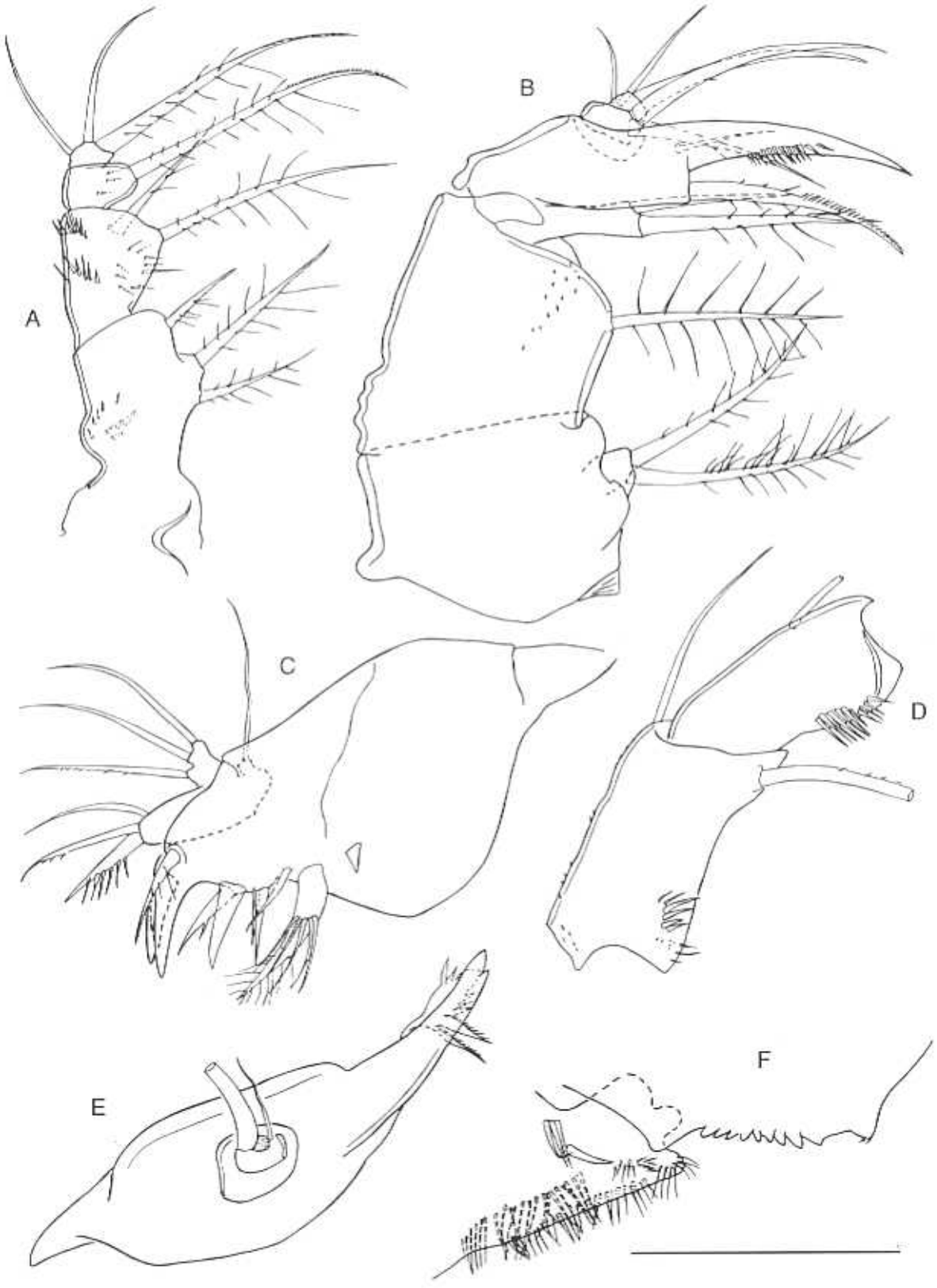

Figure 4. *Thermocyclops crucis* sp. nov., female. (A) Maxilliped, caudal; (B) maxilla, frontal; (C) maxillule, caudal; (D) antennal coxobasis and first endopodal segment, frontal; (E) mandible; (F) labrum and paragnath. (A–C) holotype, (D) paratype T-88-2 (MIZ60426), E, F show paratype T-88-1. Scale: 50 μm.

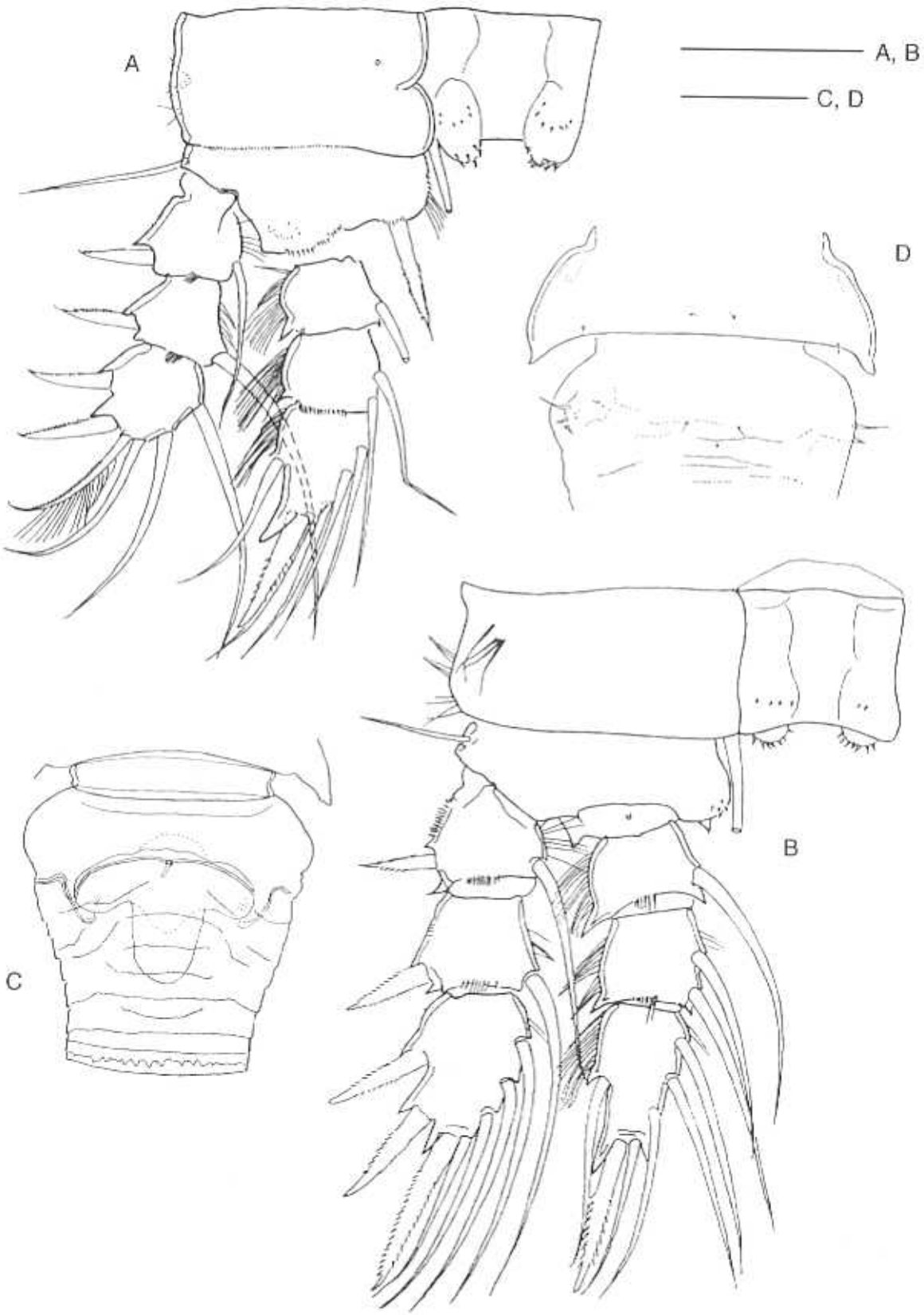

Figure 5. *Thermocyclops crucis* sp. nov. (A) P1 frontal; (B) P2, caudal; (C) genital double-somite, ventral; (D) pediger 5 and anterior half of genital double-somite, dorsal. (A–C) holotype, (D) paratype T-88-1. Scale: 50 μm.

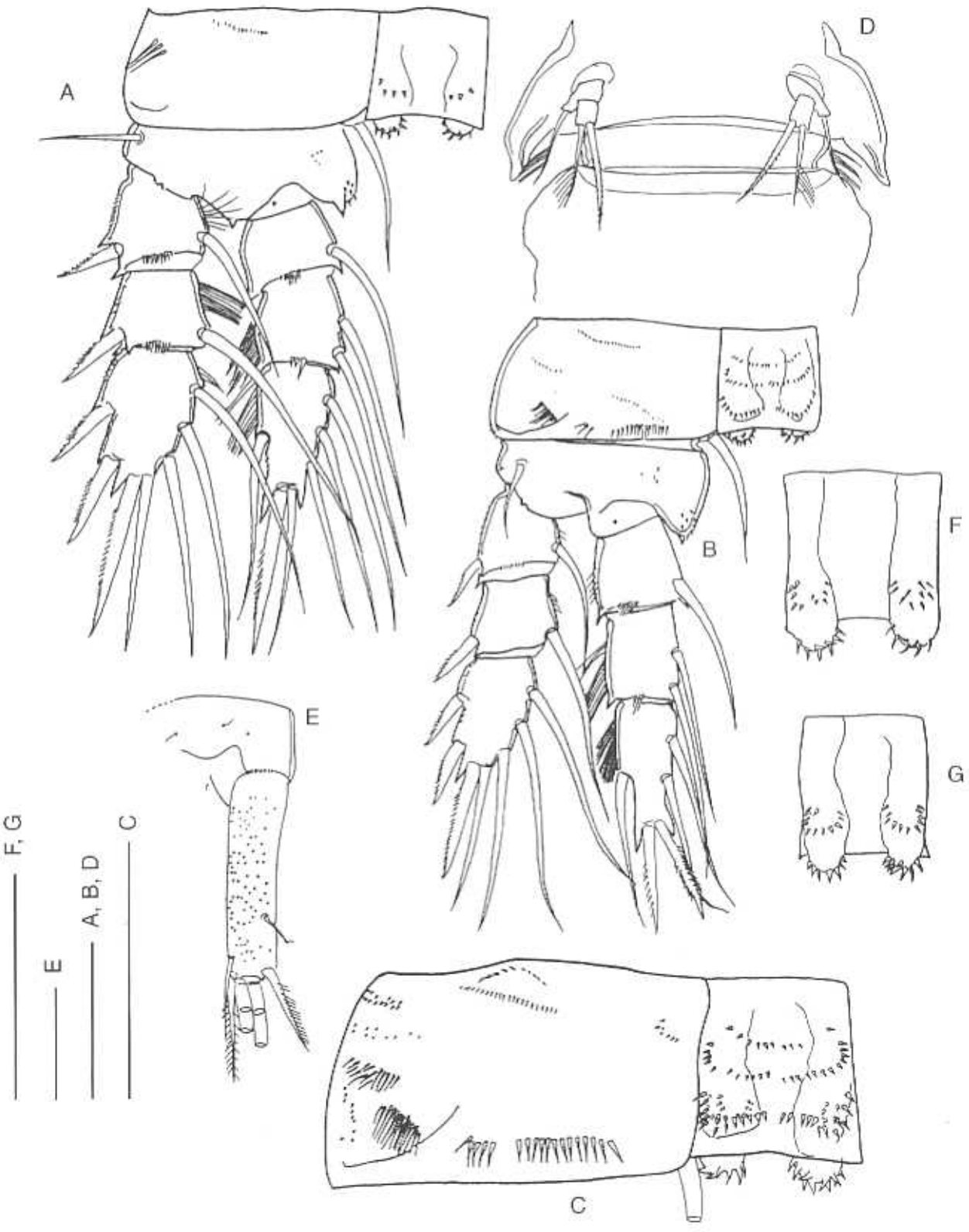

Figure 6. *Thermocyclops crucis* sp. nov., female. (A) P3, caudal; (B) P4, caudal; (C) P4 coxopodite and coupler, caudal (ornamentation on frontal surface is shown by dotted line); (D) pediger 5, ventral; (E) caudal ramus, dorsal; (F) P3 coupler, frontal; P4 coupler, frontal. (A, B, D, F, G) holotype, (C) paratype T-88-2 (MIZ60426), (E) paratype T-88-1. Scales: 50 μm.

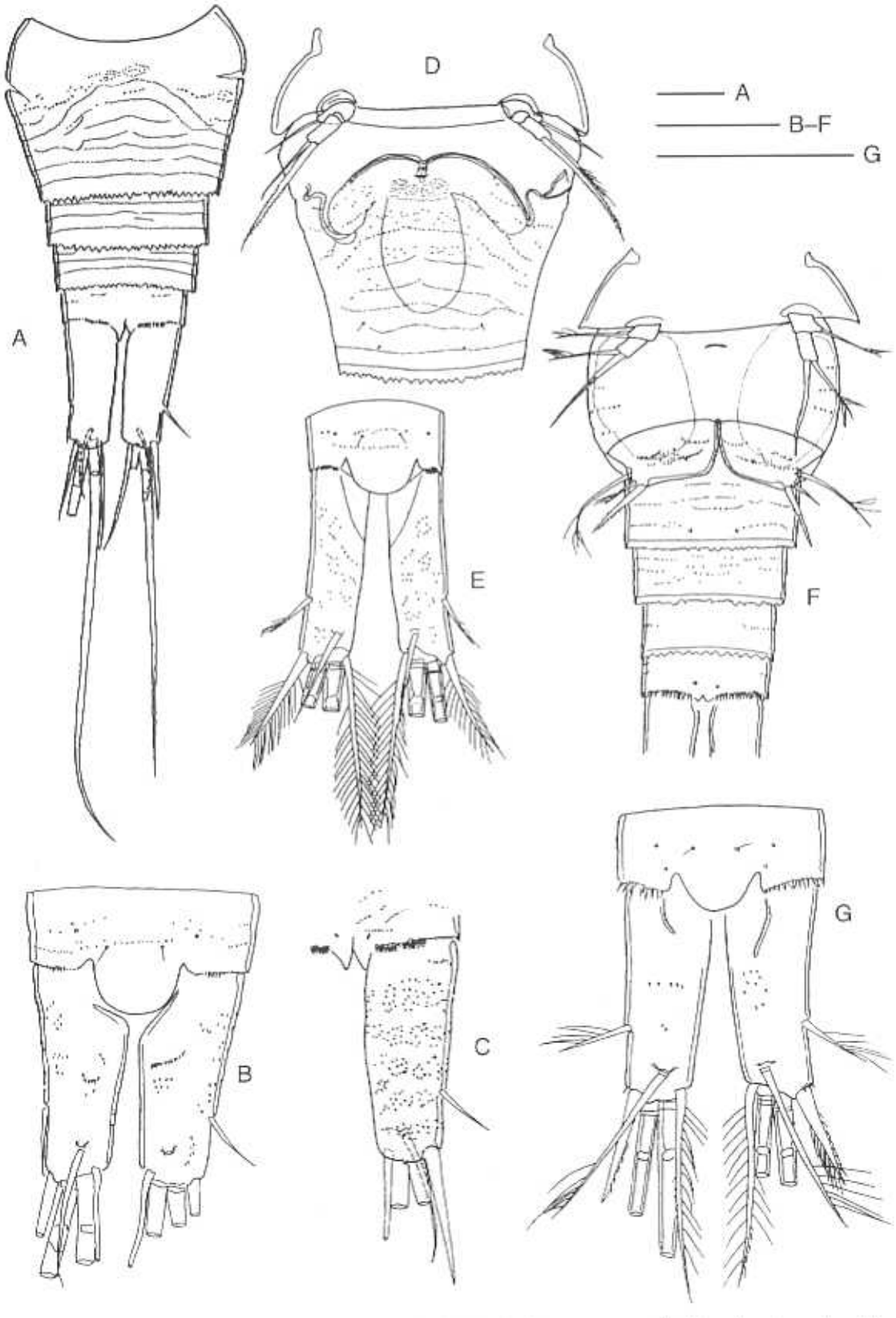

Figure 7. *Thermocyclops opercülifer* (Kiefer, 1930): (A–C) Lombok (holotype): (A) urosome, ventral; (B) anal somite and caudal rami, dorsal; (C) caudal ramus, ventral. (D–G) Sulawesi (Salua, roadside ditch). (D) Pediger 5 and genital double-somite, ventral (MIZ60428); (E) anal somite and caudal rami, dorsal (MIZ60427); (F) urosome, ventral (MIZ60433); (G) anal somite, and caudal rami, dorsal MIZ60432). Scales: 50 µm.

Figure 8. *Thermocyclops opercultfer* (Kiefer, 1930), Lombok (holotype). (A–D) Antennule, posterior. (A) Segments 1–4; (B) segments 5–10; (C) segments 11–15; (D) segments 15–17; (E) antennal coxobasis and first and second endopodal segments, frontal (4 setae on enp2, and all setae on the coxobasis are broken off; some groups of spinules discernible on the caudal surface of coxobasis are indicated by dotted line). Scale: 50 μm.

Figure 9. *Thermocyclops opercalifer* (Kiefer, 1930), Sulawesi (Salua, roadside ditch), female. (A) Maxilla, frontal; (B) maxilliped, frontal; (C) maxillule, frontal; (D) antennal coxobasis and first endopodal segment, caudal; (E) labrum and paragnaths. A, C, E and B, D show MIZ60429 and MIZ60428, respectively. Scales: 50 µm.

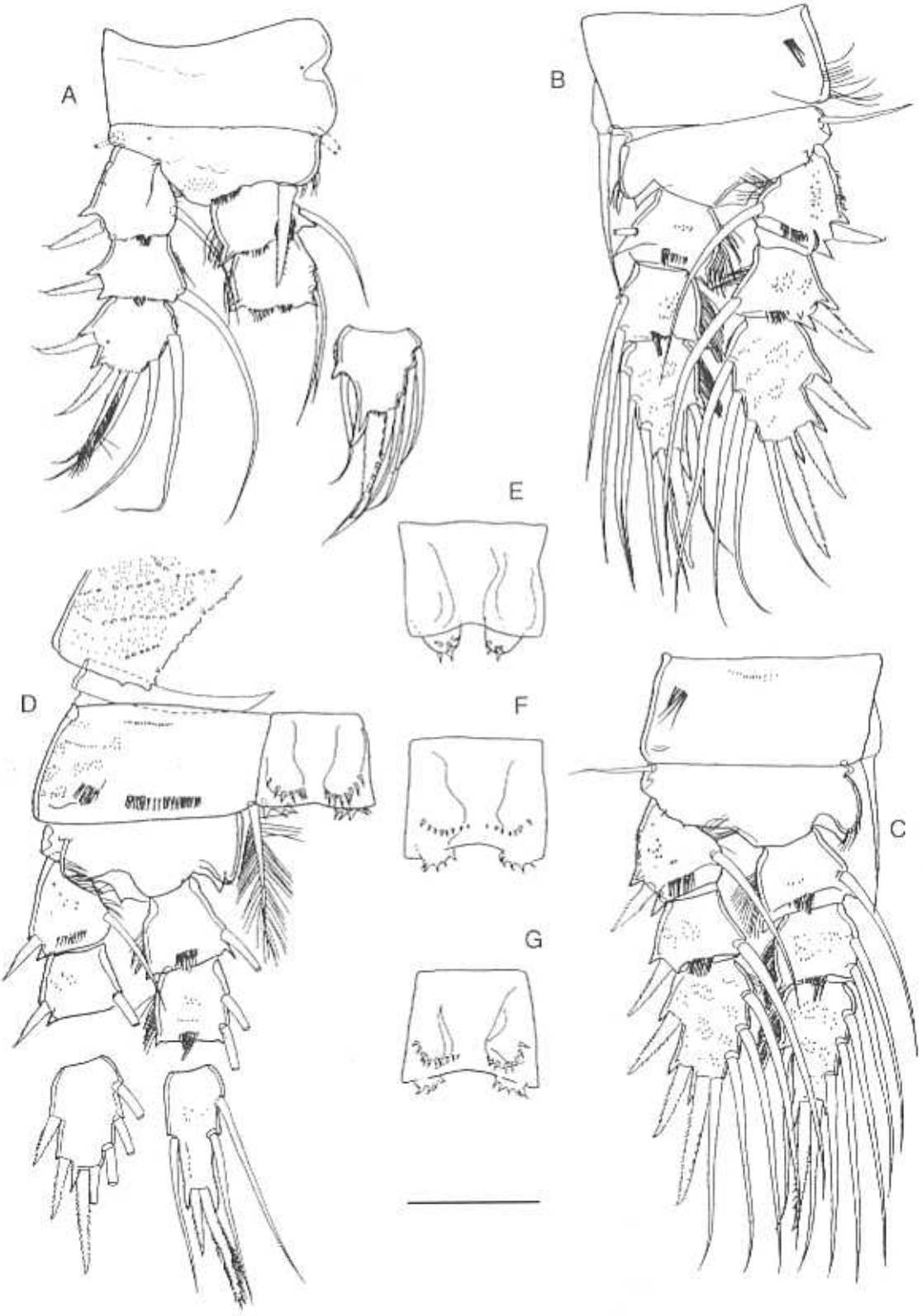

Figure 10. *Thermocyclops operculifer* (Kiefer, 1930), Lombok (holotype). (A) P1, frontal; (B) P2, caudal; (C) P3, caudal; (D) P4, caudal; (E–G) couplers, caudal. (E) P1; (F) P2; (G) P3. Scales: 50 µm.

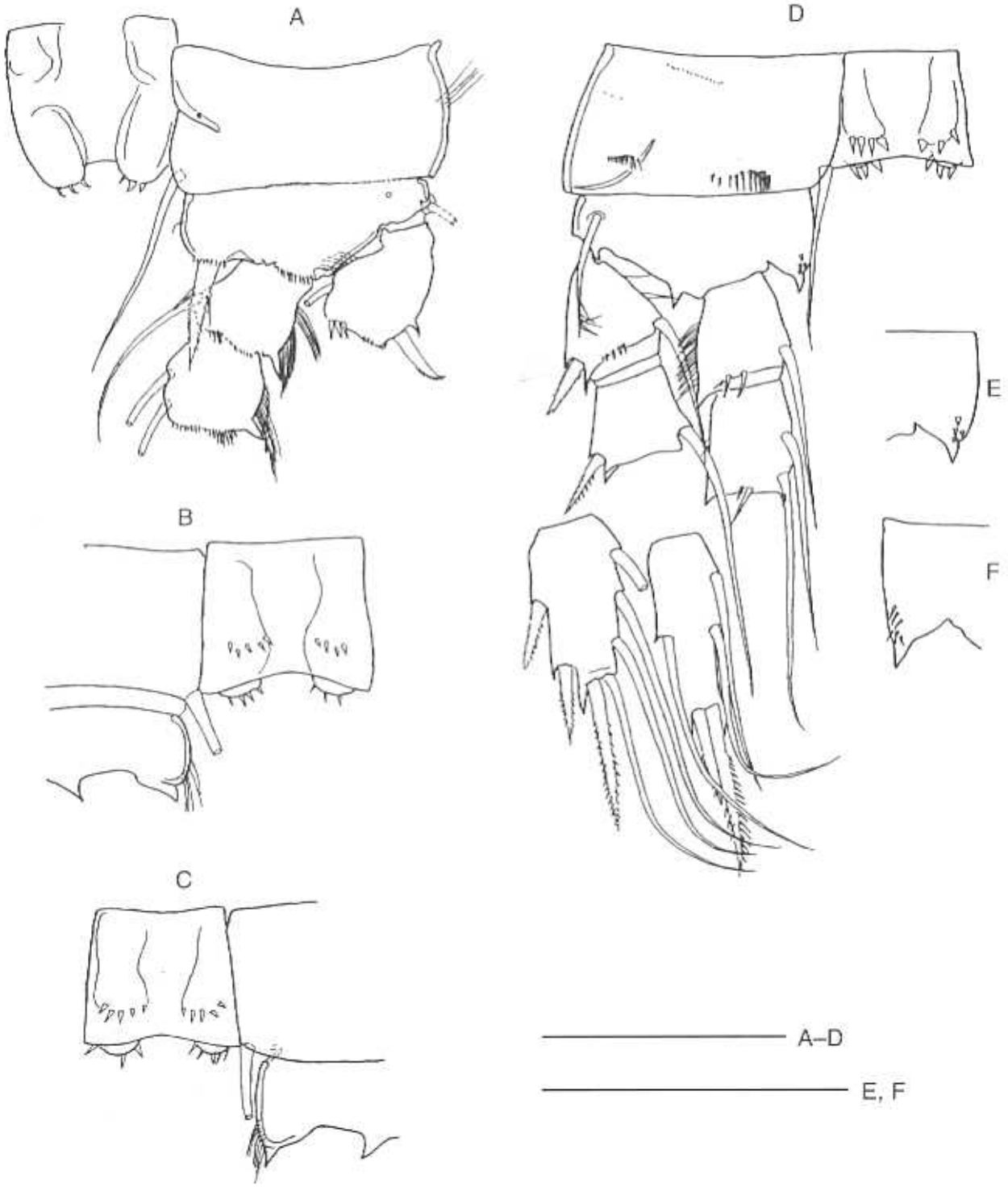

Figure 11. *Thermocyclops operculifer* (Kiefer, 1930), Sulawesi (Salua, roadside ditch), male: (A) P1 protopodite, enp1-2, and exp1, frontal; (B–C) coupler, and medial parts of coxo- and basipodite, caudal. (B) P2; (C) P3; (D) P4, caudal; (E–F) variation in the ornamentation of the medial expansion of P4 basipodite. (A, B, F and C, D, E show MIZ60432 and MIZ60433, respectively). Scales: 50 µm.

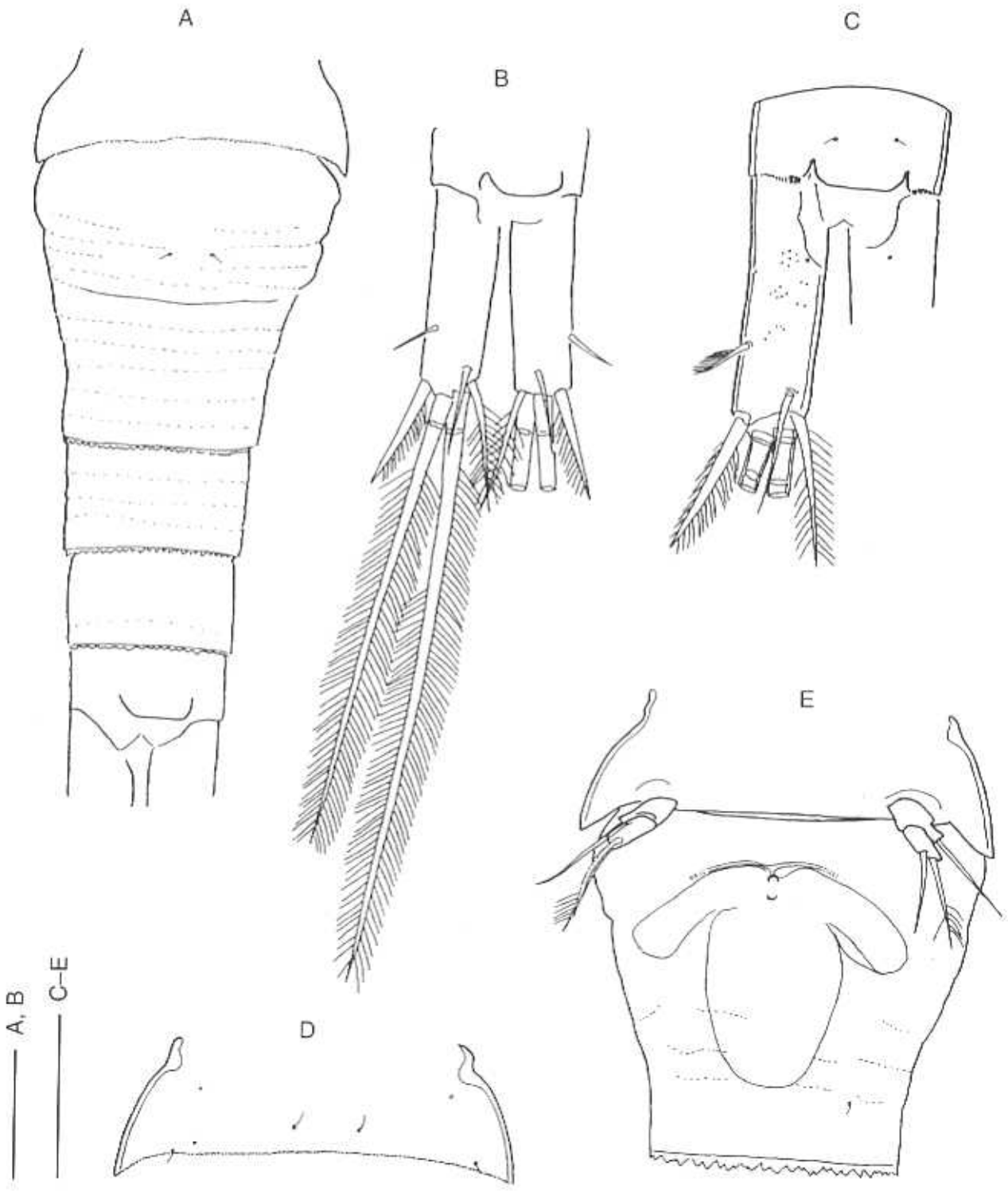

Figure 12. *Thermocyclops pseudoperculifer* sp. nov. (A) Urosome, dorsal; (B) caudal rami and setae, dorsal (spinule ornamentation of rami is not shown); (C) anal somite and caudal ramus, dorsal – original drawing was made at larger magnification than that of (B); (D) pediger 5, dorsal; (E) genital double-somite, ventral. (A–D) holotype, (E) paratype. Scales: 50 µm.

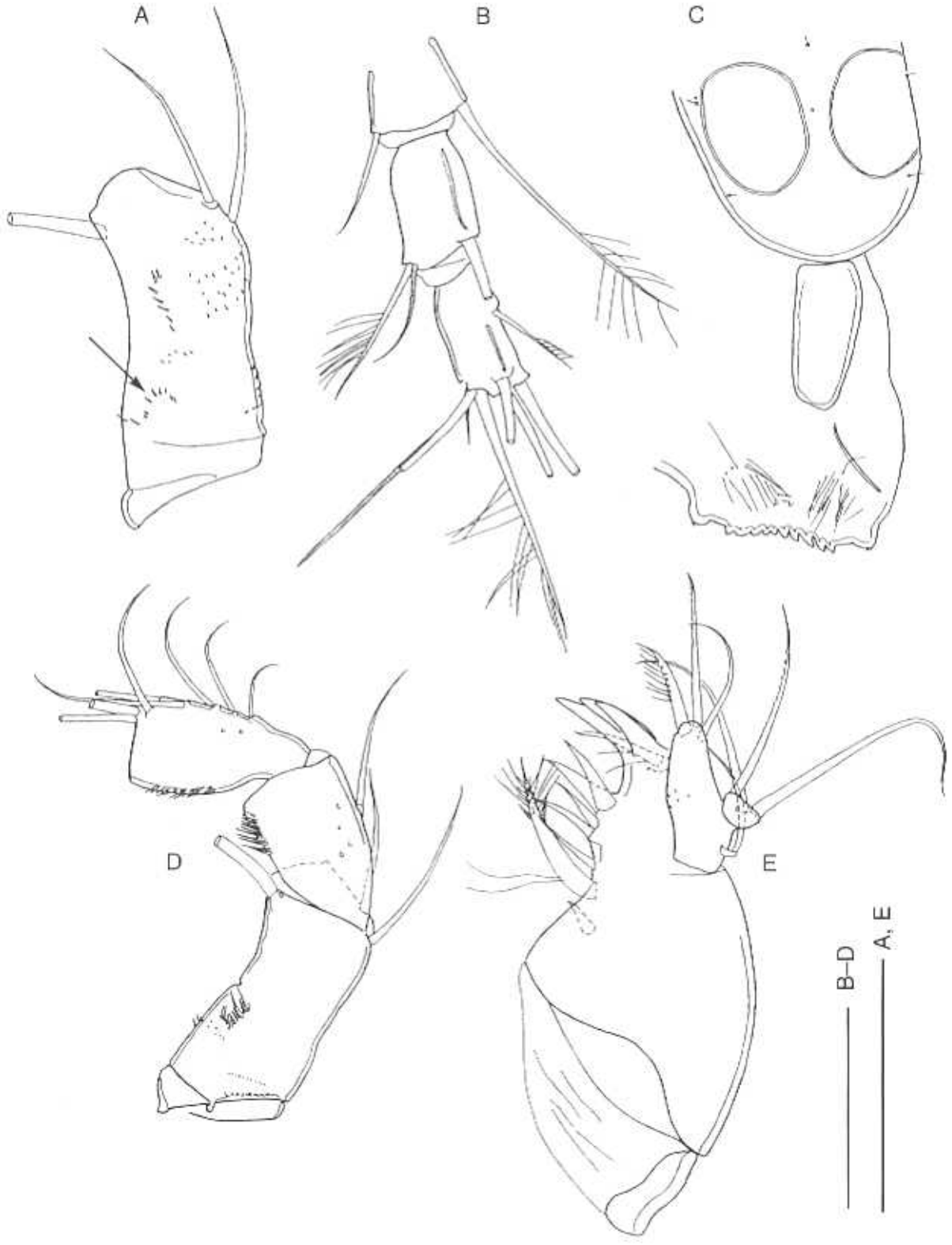

Figure 13. *Thermocyclops pseudoperculifer* sp. nov. (A) Antennal coxobasis, caudal; (B) antennule, segments 15–17, anterior; (C) rostrum, epistoma, labrum; (D) antennal coxobasis and first and second endopodal segment, frontal; (E) maxillule, frontal. (A, B, D) paratype; (C, E) holotype. Scales: 50 μm.

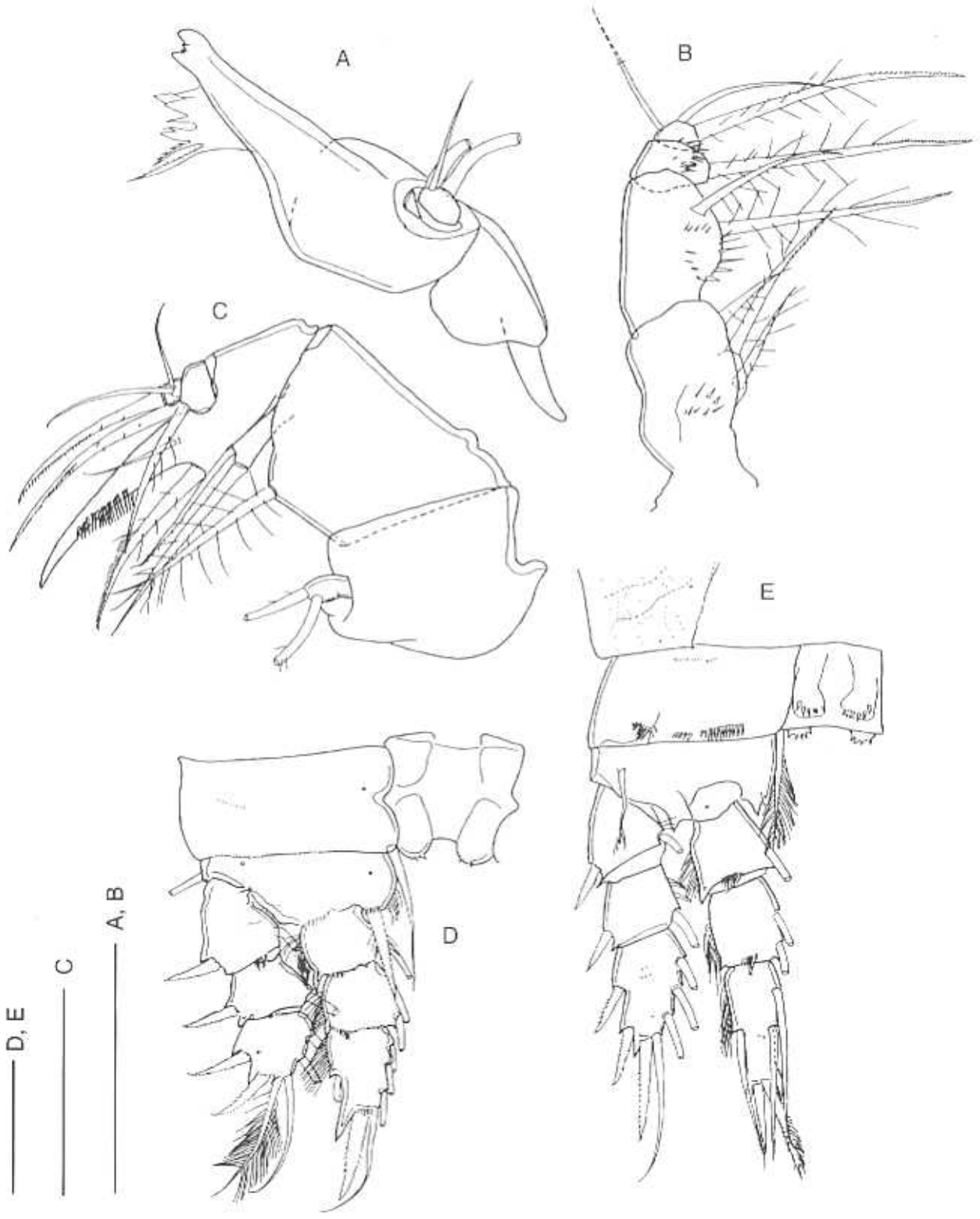

Figure 14. *Thermocyclops pseudoperecudifer* sp. nov. (A) Mandible, frontal; (B) maxilliped, frontal (distal part of the lateralmost seta of enp2 was broken off, length of the seta is given here by comparing it to the corresponding seta on maxilliped of the other side); (C) maxilla, caudal; (D) P1, frontal; (E) P4 caudal. (A–D) holotype, (E) paratype. Scales: 50 μm.

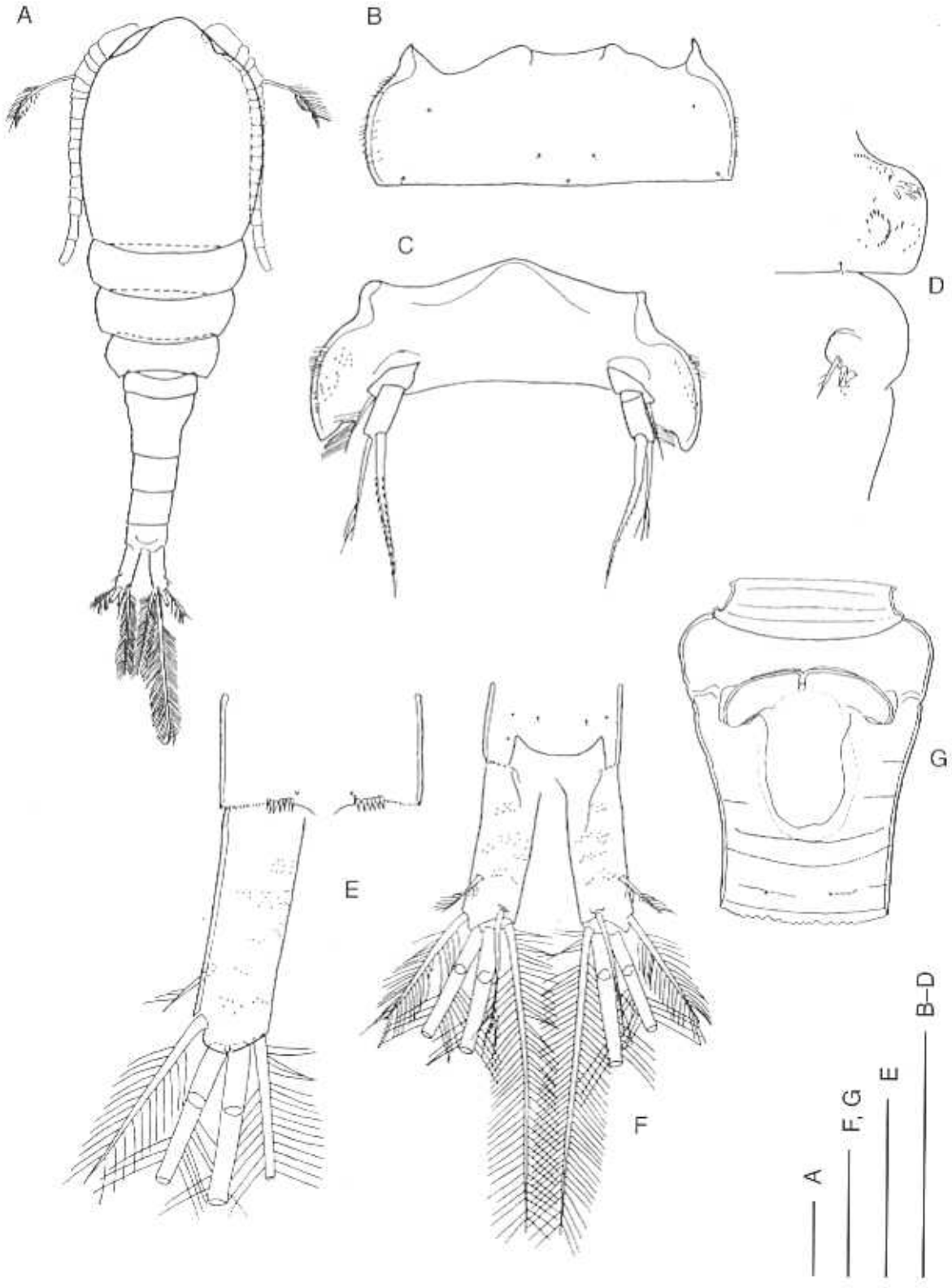

Figure 15. *Thermocyclops rylovi* (Smirnov, 1928), Australia (Cloncurry), female. (A) Habitus, dorsal; (B–D) pediger 5. (B) Dorsal; (C) ventral; (D) lateral; (E) caudal ramus, ventral; (F) anal somite and caudal rami, dorsal; (G) genital double-somite, ventral. (A) MIZ60438; (B, C, E–G) MIZ60437; (D) MIZ60436. Scales: 50 μm.

Figure 16. *Thermocyclops rylovi* (Smirnov, 1928), female. (A) antenna, caudal; (B) antennal coxobasis, caudal; (C) antennal coxobasis and first endopodal segment, frontal; (D) mandible and maxillule, frontal. (A, C, D) female from Australia (MIZ60436); (B) specimen from Uzbekistan (Qarshi, MIZ60439). Scales: 50 μm.

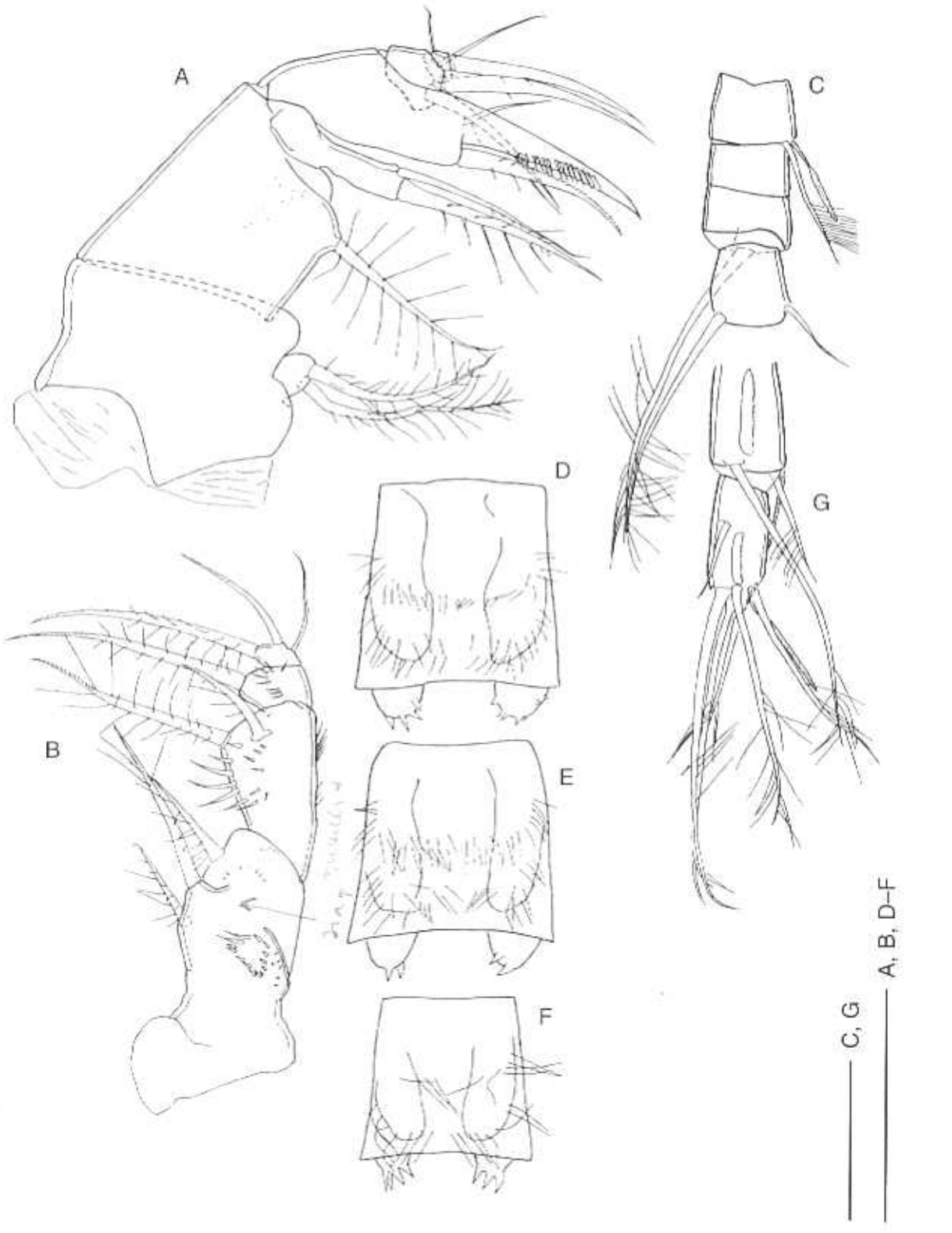

Figure 17. *Thermocyclops rylovi* (Smirnov, 1928), female. (A–C, F, G) Australia (Cloncurry). (A) Maxilla, frontal (MIZ60436); (B) maxilliped, frontal (MIZ60437); (C) antennule, segments 12–15, posterior (MIZ60436); (F) P4 coupler, caudal (MIZ60436); (G) antennule, segments 16–17, anterior (MIZ60436); (D–E) Uzbekistan (Qarshi): variable spinulation of the distal protuberances of P4 coupler (caudal) (MIZ60439, 60440). Scales: 50 µm.

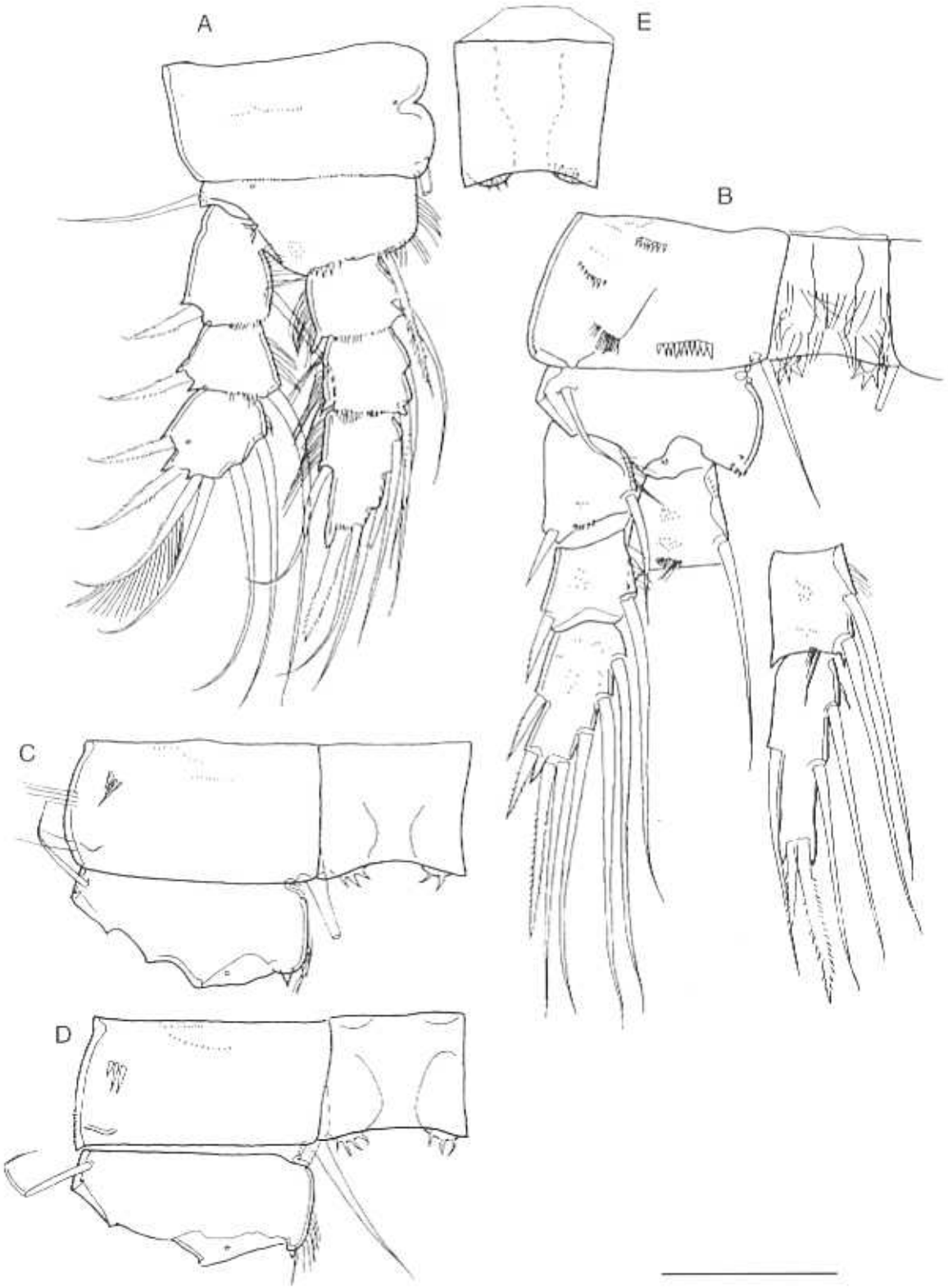

Figure 18. *Thermocyclops rylovi* (Smirnov, 1928), Australia (Cloncurry), female. (A) P1, frontal; (B) P4 caudal; (C) P2 protopodite, caudal; (D) P3 protopodite, caudal; (E) P1 coupler, caudal. All show MIZ60437. Scales: 50 μm.

Figure 19. *Thermocyclops crassus* (Fischer, 1853), female. (A, B, D) Australia (Townsville, MIZ60445). (A) Antennule, segments 12–17, anterior; (B) antennal coxobasis, first and second endopodal segments, caudal; (D) seminal receptacle. (C) Hungary (Szarvas): antennal coxobasis, caudal. Scales: 50 μm.

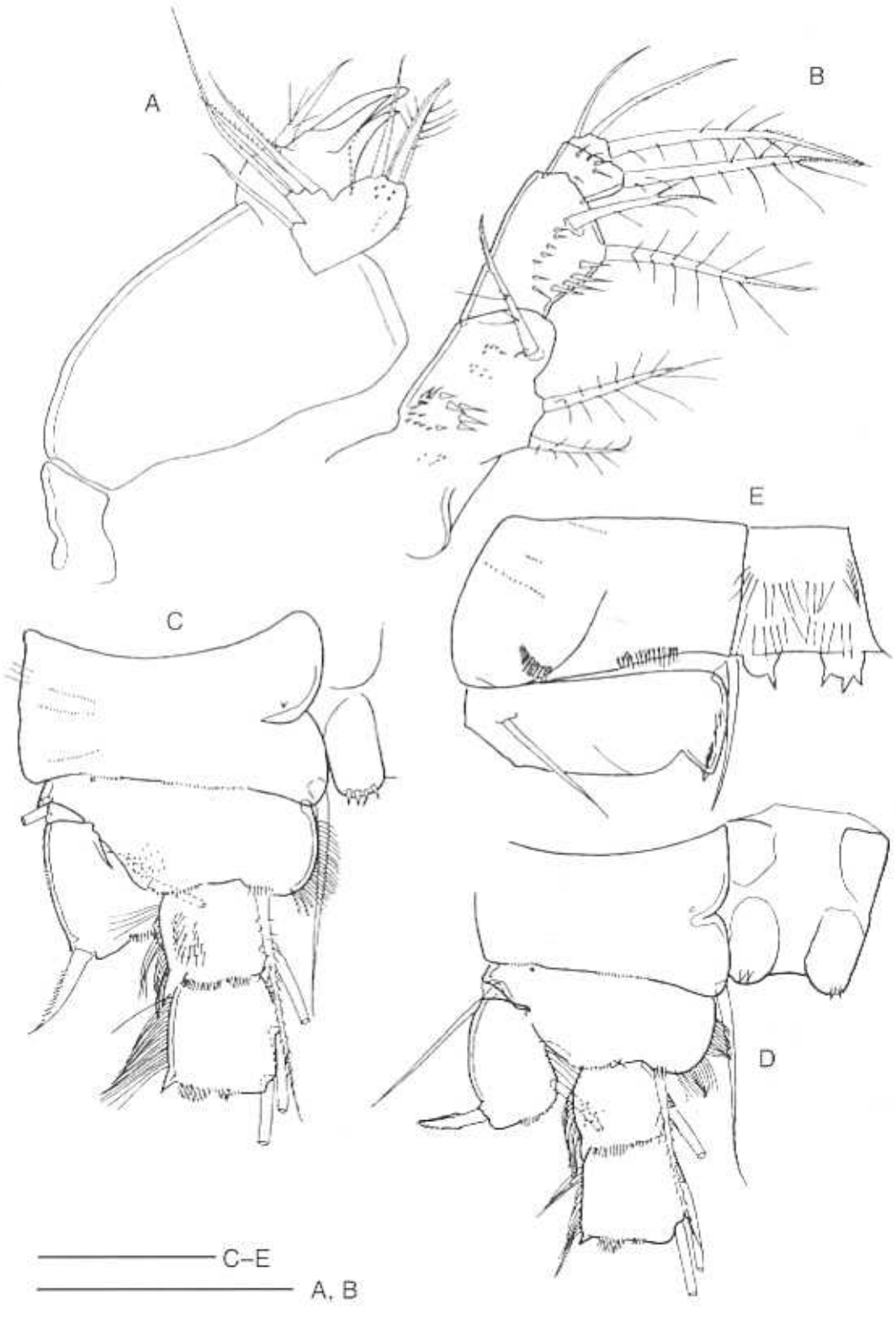

Figure 20. *Thermocyclops crassus* (Fischer, 1853), female. (A, B, D, E) (Townsville, MIZ60445): (A) maxillule, frontal; (B) maxilliped, frontal; (D) P1 protopodite, exp1, and enp1-2, frontal; (E) P4 protopodite, caudal. (C) Hungary (Szarvas): P1 protopodite, exp1, and enp1-2, frontal. Scales: 50 μm.

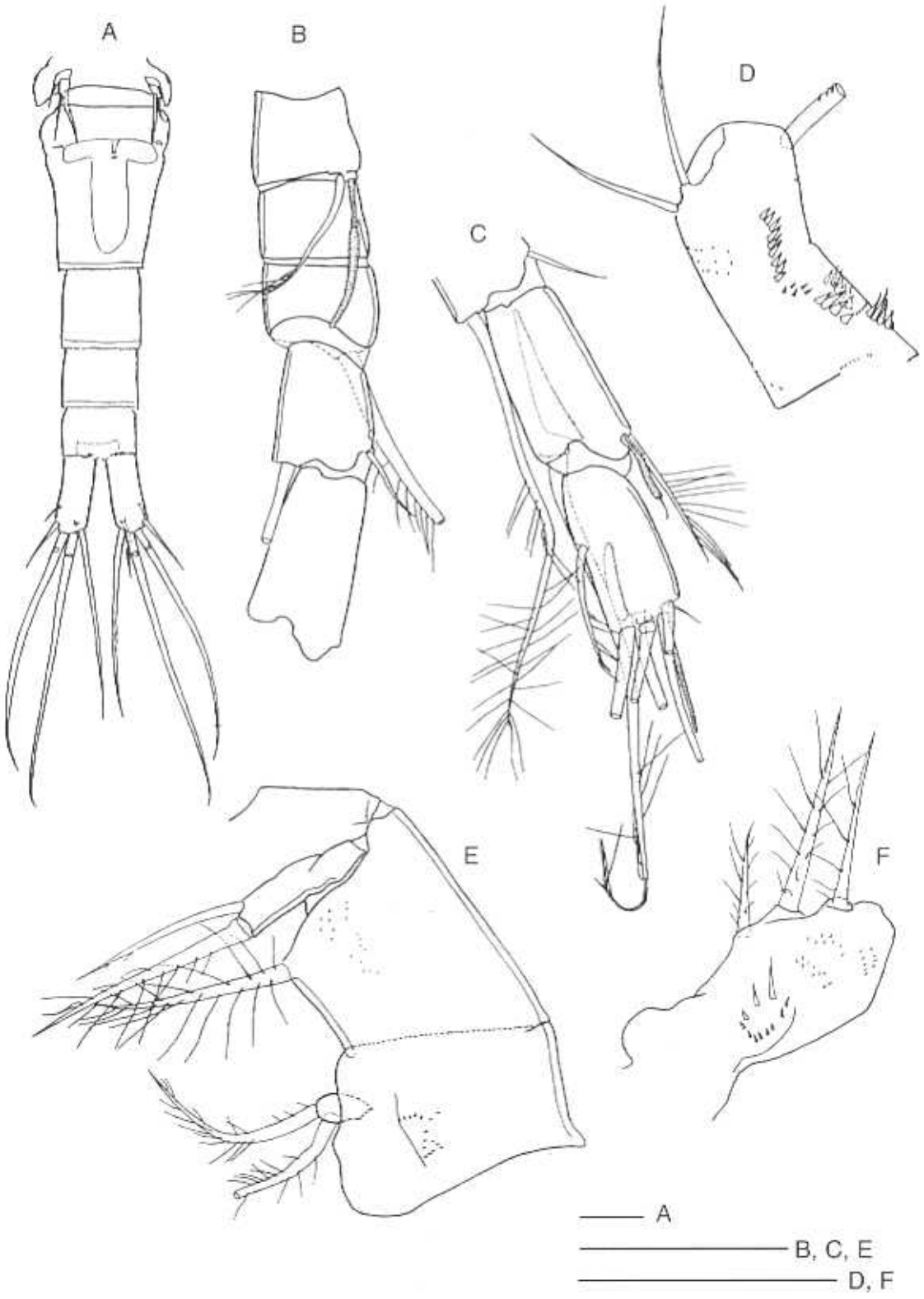

Figure 21. *Thermocyclops decipiens* (Kiefer, 1929), Townsville, female. (A) urosome, ventral; (B) antennule, segments 12–15, posterior; (C) antennule, segments 16–17, posterior; (D) antennal coxobasis, caudal; (E) maxilla syncoxopodite, frontal; (F) maxilliped syncoxopodite, frontal. Scales: 50 µm.

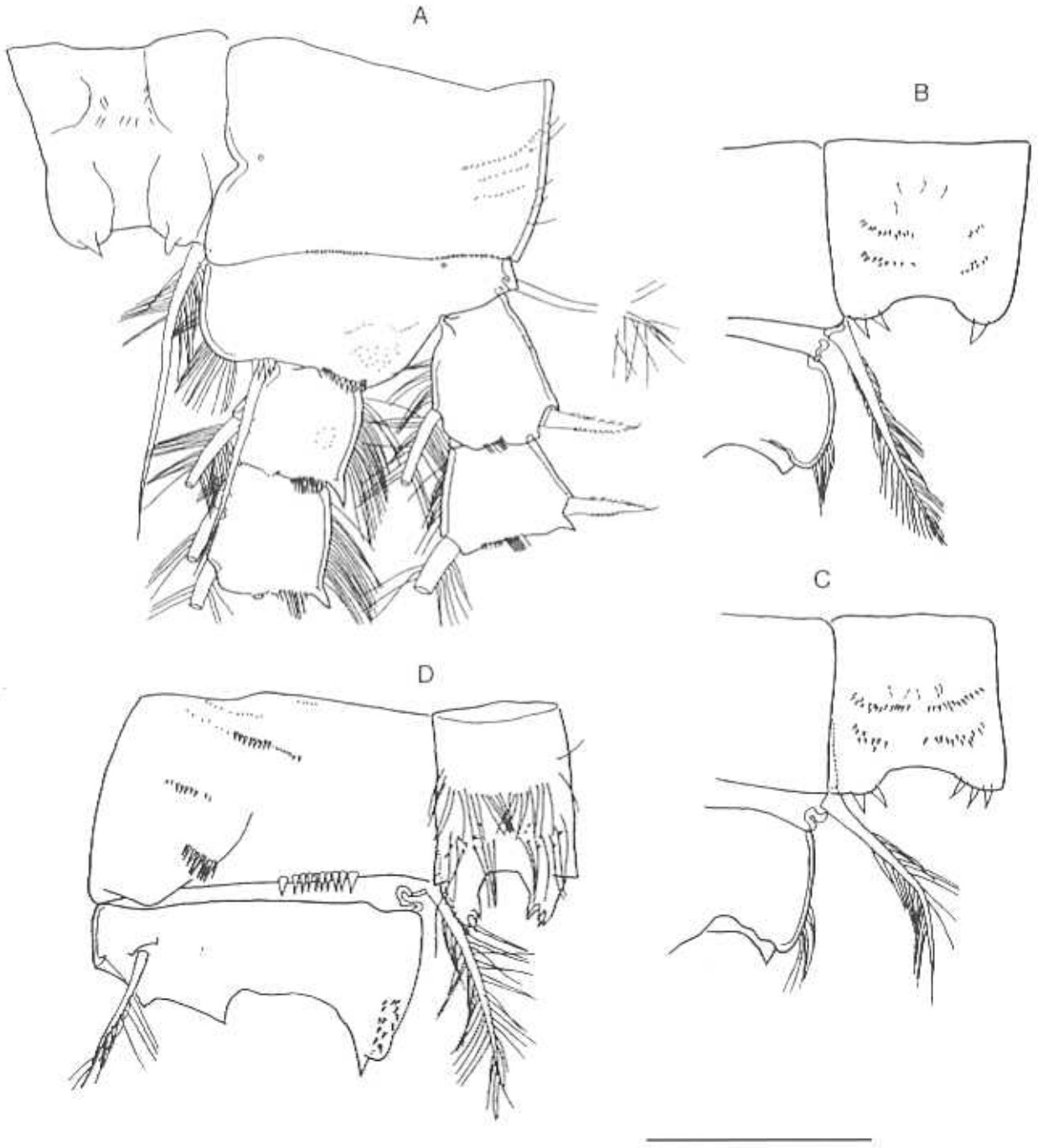

Figure 22. *Thermocyclops decipiens* (Kiefer, 1929), Townsville, female. (A) P1 protopodite, exp1-2, and enp1-2, frontal; (B) P2 coupler, medial parts of coxo- and basipodite, caudal (few hairs are present on frontal surface of coupler); (C) P3 coupler, medial parts of coxo- and basipodite, caudal (few hairs are present on frontal surface of coupler); (D) P4 protopodite, caudal (spinules are shown on frontal surface of coupler). Scales: 50 μm.