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New Record of *Centropages brevipurcus* (Crustacea: Copepoda: Calanoida) from the Gulf of Thailand and its Full Redescription

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Centropages brevipurcus Shen and Lee, 1963, known exclusively from Chinese estuaries and the Java Sea, is redescribed from the Gulf of Thailand. This is the first record of its occurrence in Thailand. The species belongs to the newly characterized *C. trispinosus* Sewell, 1914 group, which is restricted to the tropical Indo-Malayan region.

Key Words: *Centropages*, Calanoida, Copepoda, redescription, Gulf of Thailand, new species group

Introduction

The genus *Centropages* accommodates 30 valid species that are distributed in epipelagic waters (Vervoort 1964; Razouls 1982; McKinnon and Kimmerer 1988; McKinnon and Dixon 1994; Bradford-Grieve 1999; Bradford-Grieve *et al.* 1999). Vervoort (1964) pointed out that the genus required revision and that a number of poor, old descriptions had caused taxonomic confusion.

We have been intensively studying the copepod and mysid fauna in the waters of Thailand since 1996 (Pinkaew *et al.* 1998, 2001; Ohtsuka *et al.* 1999, 2000). An additional survey in 2001 revealed that the little-known calanoid copepod *Centropages brevipurcus* Shen and Lee, 1963, originally known from the Luichow Peninsula, Kwangtung Province, southern China (Shen and Lee 1963), occurs in the Gulf of Thailand. Six other congeners co-occur in the area (Suwanrumpha 1987; Pinkaew *et al.* 1998): *C. bradyi* Wheeler, 1900; *C. dorsispinatus* Thompson and Scott, 1903; *C. furcatus* (Dana, 1852); *C. gracilis* (Dana, 1849); *C. orsinii* Giesbrecht, 1889; and *C. tenuiremis* Thompson and Scott, 1903. Since the original description of *C. brevipurcus* was incomplete, we here redescribe this species from the Gulf of Thailand in detail.

Material and Methods

Plankton samples were collected from depths of less than 2 m in Prachuap Khiri Khan, the western part of the Gulf of Thailand on 25 March 2001, by towing a sledge net along the sandy bottom (net mouth area 250 mm wide, 100 mm high; mesh size 0.33 mm). The samples were fixed in 10% neutralized formalin/sea-water immediately after collection. Specimens of *Centropages brevifurcus* were sorted out of the samples, and then examined with light (Nikon Optiphot) and scanning electron (Jeol T-20) microscopes. Terminology follows Huys and Boxshall (1991).

Taxonomy

Family *Centropagidae* Giesbrecht, 1892

Genus *Centropages* Krøyer, 1849

Centropages brevifurcus Shen and Lee, 1963

(Figs 1–6)

Material examined. Twenty-four adult females and 25 adult males.

Measurements. Body length: female 0.92–1.06 mm (n=20, mean±S.D.=1.03±0.04 mm); male 0.78–0.92 mm (n=20, 0.86±0.03 mm).

Description. *Female.* Body (Fig. 1A, B) plump in prosome, widest at first pediger; prosome about 2.8 times as long as urosome; rostrum (Figs 1B, C, 2A) bearing pair of long filaments with broad bases; cephalosome distinctly separate from first pediger, with posterodorsal knob; fifth pediger asymmetrical at posterior corners, with 3 ventrolateral pairs of acutely pointed processes (Figs 1A, B, D–F, 2B); right dorsalmost process abruptly curved outward. Urosome (Figs 1A, B, D–F, 2B, C) 3-segmented, bearing minute prominences dorsally, hard to observe with light microscope (see Fig. 2C). Genital compound somite (Figs 1D–F, 2B, C) asymmetrical, expanded anterolaterally, with 2 rows of spinules on right dorsolateral side (Figs 1E, 2B); patch of spinules on left dorsolateral side, and serration along posterodorsal margin (see Fig. 2C); genital operculum (Figs 1E, 2B) located ventrolaterally on right side, with right distal corner produced posteriorly into round or somewhat pointed process; second urosomal somite with swelling ventrolaterally on right side; posterior margin of swelling concave (see Figs 1E, 2B); anal somite and caudal rami slightly asymmetrical; caudal ramus approximately twice as long as wide; caudal seta V longest of caudal setae.

Antennule (Fig. 1G–I) 22-segmented, reaching slightly beyond posterior margin of genital compound somite. Fusion pattern and armature elements as follows: I (1st segment)=1+ae (ae: aesthetasc); II–VI (2)=6+3ae; VII (3)=2+ae; VIII (4)=1+ae; IX (5)=2+ae; X (6)=2 (1 spiniform)+ae; XI (7)=2+ae; XII (8)=2+ae; XIII (9)=2+ae; XIV (10)=2 (1 spiniform)+ae; XV (11)=2+ae; XVI (12)=2+ae; XVII (13)=2+ae; XVIII (14)=2+ae; XIX (15)=2+ae; XX (16)=2+ae; XXI (17)=2+ae; XXII (18)=1; XXIII (19)=1; XXIV (20)=1+1; XXV (21)=1+1+ae; XXVI–XXVIII (22)=6+ae.

Antenna (Fig. 1J) with coxa and basis incompletely fused, bearing 1 and 2 plumose setae, respectively; endopod 2-segmented; first segment with 2 setae of unequal length subterminally; second segment bilobed, with proximal and distal lobes bearing 9 and 5 setae, respectively; exopod indistinctly 8-segmented with setal formula of 2, 1, 1, 1, 1, 1, 1, 1 + 3. Mandible (Fig. 1K) with 8 cusped teeth and 1

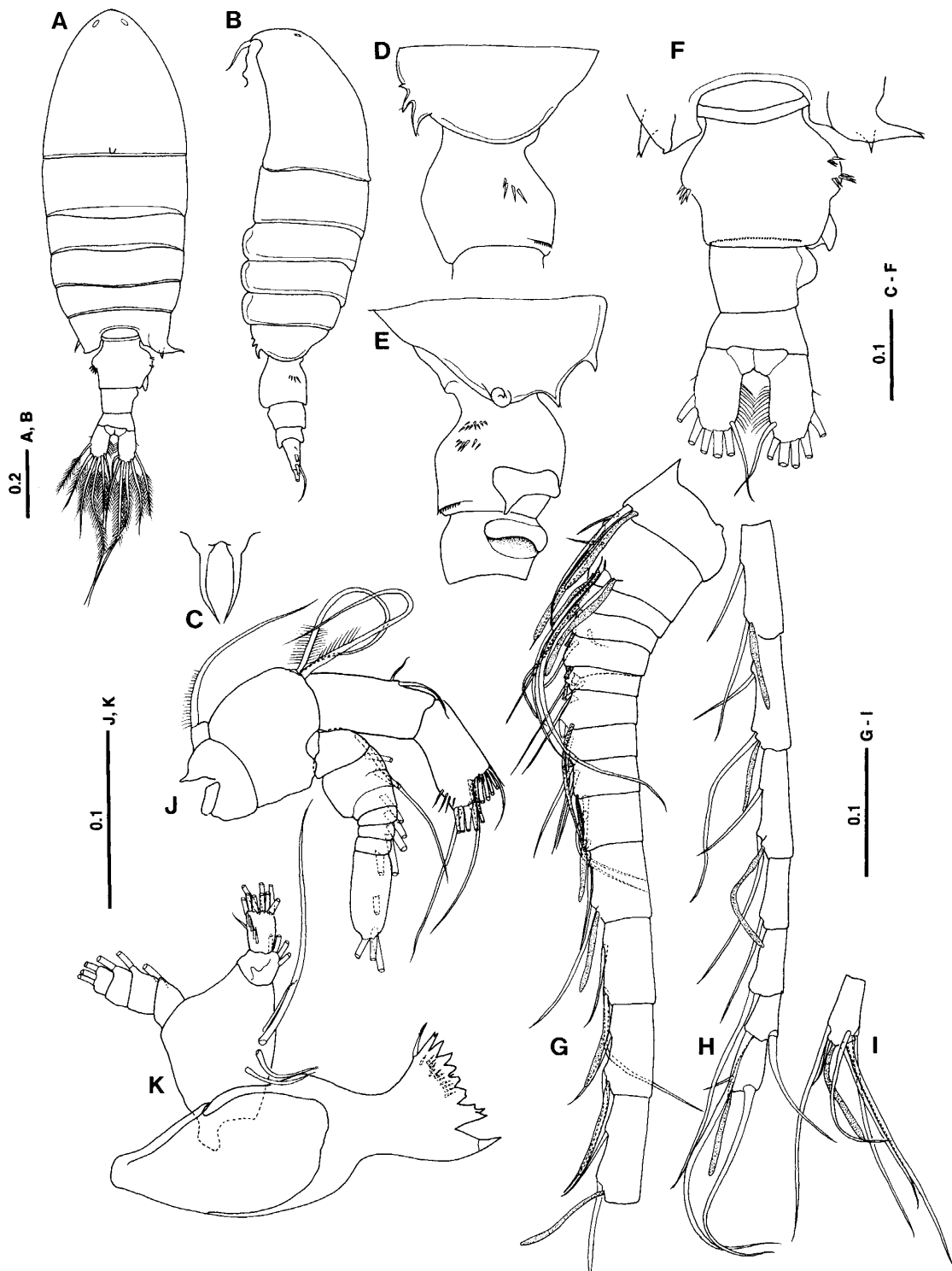


Fig. 1. *Centropages brevifurcus* Shen and Lee, 1963 from the Gulf of Thailand, female. A, habitus, dorsal view; B, habitus, lateral view; C, rostrum; D, fifth pediger and genital compound somite, left lateral view; E, fifth pediger and first two urosomites, right lateral view; F, fifth pediger and urosome, dorsal view; G, antennule, first (I) to 14th (XVIII) segments; H, antennule, 15th (XIX) to 21st (XXV) segments; I, antennule, 22nd (XXVI-XXVIII) segment; J, antenna; K, mandible. Scales in mm.

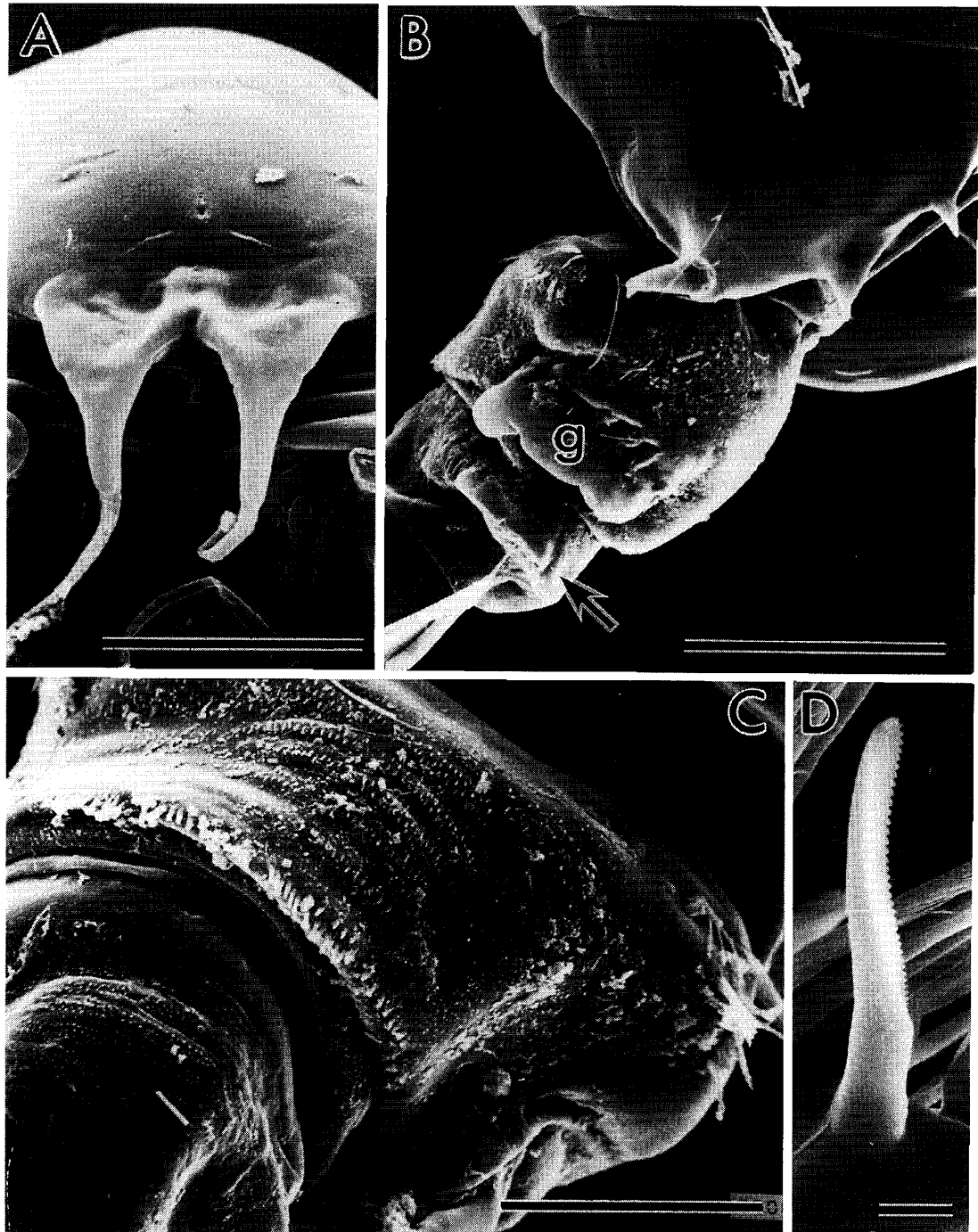


Fig. 2. SEM micrographs of *Centropages brevifurcus* Shen and Lee, 1963 from the Gulf of Thailand, female. A, rostrum; B, fifth pediger, genital compound somite, and second urosomite, ventrolateral view (g, genital operculum; arrow, ventrolateral process on second urosomite); C, genital compound somite, dorsal view; D, inner expansion of second exopodal segment of leg 5. Scales=0.05 mm (A, C), 0.1 mm (B), 0.01 mm (D).

Table 1. Seta and spine formula of legs 1 to 5. Arabic and Roman numerals indicate the number of setae and spines, respectively.

	coxa	basis	exopod 1; 2; 3	endopod 1; 2; 3
leg 1	0-1	0-1	I-1;I-1;II,I,4	0-1;0-2;1,2,3
leg 2	0-1	0-0	I-1;I-1;III,I,5	0-1;0-2;2,2,4
leg 3	0-1	0-0	I-1;I-1;III,I,5	0-1;0-2;2,2,4
leg 4	0-1	0-0	I-1;I-1;III,I,5	0-1;0-2;2,2,3
leg 5	0-1	1-0	I-1;I-1;II,I,4	0-1;0-1;2,2,2

spinulose seta along coxal cutting edge; basis bearing 4 inner setae at midlength; endopod 2-segmented, first and second segments bearing 4 and 9 setae, respectively; second segment with longitudinal row of spinules; exopod 4-segmented with setal formula of 1, 1, 1, 3. Maxillule (Fig. 3A) with 16 well-chitinized elements on praecoxal arthrite; coxal epipodite bearing 7 well developed and 2 short proximal setae and proximal patch of setules; coxal endite with 3 setae; basal exite with short seta; first basal endite with 4 setae; second basal endite completely coalescent with endopod, represented by 5 setae; endopod indistinctly 2-segmented, proximal and distal segments bearing 6 and 3 setae, respectively; exopod bearing 9 setae and transverse row of minute spinules distally. Maxilla (Fig. 3B) with praecoxal and coxal endites bearing 5, 3 and 3, 3 setae, respectively; basal endite with 1 strong and 2 short, slender setae; endopod 4-segmented with setal formula of 2, 2, 2, 2; inner seta on second endopodal segment rudimentary. Maxilliped (Fig. 3C) with setal formula of syncoxa of 1, 2, 3, 3; rudimentary praecoxal endite represented by minute seta; basis with spinular row along three-fourths of inner margin and 3 plumose setae subterminally; endopod 6-segmented; first segment incompletely incorporated into basis; second to sixth endopodal segments bearing 2, 3, 2, 2+1, and 4 setae, respectively.

Seta and spine formula of legs 1 to 5 (Fig. 4A–E) shown in Table 1. Legs 1 to 4 with paired patches of fine setules on intercoxal sclerite. Leg 1 (Fig. 4A) with relatively short, spinulose basal seta. Legs 2 to 4 (Fig. 4B–D) with distolateral corner of basis sharply pointed. Leg 4 (Fig. 4D) symmetrical, unlike that of male.

Leg 5 (Figs 2D, 4E) symmetrical; coxa with acutely pointed process near posterior margin on posterior surface; first endopodal segment produced into round swelling at outer distal corner (arrow in Fig. 4E); second exopodal segment bearing thick inner process with serration along distal three-fourths of posterior margin (see Fig. 2D).

Male. Body (Fig. 5A) more slender than that of female. Fifth pedigerous somite slightly asymmetrical, left corner more posteriorly produced than right; posterior corners furnished with 3 pairs of processes ventrolaterally as in female, lateral one largest (Fig. 5B–D). Urosome (Fig. 5A, D) 4-segmented.

Right antennule (Fig. 5E) geniculate, 22-segmented. Fusion pattern and armature elements as follows: I (1)=1+ae; II–IV (2)=3+ae; V (3)=1+ae; VI (4)=2+ae; VII (5)=2+ae; VIII (6)=1+ae; IX (7)=2+ae; X (8)=2 (1 rudimentary)+ae; XI (9)=2+ae; XII (10)=2+ae; XIII (11)=2+ae; XIV (12)=2+ae; XV (13)=2+ae; XVI (14)=2+ae; XVII (15)=2+ae; XVIII (16)=2+ae; XIX (17)=1+ae+process; XX (18)=1+ae+process; XXI–

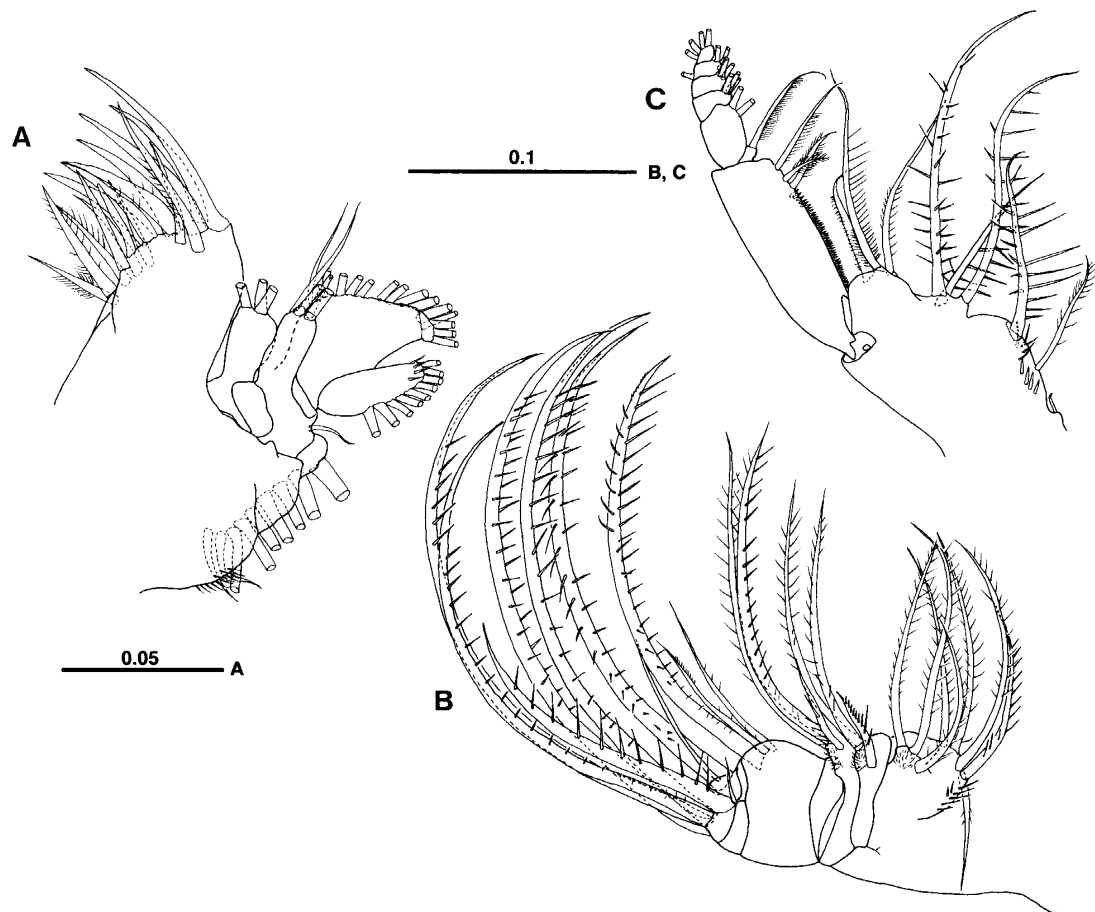


Fig. 3. *Centropages brevisfurcus* Shen and Lee, 1963 from the Gulf of Thailand, female. A, maxillule; B, maxilla; C, maxilliped. Scales in mm.

XXIII(19)=2(1 rudimentary, arrowed in Fig. 5E)+ae+2 processes; XXIV-XXV (20)=2+2+ae; XXVI(21)=1+1; XXVII-XXVIII(22)=3+ae. Distal seta on 10th (XII) to 12th (XIV) segments spiniform; 13th to 16th segments expanded; 17th segment with serrate process along entire anterior margin and pointed tip slightly covering base of 18th segment (XX); 18th segment with finely serrate process and hollow groove along entire anterior margin; 19th compound segment (XXI-XXIII) with 2 serrate proximal processes, rudimentary seta at midlength, and short terminal process (not element?); last compound segment with sharply pointed anterior process originating from segment XXVII, as long as penultimate segment.

Mouthpart appendages and legs 1-3 similar to those of female. Leg 4 (Fig. 5F, G) asymmetrical, with right distolateral bidenticulate spine of third exopodal segment larger than left one (arrowed in Fig. 5F, G).

Leg 5 (Figs 5H, I, 6) with intercoxal sclerite bearing setules on anterior surface; coxa with spiniform process subterminally on posterior surface; basis bearing outer seta at anterior terminal corner; first endopodal segment of both legs produced posterodistally into swelling with round tip as in female. Right leg with both rami 3-segmented; first exopodal segment rectangular; second exopodal segment

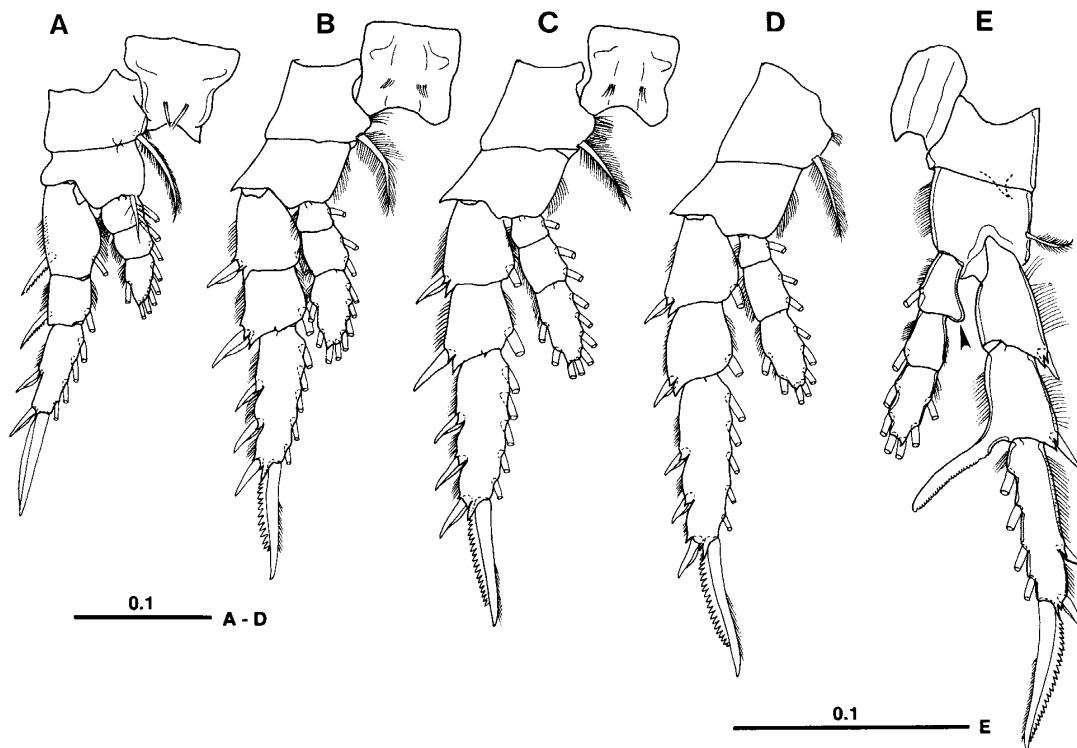
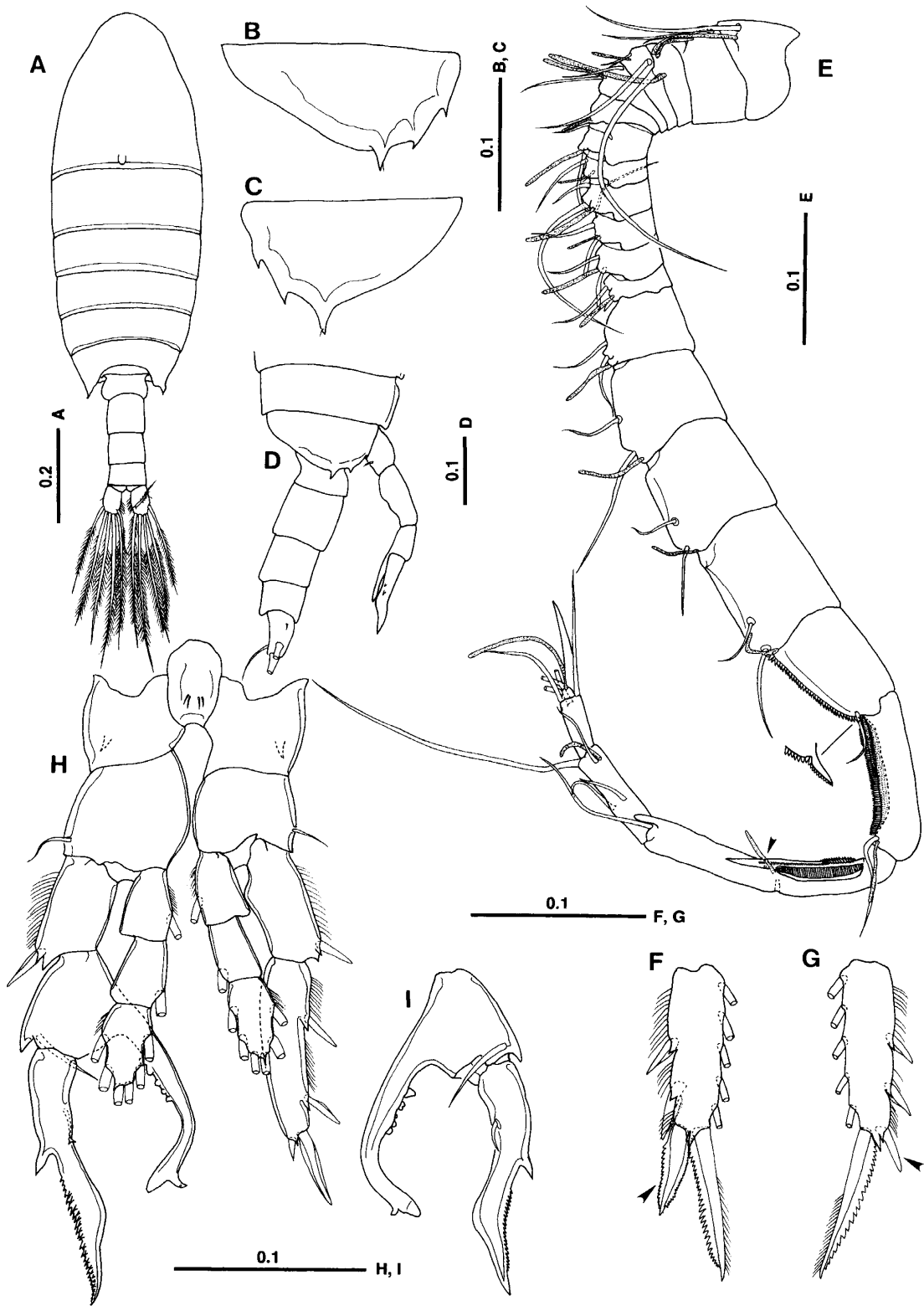


Fig. 4. *Centropages brevifurcus* Shen and Lee, 1963 from the Gulf of Thailand, female. A, leg 1; B, leg 2; C, leg 3; D, leg 4; E, leg 5, swelling at outer distal corner of first endopodal segment arrowed. Scales in mm.

drawn inwards into curved process with 2–6 round outer swellings midway and triangular inner process subterminally; third exopodal segment recurved, bearing inner seta approximately at one-seventh length, sharply pointed outer process and minute inner prominence at midlength, and 2 rows of pointed prominences along outer distal half length (see Fig. 6B); serrate distal half slightly swollen ventrally at midlength. Left leg with 3-segmented endopod and 2-segmented exopod; first exopodal segment swollen proximomedially; second exopodal segment elongate, bearing 2 spines at tip (outer one approximately 4 times as long as inner one) and 2 outer spines.

Variation. The shape and size of the three ventrolateral pairs of processes on the fifth pedigerous somite of both sexes vary somewhat among individuals. The right posterior process on the female genital operculum may be rounded or somewhat pointed at the tip. The asymmetry of male leg 4 was confirmed in all the specimens dissected. The number of outer swellings at midlength of the process on the second exopodal segment of male leg 5 ranges between two and six.

Distribution. *Centropages brevifurcus* is so far recorded only from the Luchow Peninsula of southern China (Shen and Lee 1963), the Java Sea (Mulyadi 1998), and the western part of the Gulf of Thailand (present study). Presumably the species is restricted to the tropical and subtropical coastal regions of the western Pacific.



Discussion

Examination of the present material from Thailand revealed some shortcomings in earlier descriptions (Shen and Lee 1963; Mulyadi 1998). Newly confirmed features include: (1) the cephalosome is separate from the first pediger; (2) the posterior end of the prosome of both sexes bears three ventrolateral pairs of processes; (3) the right lateral process of the female genital compound somite originates from the genital operculum and not from the somite proper; (4) the inner process of the second exopodal segment of female leg 5 is not as acutely pointed as in the original figure and is serrate along distal three-fourths of its posterior margin; (5) the second exopodal segment of right male leg 5 bears two to six rounded processes along the outer middle margin of the thumb; (6) the third exopodal segment of right male leg 5 bears a proximal seta and a minute, round prominence at midlength along the inner margin; (7) the first exopodal segment of left male leg 5 is expanded inwards proximally. This species was more precisely illustrated from the Java Sea by Mulyadi (1998) than in the original description. In his paper the above-mentioned features (1), (2), and (5) were already confirmed. The antennules and mouthparts of *C. brevifurcus* are first illustrated and described herein, according to the conventions of Huys and Boxshall (1991).

Shen and Lee (1963) pointed out the similarities between females of *C. brevifurcus* and *C. abdominalis* Sato, 1913 in having spinule patches on the genital compound somite and an outwardly curved, strong process on the right posterior corner of the prosome; however, it is not clear that these characters are homologous in the two species. On the other hand, the three ventrolateral pairs of processes of the fifth pedigers and the expanded outer distal corner of the first endopodal segment of legs 5 seem to be synapomorphies in *C. brevifurcus* and *C. trispinosus* Sewell, 1914 from southern India (Sewell 1914, 1932).

Centropages trispinosus is known only from the female, which was poorly described by Sewell (1914). The body length, the posterior prosomal corner, and leg 5 of the female are similar to those of female *C. brevifurcus*, but the third exopodal segment of leg 5 is relatively much shorter in *C. trispinosus* (ca. 1.4 times as long as the second segment) than in *C. brevifurcus* (1.7). In addition, the inner process of the second endopodal segment of female leg 5 of *C. trispinosus* is slender and pointed at the apex and lacks serration along the posterior margin. The genital compound somite carries a dorsal swelling only in *C. trispinosus*. Pending a complete redescription of both sexes, possibility cannot be excluded that this species is identical to *C. brevifurcus*.

Vervoort (1964) provisionally divided species of *Centropages* into five species groups: the *typicus*, *furcatus*, *hamatus*, *orsinii*, and *violaceus* species groups. Some new species have been added since then, and synonymies have been mostly clari-

Fig. 5. *Centropages brevifurcus* Shen and Lee, 1963 from the Gulf of Thailand, male. A, habitus, dorsal view; B, fifth pediger, right lateral view; C, fifth pediger, left lateral view; D, fourth and fifth pedigers and urosome, right lateral view; E, right antennule, rudimentary seta arrowed; F, right third exopodal segment of leg 4, distolateral spine arrowed; G, left third exopodal segment of leg 4, distolateral spine arrowed; H, leg 5, anterior view; I, second and third exopodal segments of right leg 5, posterior view. Scales in mm.

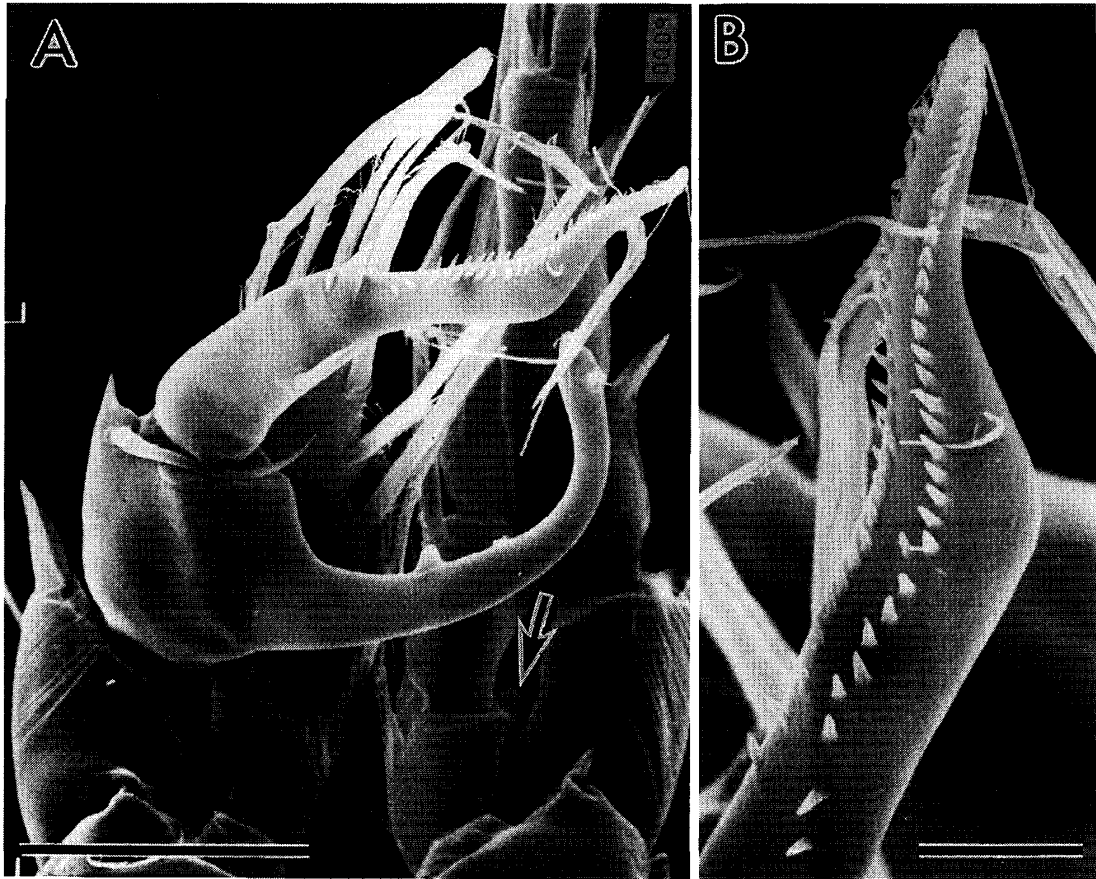


Fig. 6. SEM micrographs of *Centropages brevifurcus* Shen and Lee, 1963 from the Gulf of Thailand, male. A, leg 5, posterior view (arrow, outer distal expansion of first endopodal segment); B, distal part of third exopodal segment of right leg 5. Scales=0.1 mm (A), 0.01 mm (B).

fied by Vervoort (1964) himself, Razouls (1982), and McKinnon and Kimmerer (1988). Some of Vervoort's (1964) species groups are evidently heterogenous. *Centropages brevifurcus* was not included in any of Vervoort's (1964) groups, possibly because he might have been unaware of the original description by Shen and Lee (1963). A distinct species group comprised of *C. brevifurcus* and *C. trispinosus* may be defined as follows: posterior corners of prosome of both sexes bearing three pairs of pointed processes; legs 5 of both sexes with expansion at inner distal corner of first endopodal segment; female prosome asymmetrical posteriorly, each side with 3 acute processes increasing posteriorly in size; female genital compound somite bulbous; female leg 5 with relatively short inner extension on second exopodal segment; male urosome 4-segmented; male right leg 5 bearing exopod with recurved tip on expansion of second segment and with S-shaped third segment; male left leg 5 with distal exopodal segment bearing 2 lateral and 2 terminal short spines. In addition, asymmetry in the outer distal spines on the third exopodal segments of male leg 4 may be shared between these species. This species group is restricted to the tropical Indo-Malayan region. Although Vervoort (1964) assigned *C. trispinosus* to his *hamatus* group, this latter species group should be revised on the

basis of morphology and zoogeography.

Centropages acutus McKinnon and Dixon, 1994 from New Guinea also bears an expansion at the inner distal corner of the first endopodal segment of legs 5 of both sexes, but the unique morphology of the prosomes and antennules of both sexes and the urosome and leg 5 of the female suggests different affinities.

Acknowledgments

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