

## A Review of the Genus *Thermocyclops* (Crustacea: Copepoda: Cyclopoida) in Cambodia

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**Rachada Chaicharoen, La-orsri Sanoamuang, and Maria Hołyńska** (2011) A review of the genus *Thermocyclops* (Crustacea: Copepoda: Cyclopoida) in Cambodia. *Zoological Studies* 50(6): 780-803. Cambodia is one of the least explored areas in Southeast Asia, where very little reliable information on the freshwater copepod fauna is available. Recent and extensive collecting in 7 Cambodian provinces, from the western part of the country as far as the Mekong River, provided the material for our present paper which reviews the *Thermocyclops* fauna of Cambodia. Six species (*T. crassus*, *T. decipiens*, *T. maheensis*, *T. rylovi*, *T. vermifer*, and *T. wolterecki*) were found; and except for *T. crassus*, all of these are new records for the country. The morphology is briefly described, and the diagnostic characters are illustrated. *Thermocyclops wolterecki* is redescribed, based on specimens from Cambodia, but also from the types and other material from the type locality (Lake Lanao, the Philippines). A lectotype of *T. wolterecki* is designated here. An identification key to all *Thermocyclops* taxa so far reported from Cambodia is given. Our data suggest that the Cambodian *Thermocyclops* is linked with both the neighbouring Asian fauna and via the Malay Archipelago with the Australian fauna. <http://zoolstud.sinica.edu.tw/Journals/50.6/780.pdf>

**Key words:** Cyclopidae, Taxonomy, Zoogeography, Tropical Asia.

The 1st and so far the most comprehensive study on the cyclopid fauna of Cambodia was published by Lindberg (1952). In the ~50 samples collected by the French hydrobiologist J. Blache from 5 provinces of Cambodia, including Lake Sap (or Tonlé-Sap) and the Mekong River, Lindberg found 12 species of 8 cyclopid genera. Among those taxa 2 *Thermocyclops* species were reported: *T. crassus* (Fischer, 1853), referred to as *T. hyalinus* (Rehberg), and a new subspecies, *T. operculifer aberrans* Lindberg, 1952, described by Lindberg from Lake Sap.

The diversity of zooplankton in Lake Sap, the largest lake in Southeast Asia, was investigated by several Cambodian projects and foreign researchers (Campbell et al. 2006), yet

some publications only provided data on the species richness of copepods, without referring to generic or specific names (Nguyen and Nguyen 1991, Lamberts 2001). Ishida and Tomikawa (2007) reported a single species, *Mesocyclops thermocyclopoides* Harada 1931, from Lake Sap. Our knowledge of the cyclopid fauna of Cambodia, even when compared to neighboring countries (see Boonsom 1984, Reid and Kay 1992, Hołyńska and Vu 2000, Nam et al. 2000, Alekseev and Sanoamuang 2006), is very fragmentary.

The poor knowledge of the tropical *Thermocyclops* fauna is partly due to difficulties with identification of species, and the fact that geographically and ecologically representative collections are relatively few in tropical Asia. In

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framing a project with the goal of revising the freshwater cyclopid and calanoid fauna of Cambodia, we organized 3 collecting trips in 2007 and visited 7 provinces of the country. The present report is based on that material.

## MATERIALS AND METHODS

In total, 252 samples were analyzed from 7 provinces (Banteay Meanchey, Battambang, Siem Reap, Kampong Thom, Pursat, Kratie, and Stung Treng) of Cambodia. Collection data are given at the descriptions of the particular species, and the localities are also shown on a map (Fig. 1). Unless otherwise stated, specimens were collected by the senior author. Specimens were measured in glycerol, with bright-field and differential interference contrast optics. Drawings were made using a camera lucida on an Olympus BX50 compound microscope (Tokyo, Japan).

Telescoping segments of the prosome and urosome were measured separately, yet body length (BL) was measured as the distance between the anteriormost point of the cephalothorax and posteriormost point of the caudal ramus. The length of pediger 4 was measured as the distance between its anteriormost and posteriormost points.

Only females were identified and are described here, as the identification keys (e.g. Mirabdullayev et al. 2003) do not include characters of the male, and information on male morphology is very fragmentary.

The following abbreviations were used: enp, endopodite; exp, exopodite; P1-P4, swimming legs 1 to 4; S1, medialmost terminal caudal seta; S2, inner median terminal caudal seta; S3, outer median terminal caudal seta; S4, lateralmost terminal caudal seta; S5, dorsal caudal seta; SMNK, Staatliches Museum für Naturkunde Karlsruhe (Karlsruhe, Germany).

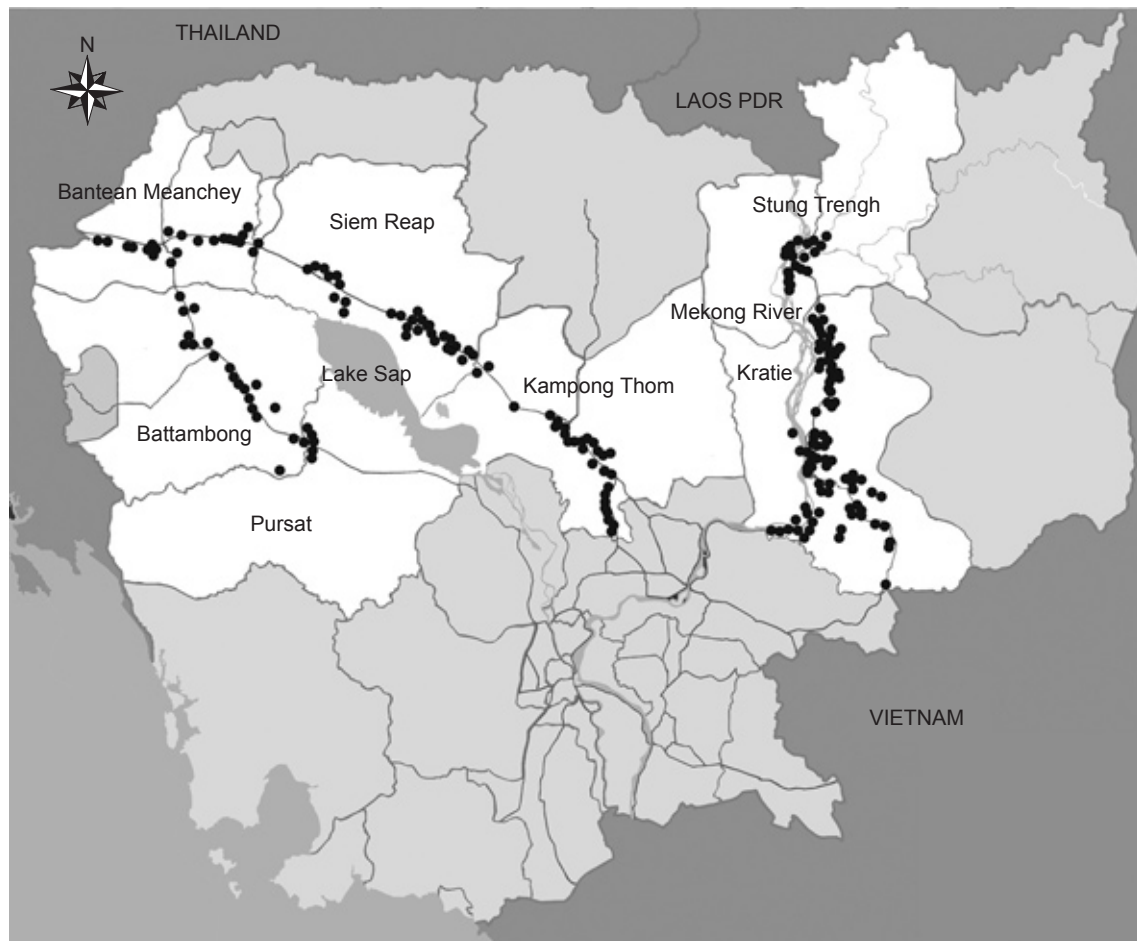


Fig. 1. Collecting localities of *Thermocyclops* species in Cambodia.

## TAXONOMY

### *Thermocyclops wolterecki* Kiefer 1938

(Figs. 2-8)

*Thermocyclops wolterecki* Kiefer 1938a: 54-98, figs. 24-28; Defaye et al. 1987: 3144-3153, figs. 30-34; Mirabdullayev et al. 2003: 271, fig. 128; Alekseev and Sanoamuang 2006: 277-290, table 2.

**Material examined:** Type material: Lectotype (female): *T. wolterecki* n. sp. Kiefer 8.5.38; Mindanao, Lanaosee Woltereck Phil. 151, 3 undissected females (lectotype marked by arrow on slide) SMNK slide 4005. Paralectotypes: *T. wolterecki* n. sp. Kiefer 8.5.38; Mindanao, Lanaosee Woltereck Phil. 151, 2 undissected females, SMNK slide 4005. *T. wolterecki* n. sp., 1 undissected female (together with 1 undissected female of *T. hyalinus*), Kiefer 8.5.38; Mindanao, Lanaosee Woltereck Phil. 151, SMNK slide 4007 (Franke 1989).

**Other material:** The Philippines: *T. wolterecki* Philippines, Mindanao, Lanaosee, coll. Woltereck (Phil. 151), G: 1092 SMNK, glas 4905 (Franke 1989), 1 ♀. Cambodia: Kampong Cham-Kratie border, Dambei Dist., canal, 12°07'N, 105°53'E, 9 June 2007, 1 ♀, slide CB5(1A,B); Kratie Prov., Bos Leav Dist., Ta Aim, stream, 12°21'N, 106°03'E, 10 June 2007, 1 ♀, slide CB11(1A,B); Kratie Prov., Kratie Dist., Kratie, stream, 12°42'N, 106°07'E, 10 June 2007, 1 ♀, CB21(1A,B); Stung Treng Prov., Stung Treng Dist., small pond, 13°31'N, 105°59'E, 11 June 2007, 1 ♀, slide CB36(1A,B); Stung Treng Prov., Stung Treng Dist., temporary pond, 13°16'N, 106°06'E, 11 June 2007, 1 ♀, slide CB46(1A,B); Siem Reap Prov., Sotnikum Dist., Lveate, canal, 13°24'N 103°47'E, 26 Oct. 2007, 10 ♀♀, slide CB55(1A,B-10A,B); Kampong Thom Prov., Baray Dist., Sroyong, canal, 12°12'N, 105°07'E, 14 June 2007, 1 female, slide CB71(1A,B); Pursat Prov., 12°41'N, 103°36'E, 26 Oct. 2007, 10 ♀♀, slide CB99(1A,B-10A,B).

**Redescription** (based on specimens from Lake Lanao): Female length 570-620 μm (lectotype ~570 μm); cephalothorax width/genital double-somite width: 2.68-3.18 (lectotype 2.68).

Pediger 5 without ornamentation (Fig. 2A, C). Genital double-somite (Fig. 2C, D) as long as wide or slightly longer. Lateral arms of seminal receptacle (Fig. 2C, D) slightly curved posteriorly. Posterior margin of anal somite with few spinules ventrally (Fig. 2B). Caudal rami (Fig. 2B) 2.2-2.5-times as long as wide (in lectotype

2.31), without hairs on medial margin. No spinules at implantation of lateral seta and S4. S1/caudal rami = 2.2-2.4; S1/S4 = 2.3-2.5; S1/S5 = 1.6-1.8 (in lectotype 2.36, 2.33, and 1.45, respectively). Tip of S2 curved ventrally (Fig. 2B).

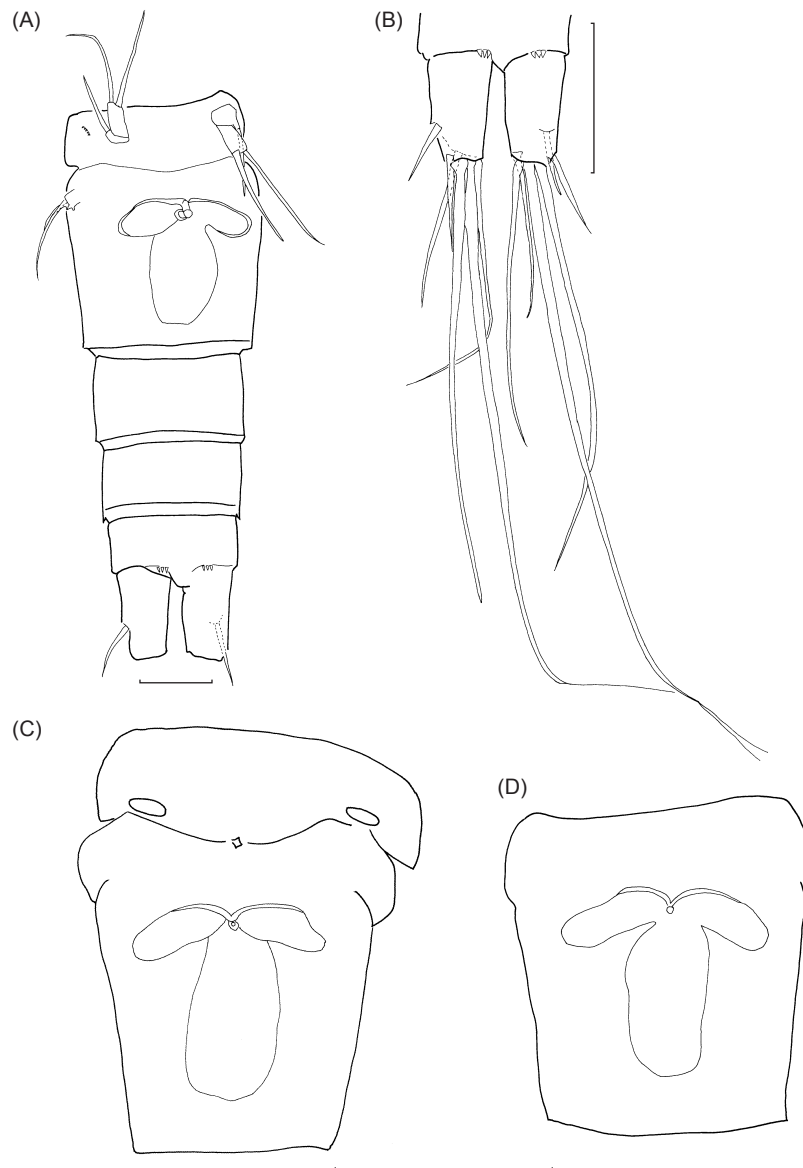
Antennule 17-segmented (Figs. 3A, B, 6A, B), reaching pediger 2. Armature formula: 8, 4, 2, 6, 4, 1+spine, 2, 1, 1, 0, 1, 1+aesthetasc, 0, 1, 2, 2+aesthetasc, 7+aesthetasc. Last 2 segments (Figs. 3B, 6B) bearing hyaline membrane, membrane on segment 17 not extending beyond insertion of medial seta, without notch. Aesthetascs on segments 12 and 16 reaching distal margin of segments 14 and 17, respectively. Lateral seta on segment 15 (Figs. 3B, 6B) not reaching middle of segment 16. Antennal enp2 with 9 setae. Posterior ornamentation of coxobasis (Figs. 3C, 6D): robust spinules in longitudinal and oblique rows near lateral margin; group of tiny spinules between oblique and longitudinal rows; few spinules on medial margin near base. Anterior surface of coxobasis (Figs. 3D, 6E) armed with spinules in short longitudinal row in proximal 1/2 of segment near lateral margin.

Mandible (Fig. 3E) with palp bearing 2 long and 1 short setae, no ornamentation near palp. Maxillule (Fig. 3F) with armature common in family, no ornamentation on maxillary palp. Maxilla (Fig. 3G) with syncoxopodite, basipodite, and 2-segmented endopodite; armature formula: 5 (syncoxopodite with 3 endites, 2, 1, and 2 setae, respectively), 2, 2, and 3. No ornamentation on syncoxopodite.

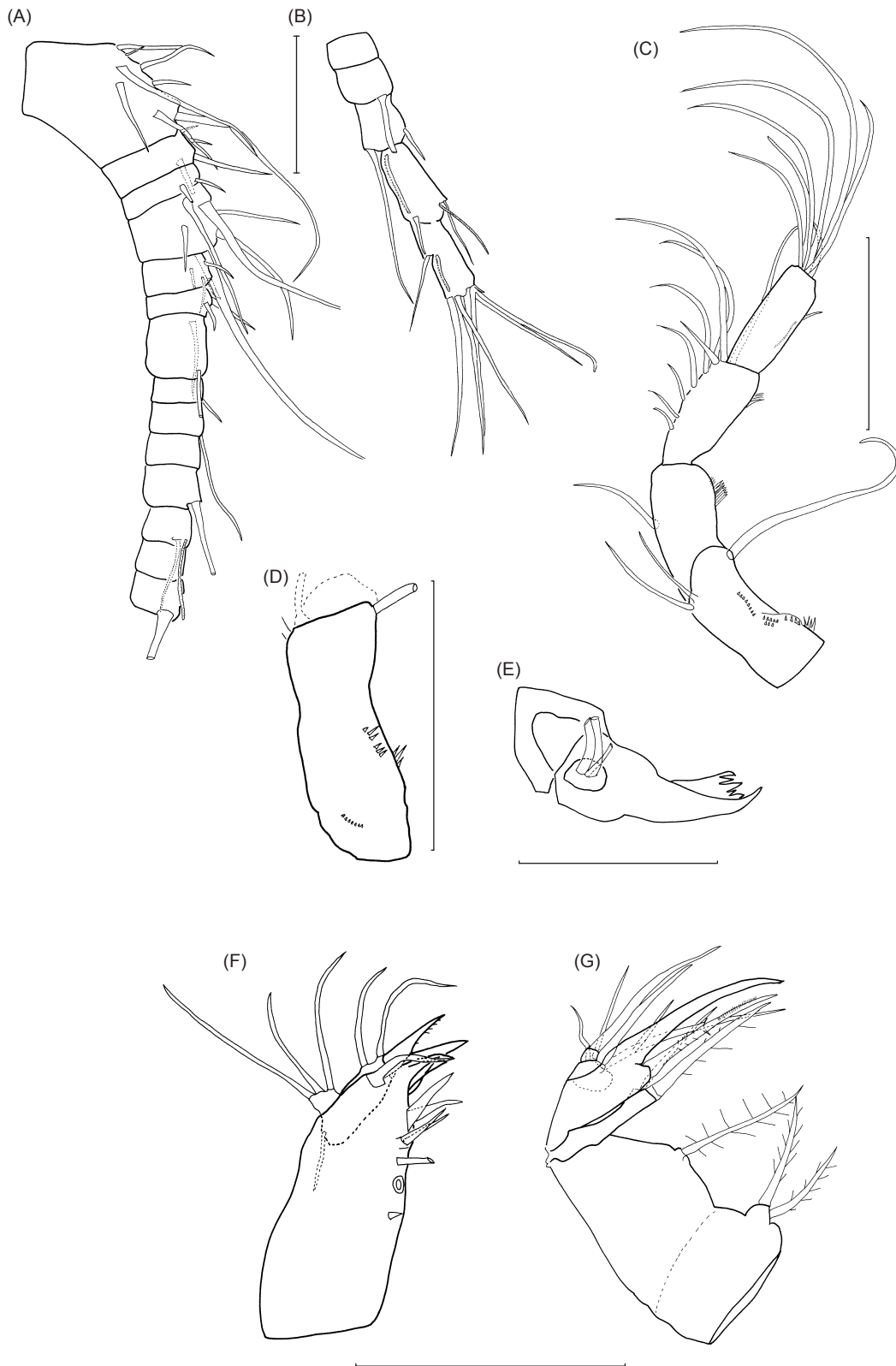
Medial spine of P1 basipodite (Fig. 4 A) reaching distal margin of endopodite 2. Few short setules present on lateral edge of spine. Medial expansion of basipodites of P1-P3 with hairs, no ornamentation on P4 (Fig. 4D). Distal protuberances of P1-P4 couplers (Fig. 4A-D) rounded. Spinules robust on protuberances of P1-P3, and tiny on protuberances of P4. P1-P3 couplers anteriorly and posteriorly bare. P4 coupler with 1 row of hairs near distal margin and 1 row of spinule-like elements in middle (Fig. 4D) in specimens from Lake Lanao. On posterior surface on P4 coxopodite, many spinules along distal margin, group of spinules arranged in row at laterodistal angle, and many small spinules near proximal margin. P4 enp3 (Fig. 4D) 3.12-3.69 (in lectotype ~3.5)-times as long as wide; of apical spines, medial one 2.0-2.4-times as long as lateral, medial spine 0.77-0.89-times as long as endopodite 3 (in lectotype 0.83). P5 (Fig. 1A) typical for genus.

**Variability:** Variation in the morphometric traits is shown in tables 1, 2. The Philippine and Cambodian populations differ in some morphometric and qualitative morphological characters. Twenty-three morphometric characters were measured in the Cambodian population and in material from the type locality, Lake Lanao (Tables 1, 2). Dice-Leraas diagrams (Fig. 5) point to the separation of the 2 populations in the lengths of the body, caudal rami, inner terminal caudal seta (S2), and dorsal caudal seta (S5). A *t*-test confirmed significant differences in the means of these traits (body length:  $n = 15$ ,  $p < 0.01$ ;

length of caudal rami:  $n = 15$ ,  $p < 0.01$ ; length of s2:  $n = 15$ ,  $p < 0.01$ ; and length of s5:  $n = 15$ ,  $p < 0.01$ ) between Cambodian and Philippine females. The qualitative morphological characters of the Cambodian specimens however almost fully match those of females from Lake Lanao, with only the ornamentation of the P4 coupler and tip of S2 differing between them. In Cambodian females (Fig. 7B), the P4 coupler bears 2 rows of hairs (in the middle and next to the distal margin), while in Philippine specimens, 1 hair-row appears near the distal margin and 1 row of spinule-like elements is present in the middle (Fig. 4D). The tip of S2 is



**Fig. 2.** *Thermocyclops wolterecki*, female (Lake Lanao, the Philippines). (A) Urosome, ventral view; (B) caudal rami, ventral view; (C, D) genital double-somite, ventral view. (A, B) SMNK Glas 4905; (C, D) paralectotypes SMNK 4005. Scale bars = 50  $\mu$ m.



**Fig. 3.** *Thermocyclops wolterecki*, female (Lake Lanao, the Philippines). (A, B) Antennule, anterior view: (A) segments 1-14; (B) segments 13-17; (C) antenna, posterior view; (D) antennal coxobasis, anterior view; (E) mandible; (F) maxillule, posterior view; (G) maxilla, anterior view. (A-G) SMNK Glas 4905. Scale bars = 50  $\mu$ m.

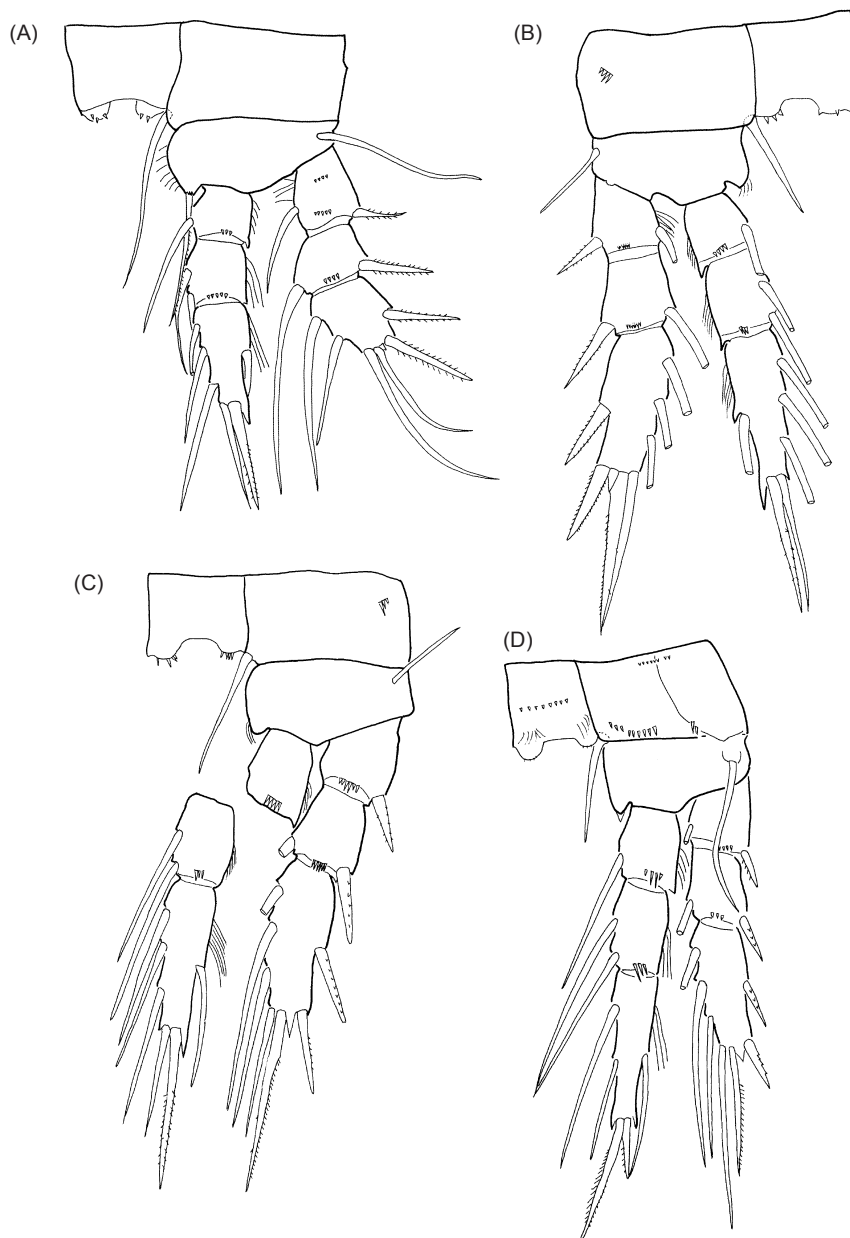
ventrally curved in Philippine (Fig. 2B) but straight in Cambodian specimens (Fig. 7C).

**Remarks:** Kiefer (1938a) originally described the species from Lake Lanao (Mindanao, the Philippines). He did not designate a holotype; therefore herein we designated a lectotype from among the syntypes (Fig. 8). Defaye et al. (1987) reported *T. wolterecki* from Papua New Guinea, and Alekseev and Sanoamuang (2006) found it in Thailand. The geographic distribution of *T. wolterecki* seems to be restricted to Asia [The

Philippines (Mindanao), Thailand, and Cambodia] and Papua New Guinea.

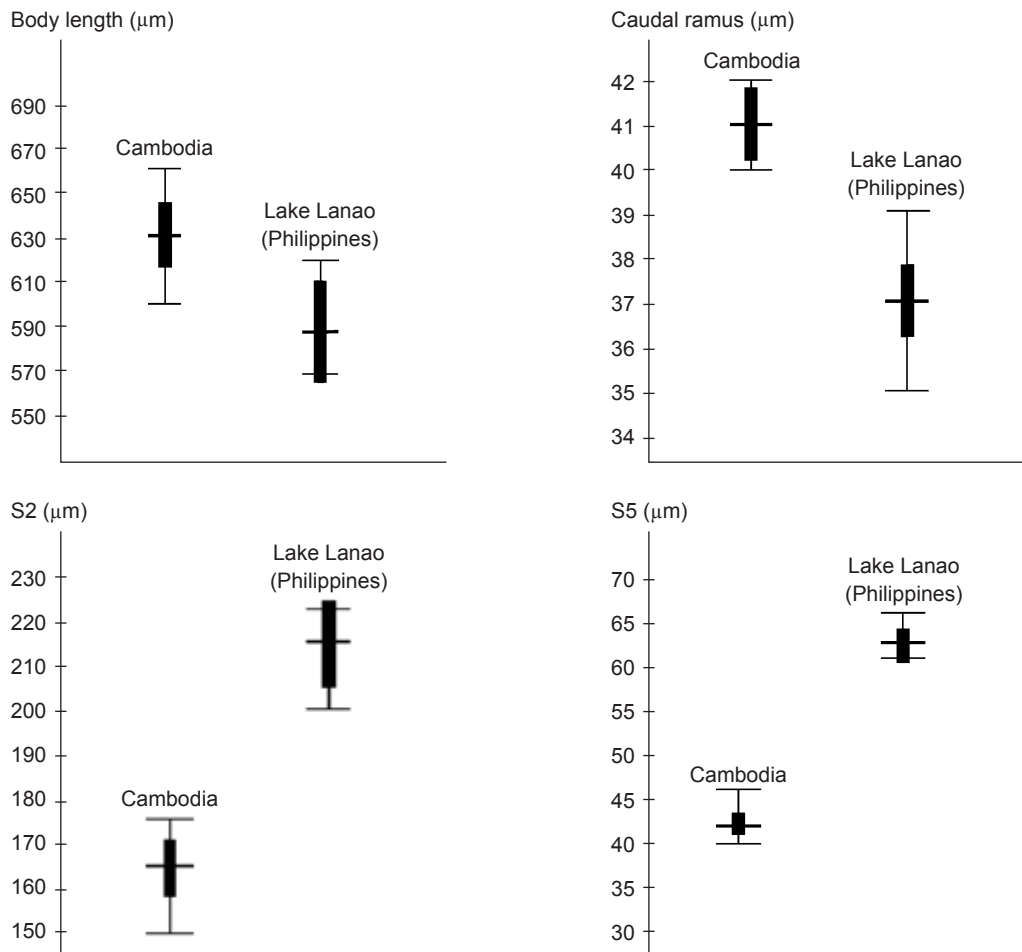
Four morphometric characters (lengths of the body, caudal rami, and S2 and S5 caudal setae), and 2 qualitative characters (ornamentation of the P4 coupler and tip of S2 caudal setae) significantly differed between the Cambodian and Lake Lanao populations.

Lake Lanao was supposedly formed in the late Tertiary. It is the deepest lake in the Philippines, with a maximum depth of 112 m, and



**Fig. 4.** *Thermocyclops wolterecki*, female (Lake Lanao, the Philippines). (A) P1, posterior view; (B) P2, posterior view; (C) P3, posterior view; (D) P4, posterior view. (A-D) SMNK Glas 4905. Scale bar = 50  $\mu$ m.





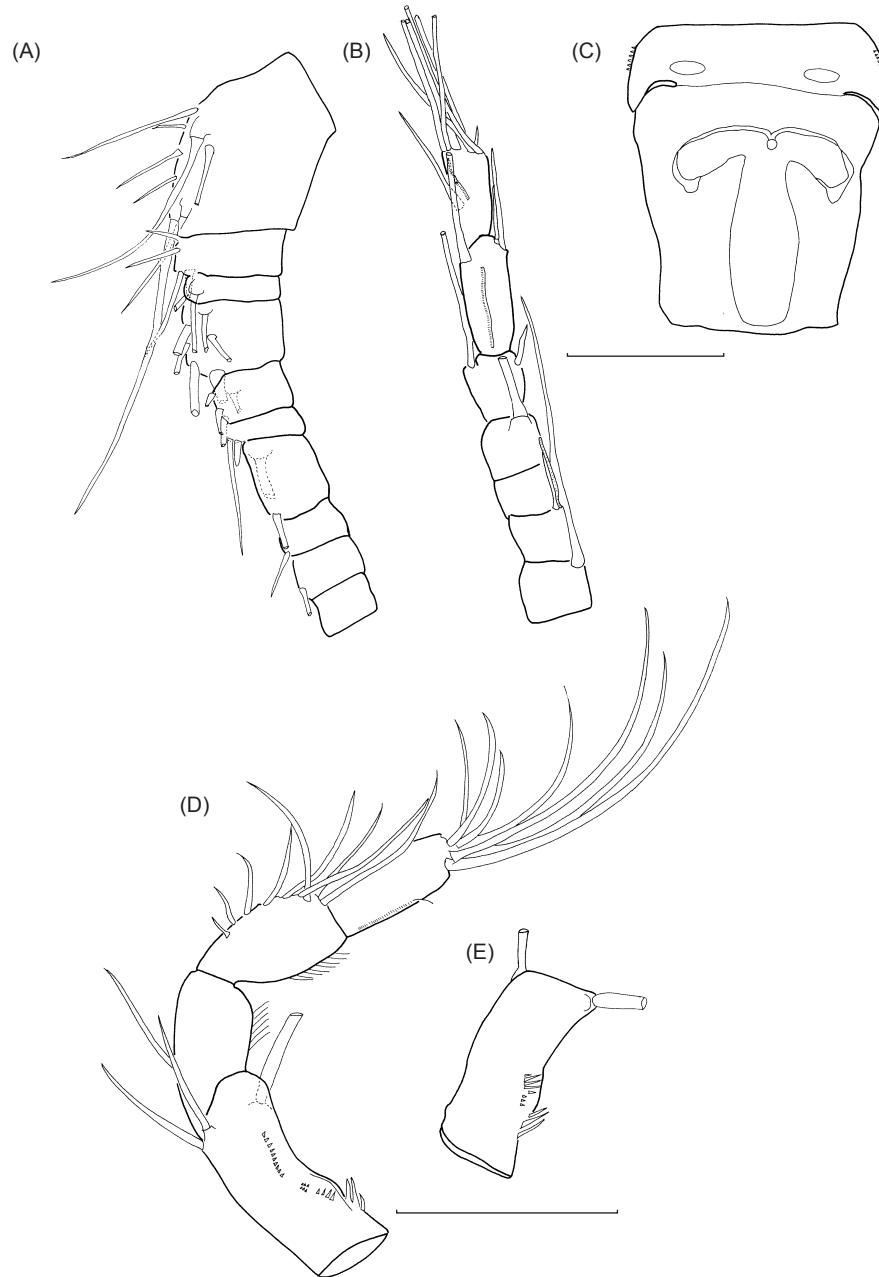
**Fig. 5.** Comparison of morphometric traits of Lake Lanao and Cambodian populations of *Thermocyclops wolterecki*. Diagrams show the mean, range, and confidence intervals ( $\pm 2$  standard errors).

**Table 1.** Morphometric data on *Thermocyclops wolterecki* in Lake Lanao (Mindanao, the Philippines, SMNK) and Cambodia (CB 55). BL, body length; C, Cambodia; Cep, cephalothorax; CR, caudal ramus; GS, genital double-somite; l, length; nd, no data; P, Philippines; Pro, prosome; Uro, urosome; w, width. M, mean; SD, standard deviation; SE, standard error

No	BL ( $\mu\text{m}$ )		Cep l/w		Pro l ( $\mu\text{m}$ )		GS (l/w)		GS w/Cep w		Uro l ( $\mu\text{m}$ )		Pro l/Uro l		CR l ( $\mu\text{m}$ )		CR l/w	
	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P
1	610	570	1.15	1.01	415	357.5	1.35	1.11	0.36	0.36	285	232	1.46	1.81	40	39	2.00	2.43
2	660	590	1.16	1.01	452.5	362.5	1.42	1.11	0.40	0.36	287.5	235	1.57	1.47	40	38	2.16	2.37
3	660	570	1.15	1.02	422.5	362.5	1.26	1.10	0.35	0.35	297.5	240	1.42	1.51	42	37	2.26	2.31
4	640	620	1.15	1.06	417.5	362.5	1.52	1.11	0.36	0.35	290	232	1.43	1.56	40	35	2.00	2.50
5	660	nd	1.21	nd	355	nd	1.35	1.00	0.42	nd	297.5	228	1.05	nd	42	38	2.10	2.31
6	610	-	1.17	-	417.5	-	1.46	-	0.35	-	302.5	-	1.38	-	44	-	2.22	-
7	610	-	1.15	-	407.5	-	1.28	-	0.34	-	300	-	1.35	-	40	-	2.10	-
8	620	-	1.15	-	412.5	-	1.25	-	0.33	-	282.5	-	1.46	-	40	-	2.10	-
9	600	-	1.22	-	352.5	-	1.17	-	0.39	-	297.5	-	1.18	-	40	-	2.10	-
10	630	-	1.16	-	387.5	-	1.25	-	0.35	-	287.5	-	1.34	-	42	-	2.10	-
SE	7.45	11.8	0.01	0.02	9.77	1.25	0.03	0.02	0/01	0.002	2.22	1.98	0.05	0.08	0.45	0.68	0.03	0.04
SD	23.57	23.6	0.03	0.04	30.89	2.5	0.11	0.05	0.03	0.01	7.02	4.41	0.15	0.15	1.41	1.52	0.08	0.08
M	630	587.5	1.17	1.05	404	361.2	1.33	1.09	0.37	0.35	293	233.5	1.37	1.58	41	37.4	2.11	2.38

is home to many endemic invertebrate and fish species, e.g., 18 endemic cyprinid species (Myers 1960, Frey 1969). In contrast, in Cambodia, *T. wolterecki* was collected from small, shallow water bodies such as ponds, rice paddies, and canals with some vegetation along the edges. Literature data suggest that some morphometric characters can be environment-dependent. Large-scale

comparisons made in *Cyclops scutifer* G. O. Sars from Eurasia and North America (Elgmork and Halvorsen 1988) showed that morphometric traits were correlated with environmental factors such as depth, temperature, and trophic condition. Relationships between the habitat and different morphological characters were also found in other cyclopid taxa. *Mesocyclops leuckarti*



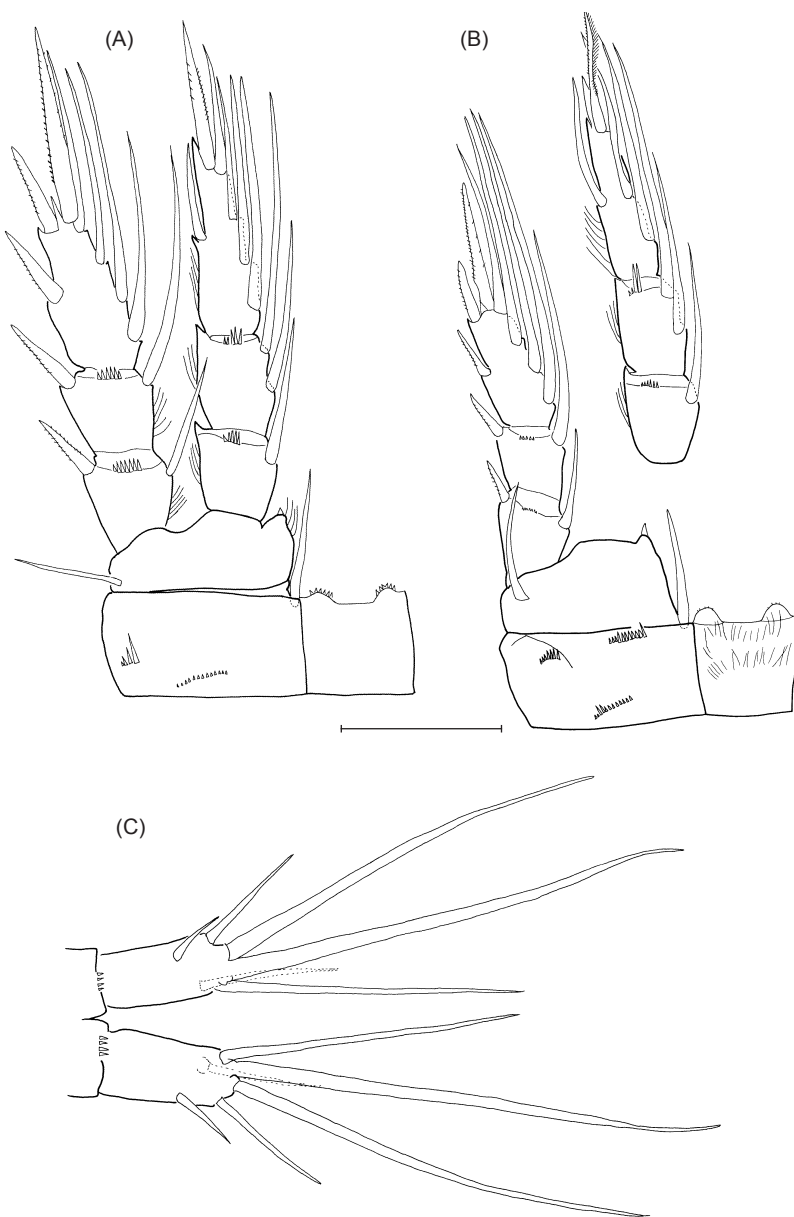
**Fig. 6.** *Thermocyclops wolterecki*, female (Cambodia). (A, B) Antennule, anterior view: (A) segments 1-10; (B) segments 11-17; (C) pediger 5 and genital double-somite, ventral view; (D, E) antenna: (D) posterior view; (E) coxobasis, anterior view. (A-E) Locality CB99. Scale bars = 50  $\mu\text{m}$ .



*bodanicola* (population from Lake Constance, Germany) (Kiefer 1938b), a “subspecies” of *M. leuckarti*, showed a smaller body length and relatively longer caudal rami and caudal setae among other traits. However, the occurrence of intermediate forms, the geographical distribution, and successful hybridization of the “*bodanicola*” and typical *leuckarti* forms (Einsle 1968, Kiefer 1978) indicated that *M. leuckarti bodanicola* was a pelagic ecotype rather than a subspecies of *M. leuckarti* (Holyńska et al. 2003). Holyńska (1997) also reported intraspecific variation in *M. dissimilis*,

where the littoral form (Lake Kitaura, Honshu, Japan) showed a larger body length, relatively longer medial spine but shorter lateral seta on P5, as well as shorter caudal rami, P4 enp3, and dorsal caudal seta, compared to a pelagic population (Lake Biwa, Honshu, Japan). Holyńska interpreted the differences as adaptations to the pelagic/littoral mode of life. In *T. kawamurai*, 1940, intraspecific variation was reported in both the body ratios and spinule ornamentation of the P3 coupler (Mirabdullayev 2006).

We suppose that curved or straight tips of



**Fig. 7.** *Thermocyclops wolterecki*, female (Cambodia). (A) P3, posterior view; (B) P4, posterior view; (C) caudal rami and setae, ventral view. (A-C) Locality CB99. Scale bar = 50  $\mu$ m.

S2 caudal setae are presumably an environment-dependent character, which vary from straight tips in the littoral population (Cambodia) to strongly curved tips in a pelagic habitat (Lake Lanao). More data are needed on the morphometrics, and S2 and P4 coupler morphology in both the littoral and pelagic populations in Lake Lanao and Cambodia to answer the following questions: Do the littoral populations of *T. wolterecki* in Lake Lanao have the same morphology as the small-water-body populations in Cambodia?; and Do forms with intermediate morphologies exist?



**Fig. 8.** Position of the syntypes of *Thermocyclops wolterecki* on slide SMNK 4105. The lectotype designated herein is marked with an arrow.

***Thermocyclops maheensis* (Lindberg, 1941)**  
(Figs. 9-12)

*Mesocyclops (Thermocyclops) maheensis* Lindberg 1941: 259-265, fig. 1, table 1; Herbst 1986: 165-180; *Thermocyclops maheensis* Mirabdullayev et al. 2003: 246, fig. 113; Alekseev and Sanoamuang 2006: 277-290, table 2.

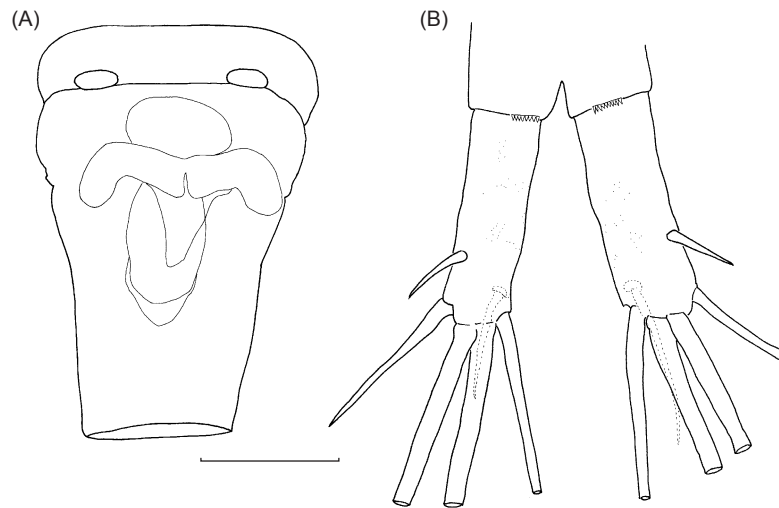
**Material examined:** Cambodia: Kratie Prov., Sambo Dist., Kbal Damrey, pond, 12°50'N, 106°10'E, 14 Feb. 2007, 1 ♀, slide CB20(1A,B); Kratie Prov., pond, 12°51'N, 106°11'E, 14 Feb. 2007, 1 ♀, slide CB21(1A,B); Stung Treng Prov., irrigation canal, 13°31'N, 105°59'E, 15 June 2007, 1 ♀, slide CB31(1A,B); Stung Treng Prov., temporary pond, 13°19'N, 106°06'E, 12 June 2007, 1 ♀ slide CB45(1A,B); Stung Treng Prov., pond, 13°16'N, 106°06'E, 12 June 2007, 1 ♀, slide CB46(1A,B).

**Diagnosis:** Female (Cambodia). Pediger 5 without lateral hairs or spinules (Fig. 9A). Seminal receptacle cruciform, lateral arms curved posteriorly. Caudal rami (Fig. 9B) with pits on ventral surface, no medial hairs. No spinules at implantation of lateral seta or S4. Tip of S2 varying from straight to strongly curved ventrally.

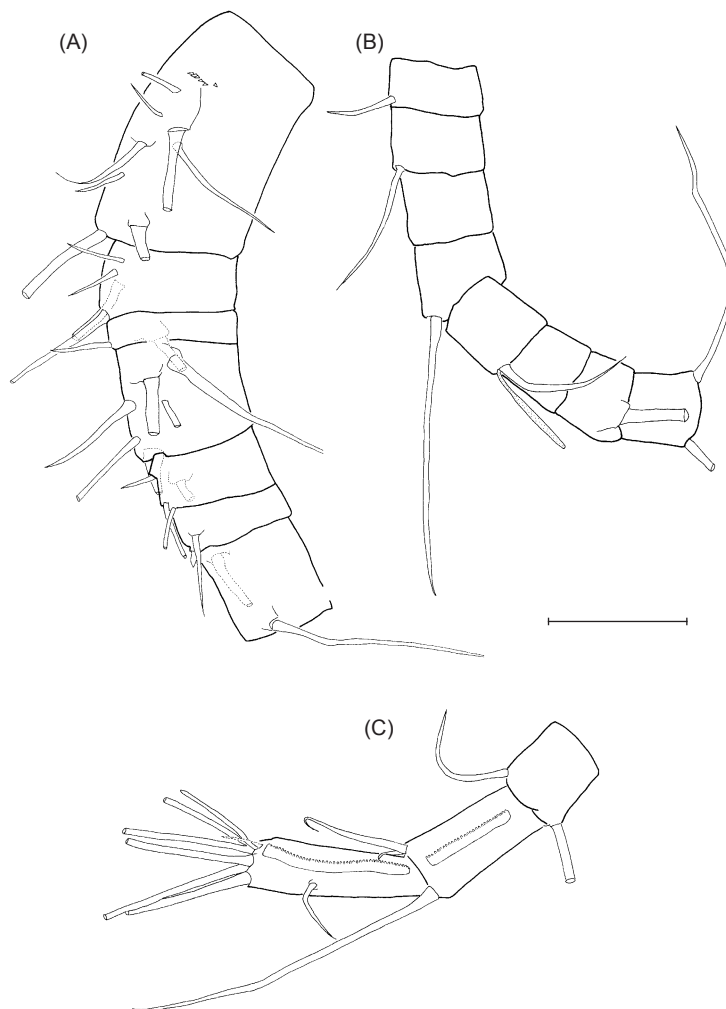
Antennule (Fig. 10A-C) 17-segmented, reaching posterior margin of pediger 4. Hyaline membrane on last segment extending beyond insertion of medial seta of segment, without notch. Antennal (Fig. 11B) enp2 with 7 setae.

**Table 2.** Morphometric data on *Thermocyclops wolterecki* in Lake Lanao (Mindanao, the Philippines, SMNK) and Cambodia (CB 55). C, Cambodia; CR, length of caudal ramus; m/l, medial spine/lateral spine of P4 endopodite 3; P, Philippines; P4 enp3, P4 endopodite 3 length/width; S1, length of medialmost terminal caudal seta; S2, length of inner median terminal caudal seta; S3, length of outer median terminal caudal seta; S4, length of lateralmost terminal caudal seta; S5, length of dorsal caudal seta; S6: length of lateral caudal seta; SE, standard error; M, mean; SD, standard deviation

No	S1 (µm)		S2 (µm)		S3 (µm)		S4 (µm)		S5 (µm)		S6 (µm)		S1/CR		S1/S4		S1/S5		P4 enp3		m/l	
	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P
1	105	87	162	207	150	150	45	37.5	40	63	20	24	2.6	2.2	2.33	2.33	2.63	1.39	3.12	3.58	2.00	2.05
2	100	87	160	200	138	140	45	37.5	44	61	20	26	2.5	2.3	2.22	2.33	2.27	1.43	3.33	2.98	1.95	1.89
3	110	87	175	222	150	148	45	37.5	40	60	22	25	2.6	2.4	2.44	2.33	2.75	1.46	3.2	3.50	1.90	1.94
4	100	87	172	220	150	143	45	37.5	40	60	20	24	2.5	2.5	2.22	2.33	2.5	1.46	3.33	3.08	2.00	2.0
5	103	95	170	222	150	150	48	36	40	65	22	28	2.4	2.5	2.14	2.64	2.56	1.46	3.18	3.41	1.90	2.1
6	105	-	172.5	-	150	-	42.5	-	39	-	20	-	2.39	-	2.47	-	2.69	-	3.42	-	1.95	-
7	100	-	175	-	153	-	42.5	-	40	-	20	-	2.50	-	2.35	-	2.5	-	3.42	-	2.00	-
8	100	-	162.5	-	143	-	47.5	-	40	-	20	-	2.50	-	2.11	-	2.5	-	3.5	-	1.90	-
9	103	-	162.5	-	133	-	45	-	43	-	22.5	-	2.56	-	2.28	-	2.38	-	3.42	-	1.90	-
10	100	-	150	-	138	-	47.5	-	40	-	20	-	2.38	-	2.11	-	2.5	-	3.2	-	2.10	-
SE	1.05	1.5	2.56	4.58	2.25	2.04	0.61	0.3	0.5	0.97	0.38	0.7	0.03	0.05	0.03	0.06	0.04	0.01	0.04	0.12	0.02	0.04
SD	3.33	3.3	8.1	10.2	7.12	4.54	1.92	0.7	1.5	2.17	1.21	1.6	0.08	0.12	0.13	0.14	0.14	0.03	0.13	0.27	0.07	0.09
M	103	89	166.3	214.5	145	146	45.3	37	40	61.8	20.8	25.4	2.50	2.38	2.27	2.39	2.53	1.44	3.31	3.31	1.96	2.00



**Fig. 9.** *Thermocyclops maheensis*, female (Cambodia). (A) Pediger 5 and genital double-somite, ventral view; (B) caudal rami, ventral view. (A) Locality CB21, (B) locality CB20. Scale bar = 50  $\mu$ m.

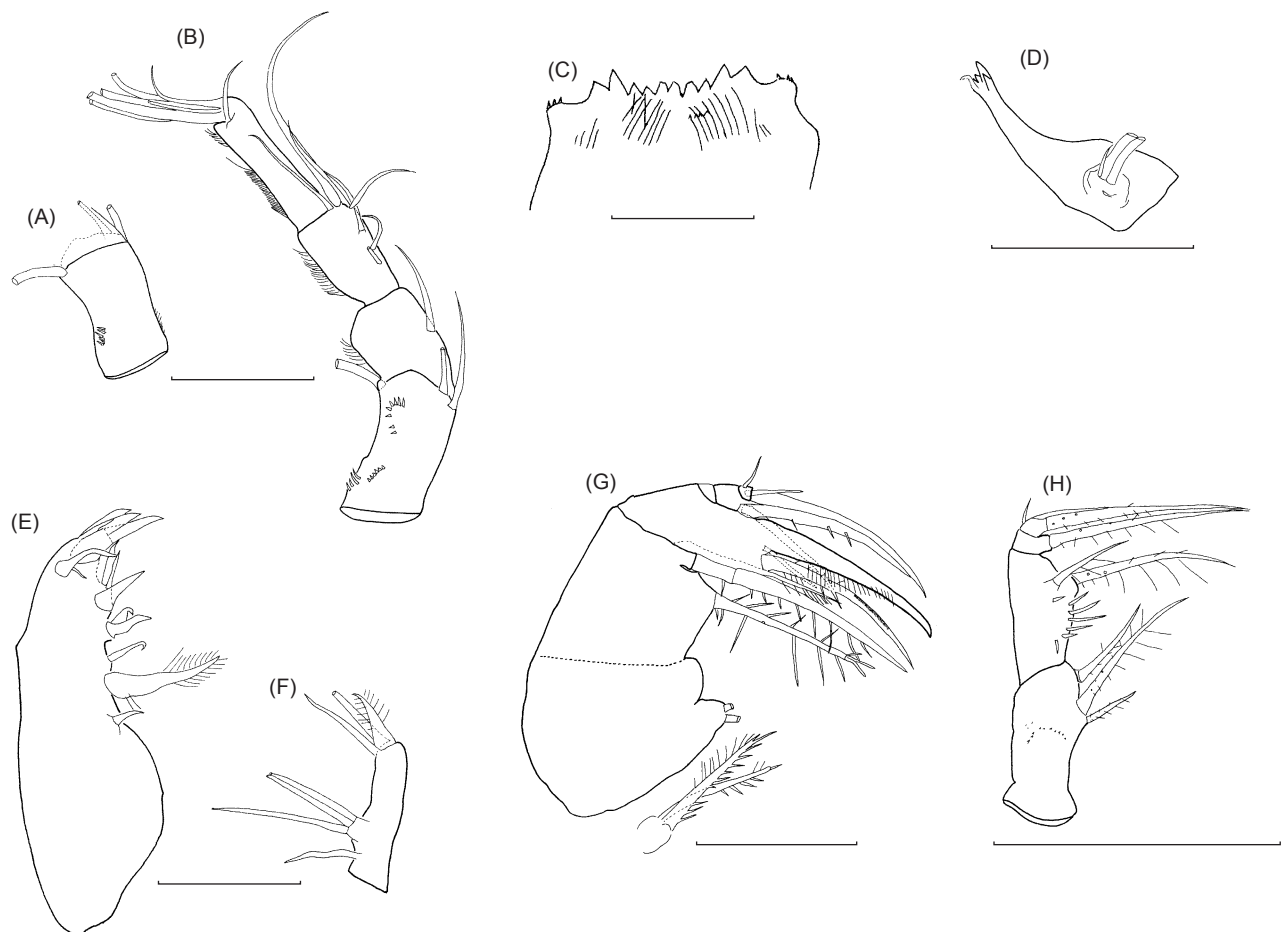


**Fig. 10.** *Thermocyclops maheensis*, female (Cambodia). (A-C) Antennule, anterior view: (A) segments 1-7; (B) segments 8-15; (C) segments 15-17. (A-C) Locality CB21. Scale bar = 50  $\mu$ m.

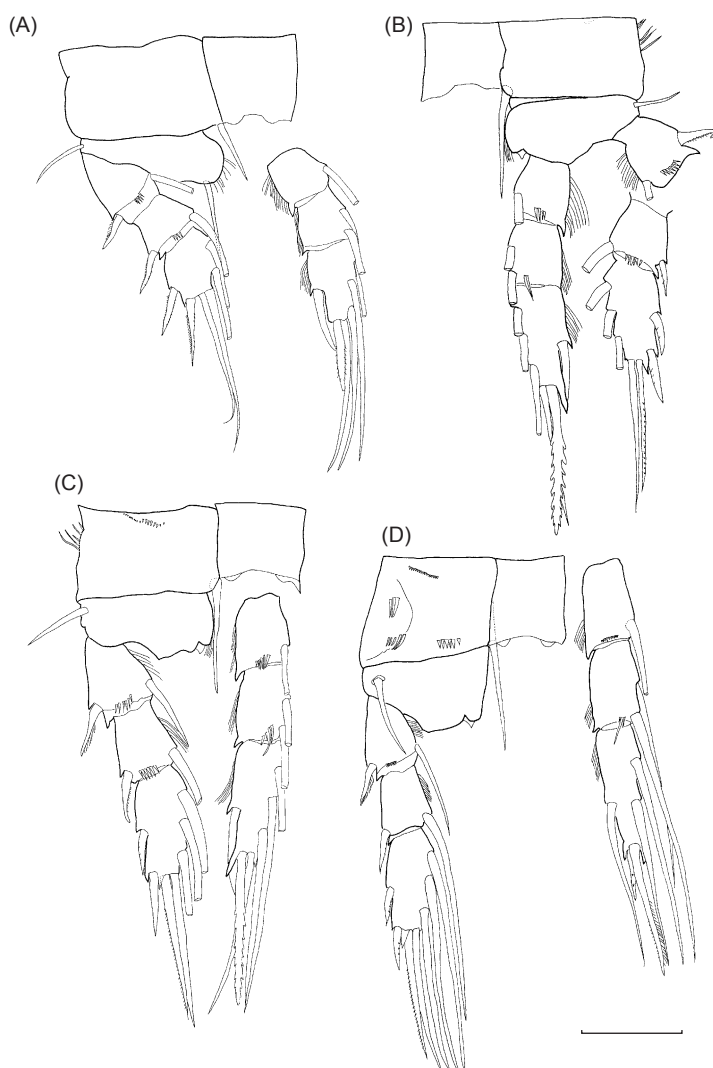
Posterior ornamentation of antennal coxobasis (Fig. 11B): 8-14 robust spinules in longitudinal row and 5 or 6 spinules in oblique row near lateral margin; group of tiny spinules between oblique and longitudinal rows absent (usually present in *Thermocyclops*); few spinules on medial margin near base. Antennal coxobasis (Fig. 11A) anteriorly with spinules in short longitudinal row in proximal 1/2 of segment near lateral margin. Lateral protuberances of labrum with small teeth (Fig. 11C), distal fringe hairs in groups. Palp of mandible (Fig. 11D) bearing 2 long and 1 short setae, no ornamentation near palp. Maxillule (Fig. 11E) with armature common in family, maxillulary palp (Fig. 11F) without ornamentation. Syncoxopodite of maxilla (Fig. 11G) without spinule ornamentation. Syncoxopodite of maxilliped (Fig. 11H) with transverse rows of spinules in middle of segment.

Medial spine of P1 basipodite (Fig. 12A) reaching distal margin of enp2. Medial expansion of basipodite of P1-P3 pilose (Fig. 12A-C), that of P4 bare (Fig. 12D). Distal protuberances of P1-P4 couplers (Fig. 12A-D) rounded and without spinules. P1-P4 couplers anteriorly and posteriorly bare. P5 typical for genus. For morphometric data see table 3.

*Remarks:* Cambodian females differ from Indian specimens (Lindberg 1941, Mirabdullayev et al. 2003) in 3 characters. Tips of the S2 caudal setae are strongly curved in Indian specimens, yet they vary from straight to strongly curved in the Cambodian population. In Cambodian females, the medial expansion of the basipodite is pilose on P1-P3 and bare on P4, while in the Mysore population, the basipodite is pilose on P1 and bare on P2-P4. The anal somite ventrally bears 9 or 10 spinules on the posterior margin in Cambodian



**Fig. 11.** *Thermocyclops maheensis*, female (Cambodia). (A) Antennal coxobasis, anterior view; (B) antenna, posterior view; (C) labrum; (D) mandible; (E, F) maxillule: (E) maxillule, posterior view; (F) maxillulary palp, anterior view; (G) maxilla, anterior view, setae on the proximalmost endite of the syncoxopodite are separately figured; (H) maxilliped, anterior view. (A-H) Locality CB21. Scale bars = 50  $\mu\text{m}$ .



**Fig. 12.** *Thermocyclops maheensis*, female (Cambodia). (A) P1, posterior view; (B) P2, posterior view; (C) P3, posterior view; (D) P4, posterior view. (A) Locality CB21, (B-D) locality CB20. Scale bar = 50  $\mu$ m.

**Table 3.** Morphometric data on *Thermocyclops* (female) from Cambodia. BL, body length; GS(l/w), genital double-somite length/width; Cep/GS, cephalothorax width/genital double-somite width; CR(l/w), caudal rami length/width; S1/CR, length of medialmost terminal caudal seta/ length of caudal rami; S1/S4, length of medialmost terminal caudal seta/length of lateralmost terminal caudal seta; S1/S5, length of medialmost terminal caudal seta/length of dorsal caudal seta; P4 enp3 l/w, P4 endopodite 3 length/width; P4 enp3 spines, P4 endopodite 3 medial apical spine/lateral apical spine; P4 enp 3 spine/segment, medial apical spine of P4 enp 3/P4 enp3 length

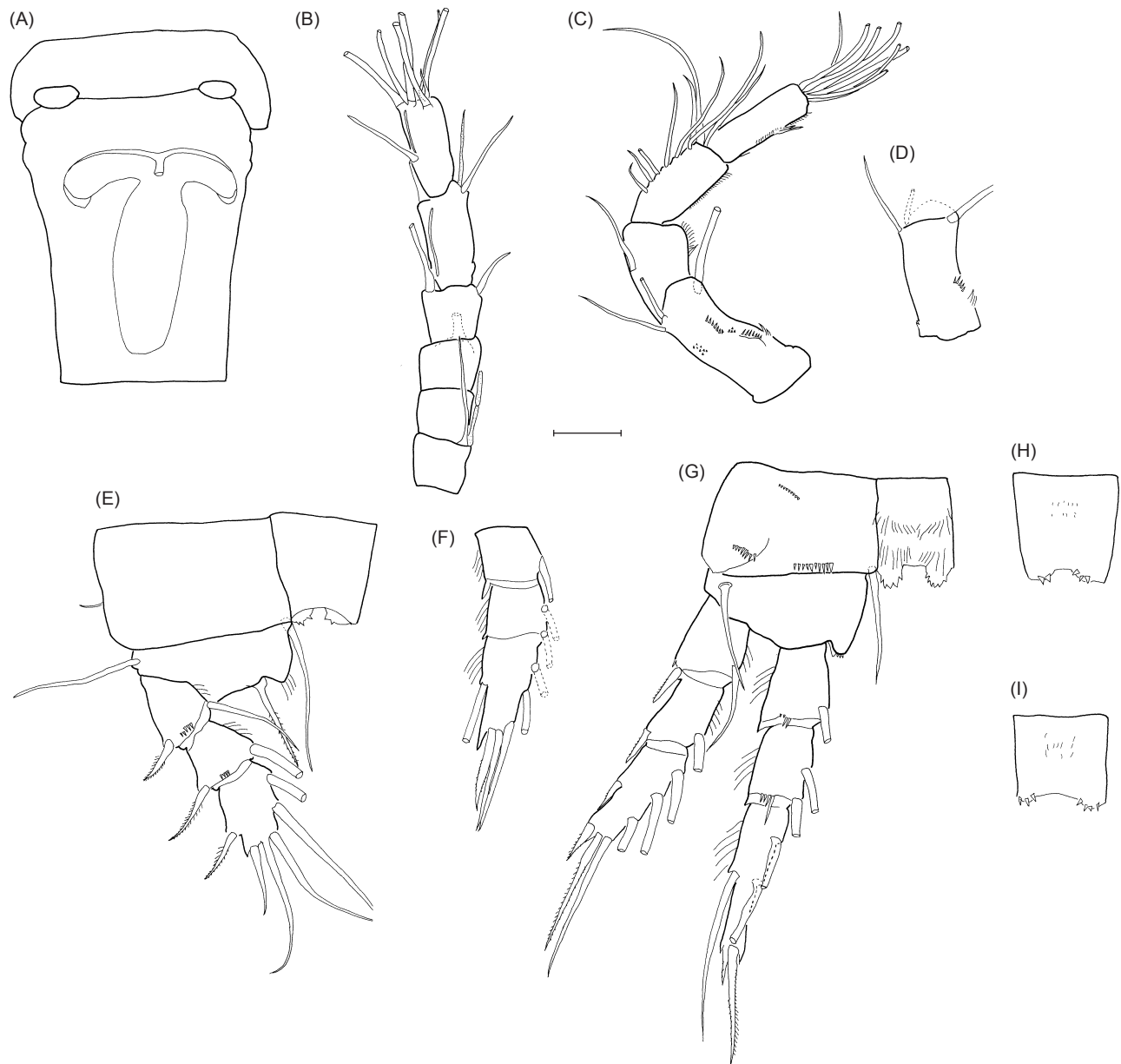
Species	BL ( $\mu$ m)	GS(l/w)	Cep/GS	CR(l/w)	S1/CR	S1/S4	S1/S5	P4 enp3		
								l/w	spines	spine/ segment
<i>T. crassus</i>	680-780	1.17-1.23	2.57-3.12	1.88-2.25	2.90-3.33	2.55-2.89	2.37-2.75	2.87-3.30	1.80-2.83	0.85-0.95
<i>T. decipiens</i>	760-890	1.16-1.28	2.04-3.05	2.20-2.88	2.46-3.10	2.48-3.26	2.07-2.69	3.0 -4.0	2.18-3.11	0.87-0.96
<i>T. maheensis</i>	810-950	1.06-1.36	1.38-1.48	3.17-3.63	2.10-2.40	2.50-3.50	1.09-1.45	2.80-3.44	1.87-2.53	0.90-0.98
<i>T. rylovi</i>	780-860	1.02-1.09	2.39-2.75	2.39-3.75	1.78-2.28	2.45-2.71	2.19-2.90	2.09-3.46	1.90-2.75	0.79-0.91
<i>T. vermifer</i>	780-800	1.09-1.27	2.30-2.90	2.20-2.80	2.10-2.90	2.20-2.90	1.80-2.80	2.94-3.64	2.16-3.05	0.85-0.98

females, while 0-6 spinules are present in South Indian specimens.

*Thermocyclops maheensis* was described from Mahé in South India (Lindberg 1941). Alekseev and Sanoamuang (2006) reported the species from the Nampong River in northeastern Thailand. The occurrence data provided here from Cambodia (Kratie and Stung Treng) are the easternmost records of this species.

***Thermocyclops vermifer* (Lindberg 1935)**  
(Fig. 13)

*Mesocyclops rylovi vermifer* Lindberg 1935 (in part): 415-419, figs. 7-9; *Mesocyclops vermifer* Lindberg 1938: 211-236; *Mesocyclops (Thermocyclops) vermifer* Lindberg 1942: 139-190; *Thermocyclops rylovi vermifer* Lindberg 1959: 1-26; *Thermocyclops vermifer* Mirabdullayev and Kuzmetov 1997: 201-212; Mirabdullayev et al. 2003: 275-277; Guo 1999: 87-95, figs. 13-22.



**Fig. 13.** *Thermocyclops vermifer*, female (Cambodia). (A) Pediger 5 and genital double-somite, ventral view; (B) antennular segments 12-17; (C, D) antenna: (C) posterior view; (D) coxobasis, anterior view; (E, F) P1: (E) protopodite and exopodite posterior view; (F) endopodite, posterior view; (G) P4, posterior view; (H) P1 coupler, anterior view; (I) P3 coupler, anterior view. (A-I) Locality CB20. Scale bar = 50 µm.



*Thermocyclops crassus* morpha *kairakkumensis* Ulomsky 1963: 95-123.

**Material examined:** Cambodia: Kratie Prov., Kratie Dist., Chang Krong, pond, 12°35'N, 106°05'E, 10 June 2007, 1 ♀, slide CB17(1A,B); Kratie Prov., Sambo Dist., Kbal Damrey, permanent pond, 12°50'N, 106°10'E, 14 Feb. 2007, 1 ♀, slide CB20(1A,B); Pursat Prov., Sbr Prah Dist., Dong Krasain, swamp, 12°20'N, 106°16'E, 28 Oct. 2007, 1 ♀, slide CB73(1A,B); Battambang Prov., Sangkei Dist., Kampong Preang, irrigation canal, 12°54'N, 103°21'E, 20 Feb. 2007, 1 ♀, slide CB77(1A,B).

**Diagnosis:** Female (Cambodia). Pediger 5 (Fig. 13A) without hairs or spinules on lateral surface. Genital double-somite as long as wide or slightly longer, with transverse rows of pits (not shown on drawing). Lateral arms of seminal receptacle (Fig. 13A) slightly curved posteriorly. Caudal rami without hairs on medial margin. No spinules at implantation of lateral seta or S4. Tip of S2 slightly curved ventrally.

Antennule 17-segmented, hyaline membrane on last segment not extending beyond implantation of medial seta, without notch (Fig. 13B). Aesthetascs on segments 12 and 16 reaching beyond middle of segments 14 and 17, respectively. Lateral seta on segment 15 (Fig. 13B) not reaching middle of segment 16. Antennal enp2 with 9 setae. Posterior ornamentation of coxobasis (Fig. 13C): 7-9 robust spinules in longitudinal and 7 spinules in oblique rows near lateral margin; group of tiny spinules between oblique and longitudinal rows; few spinules on distal 1/2 of segment near medial margin. Anterior surface of coxobasis (Fig. 13D) armed with 6-8 spinules in longitudinal row on proximal 1/2 of segment near lateral margin.

Maxillulary palp spinulose. Syncoxopodite of maxilliped with large spinules at height of insertion of proximalmost seta, small spinules distal to former group, and tiny spinules at height of insertion of distalmost seta.

Medial spine of P1 basipodite (Fig. 13E) reaching beyond distal margin of enp2, with short setules. Medial expansion of basipodite of P1-P3 pilose (Fig. 13E), that of P4 (Fig. 13G) with tiny distal spinules. P1-P3 couplers (Fig. 13H, I; P2 coupler not figured) bare on posterior surface, yet group of tiny hairs present on anterior surface; hairs on anterior surface of P2 coupler difficult to observe. P4 coupler bearing 2 rows of hairs on posterior surface, and bare on anterior surface. P5 typical for genus. For morphometric data see

table 3.

**Remarks:** The Cambodian *T. vermifer* differs from the original description (Lindberg 1935) in the lateral ornamentation of pediger 5, which is pilose in Indian females but bare in Cambodian populations. Cambodian specimens slightly differ from the Central Asian population in the medial expansion of the basipodite of P4, which is armed with tiny spinules in Cambodia but bare in Central Asia (Mirabdullayev and Kuzmetov 1997).

*Thermocyclops vermifer* is known from India (Lindberg 1935 1938), Central Asia (Pakistan, Afghanistan, Tajikistan, Uzbekistan, southern Kazakhstan, and Turkmenistan) (Mirabdullayev and Kuzmetov 1997, Mirabdullayev et al. 1998), China (Guo 1999), and Southeast Asia (Cambodia: our record).

Lindberg (1935) described *T. vermifer* from India (Deccan) under the name *Mesocyclops rylovi vermifer*, and later Lindberg (1938) raised the taxon to species level. In the original description, there is no mention that Lindberg would designate the type of *M. rylovi vermifer*. In a paper on *Thermocyclops* from the Wallacea-Expedition, Kiefer (1938a), based on comparisons with material provided by Lindberg, stated that *T. vermifer* was a junior synonym of *T. decipiens*. However, Kiefer did not mention that the examined specimens obtained from Lindberg would have been the type(s) of *T. vermifer*, nor did he provide drawings, or locality or measurement data on Lindberg's specimens. Moreover, in a subsequent publication, Kiefer (1978) wrote that he had received no material of *T. vermifer* from Lindberg. Mirabdullayev and Kuzmetov (1997) and Mirabdullayev et al. (2003) did not accept the synonymy of *T. vermifer* with *T. decipiens*, and here we use the name *T. vermifer* in the same sense as it was applied in the above-mentioned 2 publications.

### ***Thermocyclops rylovi* (Smirnov 1929)**

(Fig. 14)

*Mesocyclops rylovi* 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; Holyńska 2006: 342-344, figs. 15-18; Alekseev and Sanoamuang 2006: 277-290, table 2. *Thermocyclops neglectus prolatus* Kiefer 1952: 71, figs. 56, 58, 59, tables VI, XI.

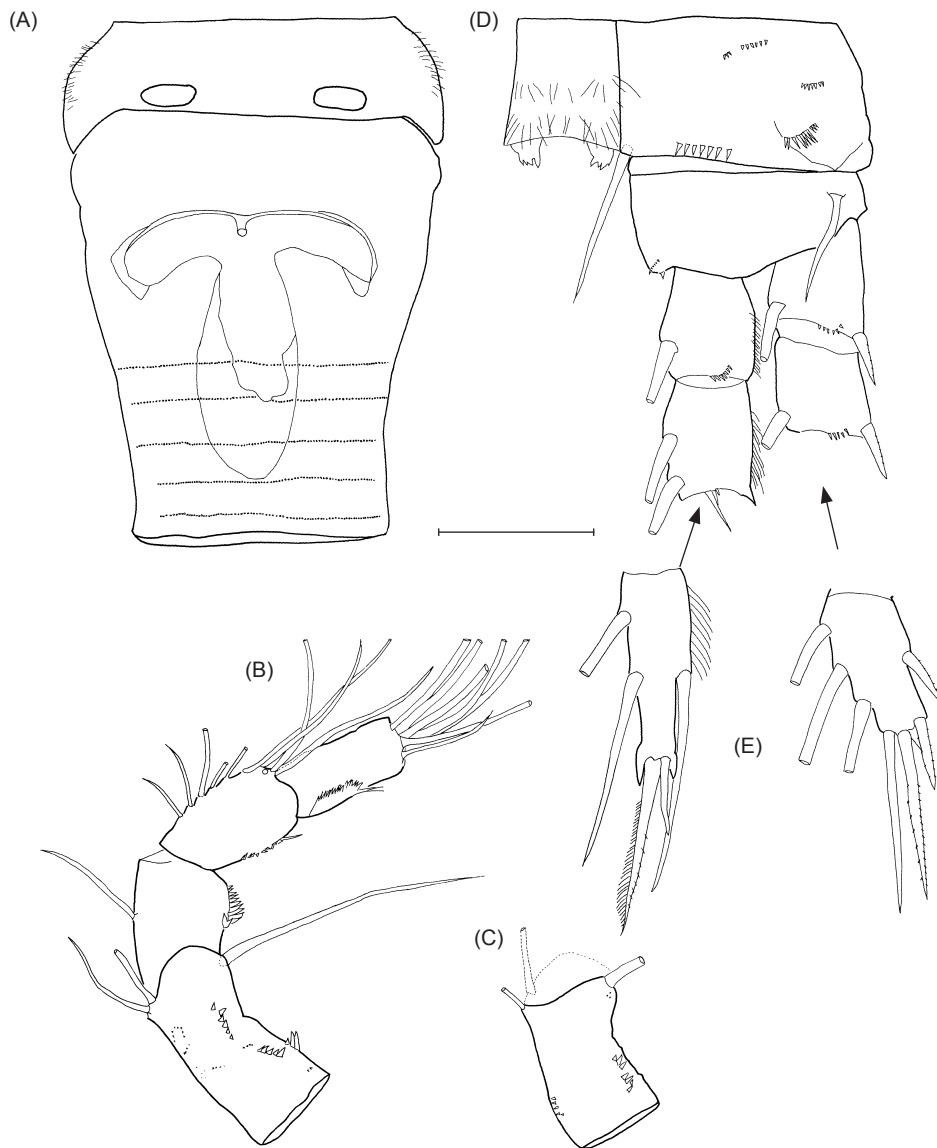
**Material examined:** Cambodia: Kratie Prov., Kratie Dist., pond, 12°31'N, 106°04'E, 11 June 2007, 1 ♀, slide CB13(1A,B); Stung Treng Prov., Stung Treng Dist., Sreipo, stream, 13°31'N,

105°59'E, 11 June 2007, 1 ♀, slide CB28(1A,B); Stung Treng Prov., Stung Treng Dist., Srah Russey, stream, 13°31'N, 105°59'E, 11 June 2007, 1 ♀, slide CB30(1A,B); Stung Treng Prov., Stung Treng Dist., pond, 13°31'N, 105°59'E, 12 June 2007, 1 ♀, slide CB36(1A,B); Kampong Thom Prov., Baray Dist., Sroyong, canal, 12°12'N, 105°07'E, 14 June 2007, 1 ♀, slide CB72(1A,B).

**Diagnosis:** Female (Cambodia). Pediger 5 with lateral hairs. Genital double-somite (Fig. 14A) as long as wide, with transverse rows of pits. Lateral arms of seminal receptacles slightly curved posteriorly. Caudal rami without medial hairs. No

spinules at implantation of lateral seta or S4. Tip of S2 straight.

Hyaline membrane on last antennular segment proximally extending to insertion of medial seta, without notch. Antennal enp2 with 9 setae. Posterior ornamentation of antennal coxobasis (Fig. 14B): 5 or 6 robust spinules in oblique row, and 7 or 8 spinules in longitudinal row near lateral margin; group of tiny spinules present between oblique and longitudinal rows; oblique field of small spinules present close to insertion of medial setae; a few tiny spinules arranged in row in middle; a few small spinules present on lateral margin near



**Fig. 14.** *Thermocyclops rylovi*, female (Cambodia). (A) Pediger 5 and genital double-somite, ventral view; (B, C) antenna: (B) posterior view; (C) coxobasis, anterior view; (D, E) P4, posterior view: (D) protopodite, exp1-2, and enp1-2; (E) exp3 and enp3. (A-E) Locality CB36. Scale bar = 50 µm.

base. Anterior surface of antennal coxobasis (Fig. 14C) bearing 5-8 spinules in longitudinal row on proximal 1/2 of segment near lateral margin.

Medial spine of P1 basipodite reaching distal margin of enp2 (not figured). Medial expansion of basipodite of P1-P3 pilose, that of P4 with distal spinules on posterior surface (Fig. 14D). Couplers of P1-P3 bare, while coupler of P4 posteriorly pilose. P5 typical for genus. For morphometric data see table 3.

**Remarks:** The Cambodian population differs from the Uzbekistan (Mirabdullayev and Kuzmetov 1997) and Australian populations (Holyńska 2006) in 3 characters. Tiny distal spinules are present on the posterior surface of medial expansions of the P4 basipodite in both the Cambodian and Australian populations, but were not reported in Central Asian specimens. On the antennal coxobasis, tiny spinules between the longitudinal and oblique rows are present in specimens from Cambodia and Uzbekistan (Mirabdullayev et al. 2003), but absent from the Australian population. On the other hand, a group of small spinules near the insertion of the medial setae of the antennal coxobasis is present in the Australian population, but absent from specimens of Uzbekistan and Cambodia.

*Thermocyclops rylovi* was first described from the Caucasus (Smirnov 1929), and it was also reported from Central Asia (Uzbekistan) (Mirabdullayev and Kuzmetov 1997), Iran (Lindberg 1936 1942), Afghanistan (Lindberg 1959), Pakistan (Defaye et al. 1987), India (Lindberg 1935, Defaye et al. 1987), and Australia (Holyńska 2006). In Southeast Asia this species is known only from Thailand (Mirabdullayev et al. 2003, Alekseev and Sanoamuang 2006) and Cambodia. To the west, the range of the species extends as far as Ethiopia and Uganda (referred to as *T. neglectus prolatus* by Kiefer (1952), but considered by Mirabdullayev et al. 2003 as a junior synonym of *T. rylovi*).

Many observations in Central Asia (Mirabdullayev et al. 2003), Iran (Lindberg 1942), and Australia (Holyńska 2006) indicate the drought and salinity tolerance of the species.

### ***Thermocyclops decipiens* (Kiefer 1929)**

(Figs. 15, 16)

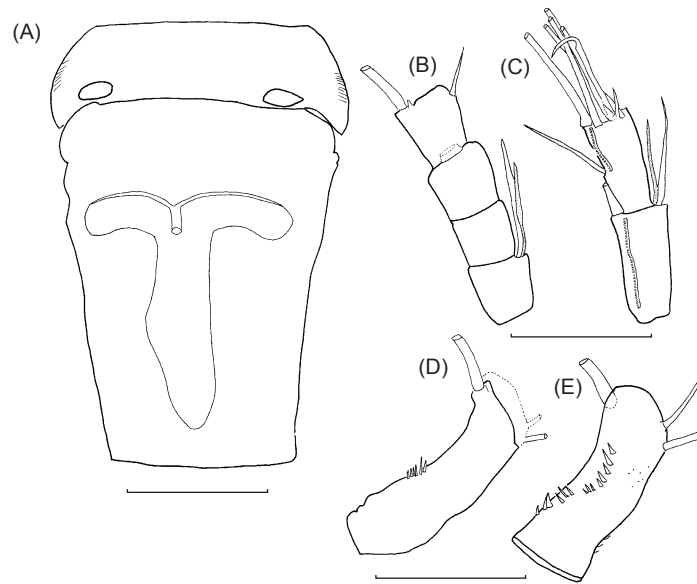
*Mesocyclops* (*Thermocyclops*) *decipiens* Kiefer 1929b: 136, fig. 12; *Thermocyclops decipiens* Mirabdullayev et al. 2003: 257, 260, fig. 121; Holyńska 2006: 345-346, figs. 21, 22; Alekseev and Sanoamuang 2006: 277-290, table 2.

**Material examined:** Cambodia: Banteay Meanchey Prov., Srey Sophorn Dist., Sei Sen, pond 13°33'N, 102°59'E, 12 Feb. 2007, 1 ♀, slide CB1(1A,B); Kratie Prov., Kratie Dist., Bossliv, stream, 12°21'N, 106°03'E, 13 Feb. 2007, 1 ♀, slide CB15(1A,B); Kratie Prov., pond, 12°53'N, 106°11'E, 14 Feb. 2007, 1 ♀, slide CB22(1A,B); Stung Treng Prov., Stung Treng Dist., Sreipo, pond, 13°30'N, 105°59'E, 11 June 2007, 1 ♀, slide CB27(1A,B); Stung Treng Prov., Srah Russey Dist., Sreipo, pond, 13°31'N, 105°59'E, 11 June 2007, 1 ♀, slide CB29(1A,B); Stung Treng Prov., Reachea Dist., Oklong, pond, 13°31'N 106°01'E, 15 Feb. 2007, 1 ♀, slide CB34(1A,B); Kratie Prov., Kratie Dist., pond, 12°21'N 106°15'E, 16 Feb. 2007, 1 ♀, slide CB49(1A,B); Kampong Thom Prov., Baray Dist., Tropeang Chhouk, canal, 12°22'N, 105°05'E, 14 June 2007, slide CB73(1A,B).

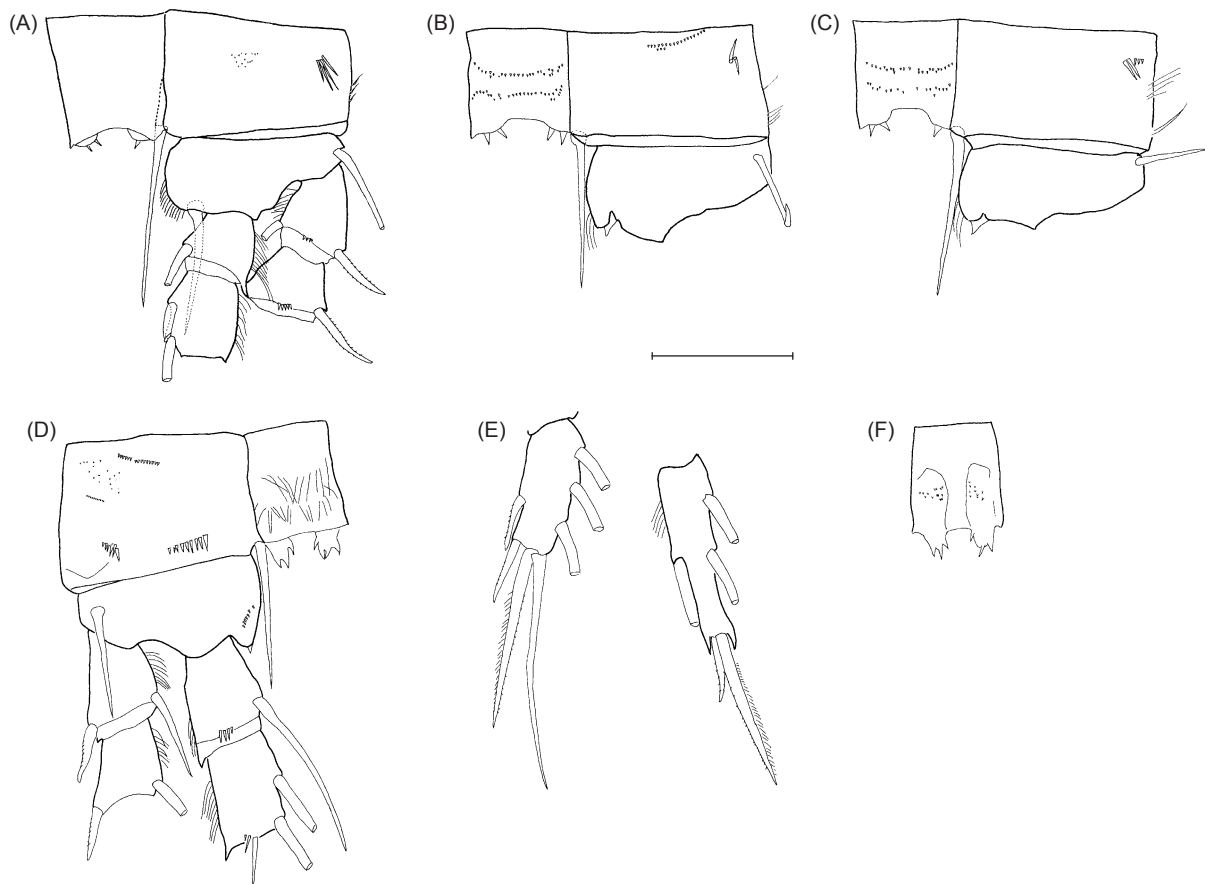
**Diagnosis:** Female (Cambodia). Pediger 5 (Fig. 15A) with lateral spinules. Lateral arms of seminal receptacle perpendicular to body axis and slightly curved at their extremity. Caudal rami with smooth surface. No spinules at implantation of lateral seta or S4. Tip of S2 straight.

Hyaline membrane on segment 17 not extending beyond insertion of medial seta, without notch (Fig. 15C). Aesthetasc on segment 12 reaching middle of segment 14 (Fig. 15B). Antennal enp2 with 9 setae. Posterior ornamentation of antennal coxobasis (Fig. 15E): 6-8 robust spinules in longitudinal row and 4 or 5 spinules in oblique row near lateral margin; group of tiny spinules present between oblique and longitudinal rows; a few spinules present close to insertion of medial setae. Anterior surface of antennal coxobasis (Fig. 15D) bearing 5 or 6 large spinules in longitudinal row on proximal 1/2 of segment near lateral margin.

Syncoxopodite of maxilliped with large spinules at height of insertion of proximalmost seta, and a group of small spinules distally to group of large spinules. Medial spine of P1 basipodite (Fig. 16A) reaching 2/3 of enp2, with setules along both sides of spine. Medial expansion of basipodite of P1-P3 pilose, that of P4 (Fig. 16D) with small distal spinules on posterior surface. P1 coupler bare on posterior surface, yet group of spinules present on anterior surface. P2 and P3 couplers bearing 2 rows of small spinules on posterior surface (Fig. 16B, C), and bare on anterior surface. P4 coupler with 2 rows of long hairs on posterior surface (Fig. 16D), and with group of spinules on anterior surface (Fig. 16F); distal protuberances



**Fig. 15.** *Thermocyclops decipiens*, female (Cambodia). (A) Pediger 5 and genital double-somite, ventral view; (B, C) antennule: (B) segments 12-15, posterior view; (C) segments 16 and 17, anterior view; (D, E) antennal coxobasis: (D) anterior view; (E) posterior view. (A, D, E) Locality CB34, (B, C) locality CB49. Scale bars = 50  $\mu$ m.



**Fig. 16.** *Thermocyclops decipiens*, female (Cambodia). (A) P1, posterior view; (B) P2 protopodite, posterior view; (C) P3 protopodite, posterior view; (D, E) P4, posterior view: (D) protopodite, exp1-2, and enp1-2; (E) exp3 and enp3; (F) P4 coupler, anterior view. (A) Locality CB1, (B-F) locality CB34. Scale bar = 50  $\mu$ m.

conspicuously high. P5 typical for genus. For morphometric data see table 3.

**Remarks:** The Cambodian *T. decipiens* differs from the type (Kinshasa, Congo; Mirabdullayev et al. 2003) in a single character. On the posterior surface of the antennal coxobasis, a group of spinules below the medial setae is present in both the Australian (Holyńska 2006) and Cambodian females (Fig. 15E), yet absent from the type material (Mirabdullayev et al. 2003). These spinules are extremely tiny in specimens from the Philippines and Indonesia for instance; therefore it is possible that the size reduction of spinules might result in the full disappearance of this group in other populations (Holyńska 2006). The aesthetasc on antennular segment 16 is seta-like in Cambodia, while it abruptly narrows in 1 Australian specimen (Holyńska 2006). Another difference is in the ornamentation of the anterior surface of the P2 and P3 couplers, which are bare in Cambodian populations and pilose (with a few hairs) in the Australian female.

This pantropical species is known from Central and South America, Africa, India, Sri

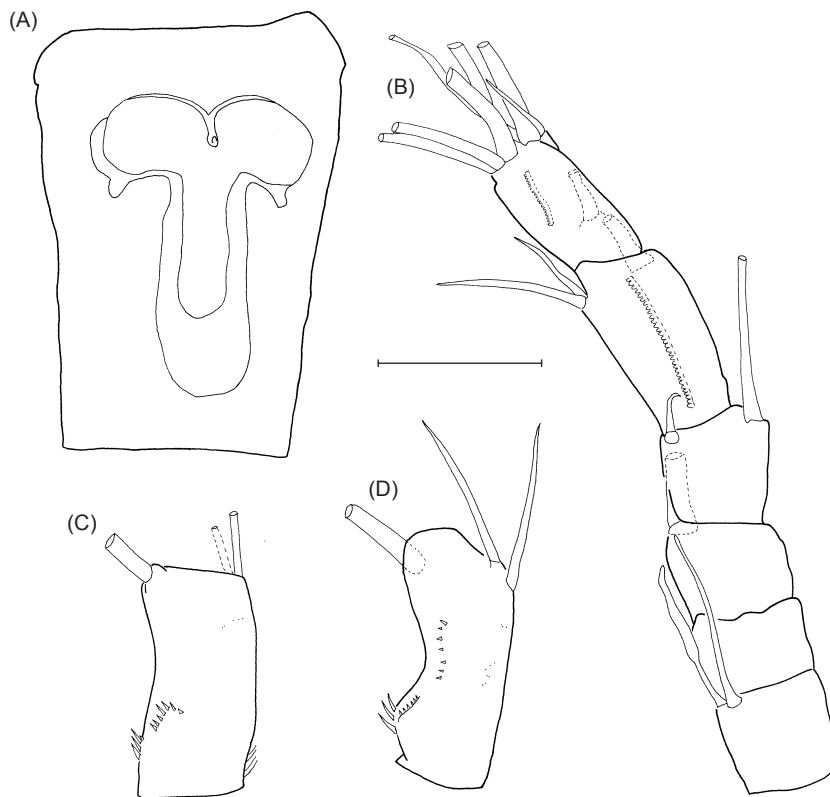
Lanka, Indonesia, and Australia (Mirabdullayev et al. 2003); in Southeast Asia it was reported from Thailand (Alekseev and Sanoamuang 2006), Vietnam (Mirabdullayev et al. 2003), and Cambodia (our record). It even occurs in groundwater in West Indian islands (Pesce 1985), where it has somewhat different ornamentation of the P4 coupler and more-elongated caudal rami.

### ***Thermocyclops crassus* (Fischer, 1853)**

(Figs. 17, 18)

*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: 305-306, fig. 77; *Thermocyclops crassus* Dussart 1969: 210-213, fig. 108; Mirabdullayev et al. 2003: 265-267, fig. 125; Holyńska 2006: 344-345, figs. 19, 20.

**Material examined:** Cambodia: Banteay Meanchey Prov., Srisophol Dist., Sei Sen, pond, 13°33'N, 102°59'E, 12 Feb. 2007, 1 ♀, slide CB1(1A,B); Prek Toam, Kratie Prov., Kratie Dist., Bossliv, Khong River, 12°21'N, 106°03'E, 13 Feb. 2007, 1 ♀, slide CB15(1A,B); Stung Treng



**Fig. 17.** *Thermocyclops crassus*, female (Cambodia). (A) Genital double-somite, ventral view; (B) antennule, segments 12-17, posterior view; (C, D) antennal coxobasis: (C) anterior view; (D) posterior view. (A) Locality CB72, (B-D) locality CB88. Scale bar = 50  $\mu$ m.

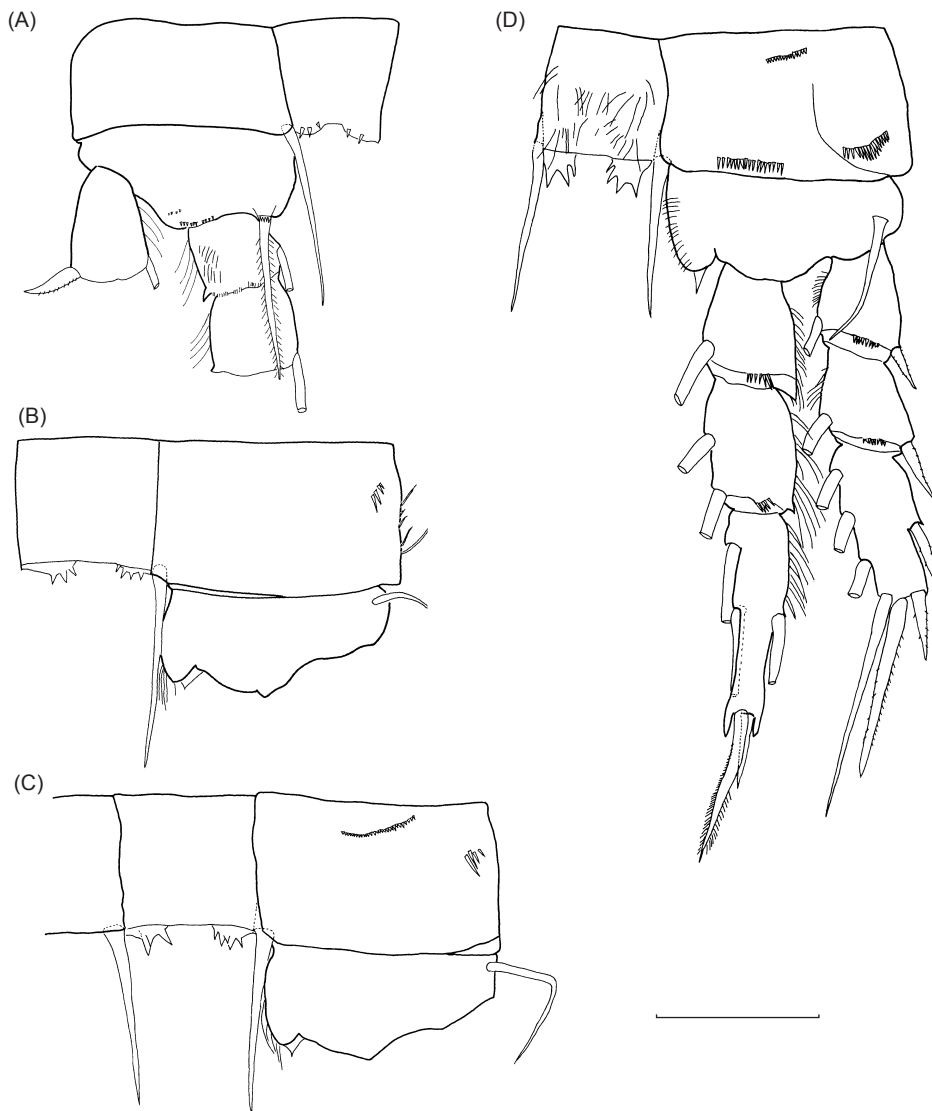


Prov., Stung Treng Dist., Sreipo, pond, 13°31'N, 105°59'E, 15 Feb. 2007, 1 ♀, slide CB32(1A,B); Siem Reap Prov., Chikreng Dist., Kok Thlok Krom, pond, 13°08'N, 104°18'E, 18 Feb. 2007, 1 ♀, slide CB65(1A,B); Siem Reap Prov., pond, 13°35'N, 103°23'E, 19 Feb. 2007, 1 ♀, slide CB72(1A,B); Battambang Prov., Mong Rusey Dist., Prey Toch, irrigation canal, 12°54'N, 103°22'E, 20 Feb. 2007, 1 ♀, slide CB87(1A,B); Siem Reap Prov., Pour Dist., Thnal, pond, 13°22'N 103°48'E, 15 June 2007, 1 ♀, slide CB88(1A,B).

**Diagnosis:** Female (Cambodia). Pediger 5 with lateral spinules. Lateral arms of seminal receptacle (Fig. 17A) short, wide, and perpendicular to body axis. Caudal rami short,

without hairs on medial margin. No spinules at implantation of lateral seta or S4. Tip of S2 strongly curved ventrally.

Hyaline membrane of last antennular segment proximally not extending beyond insertion of medial seta, without notch (Fig. 17B). Antennal enp2 with 9 setae. Posterior ornamentation of coxobasis (Fig. 17D) composed of small spinules in longitudinal and oblique rows near lateral margin, and a few tiny spinules on distal 1/2 near medial margin. Tiny spinules absent between oblique and longitudinal rows. Frontal surface of coxobasis (Fig. 17C) armed with spinules in curved row on proximal 1/2 of segment near lateral margin. Maxillulary palp spinulose. Syncoxopodite



**Fig. 18.** *Thermocyclops crassus*, female (Cambodia). (A) P1, anterior view; (B) P2, protopodite, posterior view; (C) P3, protopodite, posterior view; (D) P4, posterior view. (A-D) Locality CB88. Scale bar = 50  $\mu$ m.



of maxilliped with large spinules at height of insertion of proximalmost seta, small spinules distal to former group, and tiny spinules at height of insertion of distalmost seta.

Medial spine of P1 basipodite (Fig. 18A) reaching beyond distal margin of enp2. Medial expansion of basipodites of P1-P4 (Fig. 18A-D) pilose. P1-P3 couplers bare on posterior and anterior surfaces. P4 coupler (Fig. 18D) bearing 2 rows of hairs on posterior surface and bare on anterior surface; distal protuberances high. P5 typical for genus. For morphometric data see table 3.

*Remarks:* Cambodian specimens differ from European and Australian females (Mirabdullayev et al. 2003, Hołyńska 2006) in 2 characters. The posterior surface of the antennal coxobasis has a simpler spinule pattern in Cambodian females: the group between the longitudinal and oblique rows, and spinules near the insertion of the medial setae, which are present in European and Australian females, are both missing from Cambodian females. On the posterior surface of the P4 coxopodite, lateral rows of small spinules that are present in European and Australian specimens are absent from Cambodian ones. The medial margin of the basipodites of P1-P4 bears spinules in specimens from Germany (Mirabdullayev et al. 2003), yet it is pilose in Cambodian ones.

*Thermocyclops crassus* lives in Eurasia and also occurs in (Papua) New Guinea, and Vanuatu. It is widespread in temperate Australia, and known from a few localities in North Australia and Africa (Kizito et al. 1993, Dussart and Defaye 2006). *Thermocyclops crassus* has a restricted distribution in southeastern Mexico and the northeastern US, which suggests that the species was introduced to America (Reid 1989, Duchovnay et al. 1992, Reid and Pinto-Coelho 1994, Gutiérrez-Aguirre and Suárez-Morales 2000, Silva 2008).

Lindberg (1952) reported the occurrence of *T. crassus* in Cambodia from Phnom Pheng, Kandal, Pursat, and Kampong Cham, and found the species to be the most common representative of the genus in the country. Our data confirm this; *T. crassus* was the most often encountered species and is widely distributed in the 7 provinces of Cambodia we studied.

## DISCUSSION

Twelve taxa, nearly 1/4 of the world fauna of *Thermocyclops* (55 (sub)species) (Dussart and

Defaye 2006), occur in Southeast Asia: *T. crassus*, *T. decipiens*, *T. maheensis*, *T. operculifer* Kiefer, *T. operculifer aberrans*, *T. orientalis* Dussart and Fernando, *T. philippinensis* (Marsh), *T. rylovi*, *T. taihokuensis* Harada, *T. trichophorus* Kiefer, *T. vermifer*, and *T. wolterecki* (Lindberg 1952, Nam et al. 1998, Mirabdullayev et al. 2003, Alekseev and Sanoamuang 2006, our report). Only 3 species (*T. operculifer*, *T. philippinensis*, and *T. trichophorus*) seem to be endemic to the region, while the rest of the Southeast Asian fauna is shared with neighboring regions of Asia and also Australia. The ranges of a few Southeast Asian taxa extend as far as Papua New Guinea (*T. wolterecki*) or Australia (*T. crassus*, *T. decipiens*, *T. operculifer aberrans*, and *T. rylovi*), and dispersal from the Asian continent to Australia was suggested by Hołyńska (2006). Boxshall and Defaye (2008) analyzed the occurrence of freshwater cyclopoid species that inhabit more than 1 zoogeographic region, and also found that the Oriental region (Southeast Asia + India) showed the greatest similarity with Australia (including New Guinea).

From Cambodia, 7 species are known: *T. crassus*, *T. decipiens*, *T. maheensis*, *T. operculifer aberrans*, *T. rylovi*, *T. vermifer*, and *T. wolterecki* (Fig. 19). With the exception of *T. crassus*, all *Thermocyclops* taxa described here are new records for the country. For comparison, 6 species were reported from Thailand with an almost 3-fold larger area.

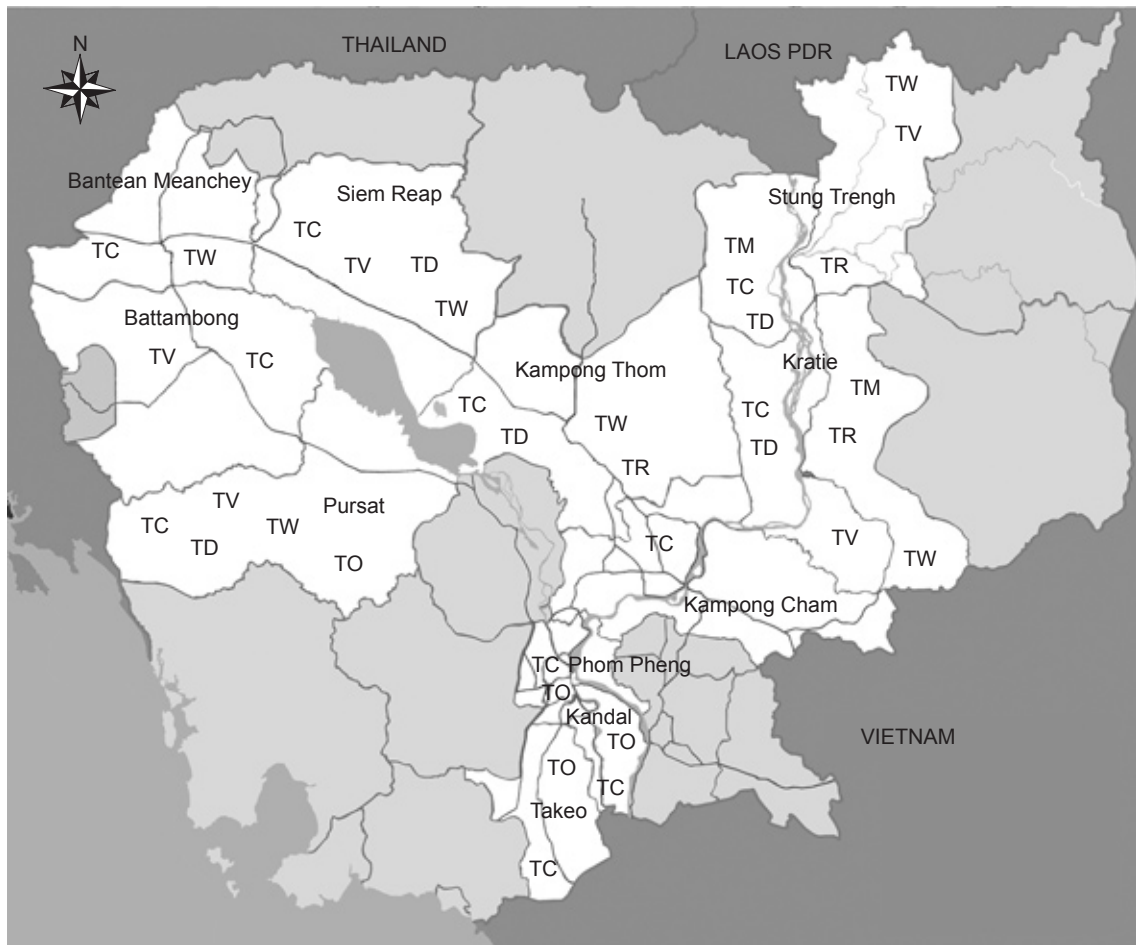
There is a single problematic Cambodian form, *T. operculifer aberrans*, which unfortunately we could not find in our samples, although a redescription (preferably from the type locality, Lake Sap) is badly needed for this poorly known taxon. Karanovic (2006) found this taxon in subterranean waters in Western Australia (Pilbara). He ascribed *T. operculifer aberrans* species rank, and considered a Malaysian taxon referred by Fernando and Ponyi (1981) as *Thermocyclops* cf. *schmeili*, and a Javanese form assigned by Defaye et al. (1987) as *T. operculifer* to be conspecific with *T. aberrans*. Almost at the same time in a paper on *Thermocyclops* of North Queensland, Hołyńska (2006) redescribed *T. operculifer*, and described a new species, *T. pseudoperculifer*, which is very closely related (even perhaps synonymous) to *T. aberrans*. *Thermocyclops pseudoperculifer* seems to differ from *T. aberrans* sensu Karanovic (2006) in the ornamentation of the posterior surface of the P1 coupler (spinulose in *T. aberrans* from Western Australia and bare in *T. pseudoperculifer*), and setulation of the medial spine of P1 basipodite (long

setules present on the proximal 1/2 of the spine in *T. pseudoperculifer* and long setules absent from *T. aberrans* of Western Australia). To resolve the relationships between the Asian and Australian taxa, in the future we need to compare these forms with the topotype material of *T. operculifer aberrans*.

**Identification key to Cambodian species of *Thermocyclops* (females)**

1. Hyaline membrane on last segment of antennule proximally extending beyond insertion of medial seta (Fig. 10C); no ornamentation present on posterior surface of P4 coupler.....*T. maheensis* Lindberg, 1941
- Hyaline membrane on last segment of antennule not extending beyond insertion of medial seta (Fig. 17B); hairs or spinules present on posterior surface of P4 coupler ....(2)
2. Lateral arms of seminal receptacle short and wide, perpendicular to body axis (Fig. 17A).....*T. crassus* (Fischer, 1853)

- Lateral arms of seminal receptacle elongate, slightly or strongly curved to rear.....(3)
- 3. Distal protuberances of P4 coupler armed with large spinules (Fig. 16D); P3 coupler bearing hairs or spinules on posterior or anterior surface .....(4)
- Distal protuberances of P4 coupler armed with tiny spinules (Fig. 4D); P3 coupler posteriorly and anteriorly bare .....*T. wolterecki* Kiefer, 1938
- 4. P4 coupler posteriorly spinulose; s1/s4 about 1.0; of apical spines of P4 enp3, medial spine -1.6-times as long as lateral spine ..... *T. operculifer aberrans* Lindberg, 1952
- P4 coupler posteriorly pilose; s1/s4 > 2.0; of apical spines of P4 enp3, medial spine at least 1.8-times as long as lateral spine .....(5)
- 5. Pediger 5 laterally bare..... *T. vermifer* Lindberg, 1935
- Pediger 5 with lateral hairs or spinules.....6
- 6. Transverse rows of pits present on genital double-somite (Fig. 14A); P2 and P3 couplers posteriorly bare; pediger 5 with lateral hairs (Fig. 14A)..... *T. rylovi* (Smirnov 1929)
- Transverse rows of pits absent from genital double-somite (Fig. 15A); P2 and P3 couplers posteriorly spinulose (Fig. 16B, C); pediger 5 with lateral spinules (Fig. 15A) .....*T. decipiens* Kiefer, 1929



**Fig. 19.** Geographic distribution of *Thermocyclops* in Cambodia. TC, *Thermocyclops crassus*; TD, *T. decipiens*; TM, *T. maheensis*; TR, *T. rylovi*; TV, *T. vermifer*; TO, *T. operculifer aberrans*; TW, *T. wolterecki*.

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